GEOLOGY AND MINERAL RESOURCES OF THE FAR EAST

Edited by
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PREFACE

The geologist's units are often continents and oceans, centuries and millenia. Within the vast scope of geology, this book is devoted to China, Korea and Manchuria. It complements other English-language studies of Asian geology by Japanese geologists: *Geology of Japan* (1963), *Geology and Palaeontology of Southeast Asia* (volume I, 1964; volumes II and III forthcoming), and *Geologic Sheet Maps of the Far East* (1964).

This volume is derived from the formation of a committee in March, 1950, by the Tokyo Geographical Society, which had the purpose of compiling material on the geology and mineral resources of the Far East. Inaugurating a program for the preservation, compilation, and publication of such data, the committee collected articles from more than 200 specialists who had been repatriated after the war, and edited a three-volume series, *Toa Chishitsu Kosan Shi* (Geology and Mineral Resources of the Far East). One volume was devoted to each of the major areas, China, Manchuria, and Korea.

The series was published in 1952 and is now out of print. Since it was the committee's hope that the study be made accessible to Western as well as Japanese scholars, it is considered appropriate to publish an English version of the series rather than a second edition in Japanese.

The present volume consists of a selection of seventeen articles from the 1952 edition. It deals with stratigraphy, geology and mineral resources in the three areas. The remaining articles will be translated and edited for future publication.

Much of the basic research data were gathered before and during World War II. The intervening years have been ones of accelerating scientific research with the development of new tools and techniques, but since all of China and Manchuria and the northern half of the Korean Peninsula is now closed to Western—and Japanese—geologists, and since a few decades are minute in terms of geologic time, the value of the studies based on these data and included here have increased. Some articles were, of necessity, written from memory due to the destruction of data.

Publication of the Japanese and English editions was made possible by grants from the Ministry of Education and the generosity of the United States Geological Survey, which supplied the committee with topographic base maps and continued assistance in translating and editing.

The editors have striven for consistency in Romanization, particularly of place names. Some names conform to U.S. Board of Geographic Names style but no feasible way of obtaining complete consistency was available. A glossary is, however, provided.

Because of the trying conditions under which some of the articles were written, it was not always possible to include an extensive bibliography.

We would like to acknowledge with gratitude the assistance of the following staff members of the U.S. Geological Survey who, while they were stationed in Tokyo, were especially active in the promotion of the committee's work: Messrs. T. KUROSAKA, S. K. NEUSCHEL, M. E. WING, C. S. JOHNSON, Helen L. FOSTER, D. H. DOAN, G. CORWIN, and R. C. KEPFERLE.

We would also like to thank Miss Reiko FUSEJIMA who prepared the glossary and Miss Ellen LOGAN who edited the English text.

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KOREA

Synopsis of the Geological Systems of Korea

Iwao Tateiwa

Introduction

It has been known since C. Gottsche published the first contribution on the geology of Korea in 1886 that Korean and Japanese geological characteristics are strikingly dissimilar, and that those of Korea and South Manchuria or North China are comparatively similar. In the intervening years, geologists have been able to study extensively the geology of these areas, but many problems of detailed comparison remain unsolved. This volume's research projects, suspended by World War II, are by no means an exhaustive treatment of East Asian geology; much remains for future study.

In this paper the writer intends to give a general idea of the sequence of geological events to which Korea was subjected. For this purpose I have drawn up a generalized table, compiled on the basis of up-to-date information and some revised considerations by the writer.

Before presenting the table, however, I wish to point out briefly the principal differences and similarities in the geology of Korea and Japan, and Korea and South Manchuria or North China, and to discuss some important problems of the stratigraphy and crustal movements of Korea. Such comparisons and discussion, together with the table, may be of significance not only with reference to Korea, but the vaster area of East Asia as well.

Comparison with Japan

Comparing the geology of Korea with that of Japan, we can easily find marked dissimilarities in such aspects as the areal distribution of dominant rocks, sedimentation environments, crustal movements, epochs and lithological characteristics of igneous activities.

Mesozoic or older rocks, including neo-granites which may be from the later Cretaceous to the beginning of the Tertiary, are extensively distributed in Korea. Pre-Cambrian granite-gneisses and crystalline schists, together with granites, the majority of which may belong to the neo-granite referred to above, cover more than half of all Korea. Terrain with eruptive rocks of the Tertiary or later is much narrower than that of Japan; the rocks occupy isolated and narrow areas, or thinly cover older rocks. In this connection, however, the writer must point out the noteworthy phenomena that Cenozoic andesites, very common and widespread in the Japanese archipelago, are distributed in a far narrower area in Korea;[1] multifarious alkaline volcanic rocks, probably of the late Tertiary or Pleistocene, are widely distributed in northeastern Korea and form an essential portion of the petrographic province of alkaline rocks in East Asia; and that there are fairly extensive areas of basaltic lava in North Korea, one of which extends far into Manchuria as a basaltic lava plateau surrounding Mt. Paektu, and the outpouring of this lava may suggest some genetic connection with a crustal condition under which the land was diversely disjuncted by normal faults and tilted.

In sedimentary environments there are also various differences between Korea and Japan which are worthy of special notice. Korea was subjected to large-scale transgressions of oceanic water at least twice during the Pre-Cambrian and twice during the Paleozoic, which left thick deposits of marine sediments. But, after the sea retreated from Korea in the Late Paleozoic, the environment was greatly changed and the land was never again covered extensively by marine water. During the Mesozoic, the land was often covered by more or less extensive lacustrine or partly littoral water; and in the Cenozoic only the marginal terrains were under lacustrine, lagoonal, or littoral water. In Japan, however, extensive terrain was almost continuously under sea water from the Silurian to the Tertiary or later.

Paleogeographic changes: Of course, paleogeographic changes of land and water were not the same in Korea and Japan. For instance, the Upper Paleozoic sediments of the Kitakami mountainland in northern Japan are interrupted by four or more stratigraphic hiatuses, while in Korea, the Upper Paleozoic Heian[2] system shows only one doubtful hiatus for the Uralian interval. The Tertiary formations of Japan have such variable rock facies and are so diversely divided by frequent unconformities that it seems a difficult and laborious task for geologists to work out stratigraphic relations within a single basin or among beds in different basins. Other instances of paleogeographic diversity may be suggested by the Mesozoic stratigraphy in Japan. In general, diversity and frequency of paleogeographic changes in Korea were minor but the changes themselves seem to have occurred in far more extensive areal units than in Japan.

1) Among the Cenozoic lavas in Korea, which have generally been called basalt, there are some which are two-pyroxene andesite. Except for these, andesite is found mainly in association with the Tertiary beds in the Yŏnil district of North Kyŏngsang-do. In Korea, andesitic rocks are widely distributed in the terrain of the Cretaceous Shiragi series.

2) Formation names in Korea were often originally formed by Japanese readings of Korean geographic names and have been widely introduced in Japan and abroad by these names; examples are (Korean reading is in parentheses):

Shōgen (Sangwŏn) system; Chōsen (Chosŏn) system; Heian (P'yŏngan) system; Daidō (Taedong) series; Shiragi (Silla) series; Bukkokuji (Pulguksa) group; Taihō (Taebo) disturbance; Shōrin (Songnim) disturbance; Ennichi (Yŏnil) group; Meisen (Myŏngch'ŏn) group; etc.

I have used the Japanese readings throughout this paper.

Crustal movement: In Korea, Jurassic strata or, strictly speaking, strata of the Middle Jurassic or older were strongly folded and thrusted and, due to repeated thrusts, often exhibit "schuppen" structures. Younger strata, however, are more or less tilted with angles of less than 30° or are nearly horizontal, although these are frequently disrupted by faults, dominantly normal, and exhibit insignificant folding.[3)]

We may conclude from these facts that Korea was under compressive stress until the middle Mesozoic, but subsequently changed into an area in which the land was faulted and tilted, block by block, and had also some subordinate folding of strata. The present geomorphologic features of Korea are considered to have originated largely in these block movements.

The crustal movements thus suggested by studies of Korean geology may be classified as follows:

1. Orogenic movements of the early Mesozoic (post-Heian and pre-Daidō), namely the Shōrin disturbance as defined by T. Kobayashi (1930). The movement may be comparable in time to the Akiyoshi disturbance in Japan and the Tsingling movement in North China, which has been interpreted as a prolongation of the worldwide Helcynian movement.

2. Orogenic movements of the late Jurassic period (post-Daidō and pre-Rakutō), namely, the Taihō disturbance as defined by E. Konno (1928). The disturbance can be correlated to that of the Ōga phase of the Sakawa orogenic cycle in Japan, and may represent an earlier phase of the East Asiatic Yenshanian movement in Korea.

3. Two phases of inland (?) basin subsidence in which Flysch-type sediments of the Rakutō and Shiragi series were deposited, accompanied by a widespread effusion of intermediate or basic lavas in the Shiragian phase. Both may also represent phases of the Yenshanian movement.

4. Block movements closely related to the large-scale intrusion and extrusion of acidic rocks of the Bukkokuji group. Subsidence of the Tsushima basin, in which thick sediments of the Taishū group were deposited, is an event which may be included in the same phase as the block movements. The movement may be interpreted as a prolongation of the Yenshanian movement of China, and is roughly comparable in age to the North American Laramide Revolution (Tateiwa, 1934).

5. Block movements of the middle Tertiary, the essential portion of which probably began in the Oligocene and lasted to the pre-Ennichi stage of the Miocene. The movement resulted in local extrusions of basaltic and other lavas, faulting dominantly in the Sinian direction (approximately NE–SW) and a conspicuous warping of the Miocene terrain in the Kilchu–Myŏngch'ŏn district, North Hamgyŏng-do.

[3)] In an exceptional case, later Mesozoic overthrusting was indicated by old massifs thrust at a low angle over the later Mesozoic Shiragi series in the northern part of North Kyŏngsang-do, and some faults in the Sinian direction (NE–SW) in South Korea are observed to have moved in the reverse direction.

The movement may be a prolongation of the Nanling movement of China which is considered to be a part of the Himalayan movement. In Korea, however, it seems to be more closely related in genesis to the Ōyashima movement, in which strong pressure toward the Pacific Ocean up-folded the Japanese archipelago.

Of these, the former two are separated by an intervening phase of inland basin subsidence in which terrestrial sediments of the lower Jurassic Daidō series were deposited. The sediments are more than 2,600 m thick in South Ch'ŭngch'ŏng-do, South Korea.

The fourth series of movements was followed by stages of epeirogenic movements and widespread peneplanation. Remnants of the erosion are observable in limited patterns on the Kaema plateau and on the tops of some high mountains. It may be correlated with the Peitai stage of peneplanation in North China.

Phases 2, 3, and 4 are undoubtedly closely related in time and may represent as a whole the Yenshanian movement in Korea and its prolongation. The Yenshanian movement in Korea thus defined is correlated in time with the Sakawa orogenic cycle in Japan described by T. Kobayashi (1941). Summarizing what has been emphasized concerning the crustal movements of Korea, the present writer has drawn up the following table:

1. Shōrin disturbance
2. Taihō disturbance, preceded by a phase of inland basin subsidence
3. (a) Rakutō phase
   (b) Shiragi phase
4. Bukkokuji disturbance, followed by a stage of widespread peneplanation, *i.e.* the Peitai stage. The disturbance may be roughly correlated in time with the North American Laramide Revolution.

} Yenshanian and its prolongation (items 1–4)

5. Nanling movement, a part of the Himalayan (Ōyashima) movement.

Crustal movements are also thought to have occurred in the Pre-Cambrian. The entire situation and characteristics of these movements, however, remain obscure.

A noteworthy phenomenon is that the bedding planes of strata dating from the Lower Cambrian to the Triassic in Korea are found parallel to each other, although they are interrupted by one or two stratigraphic intervals. Moreover, as far as I know, the Lower Cambrian beds lie disconformably against the Late-Proterozoic Sinian system which, in turn, undoubtedly rests disconformably upon the complex of crystalline schists in the terrain between Sunch'ŏn and Sukch'ŏn and in the eastern part of Sŏngch'ŏn-gun, South Pyŏngan-do. The facts suggest that no conspicuous orogenic movements occurred in Korea from the Late Proterozoic until sometime in the Triassic, and in South P'yŏngan-do the quiescent age goes back still farther.

Volcanic activity and earthquakes: In historical times, volcanic activity was insignificant in Korea. There are only two sets of legends which convincingly indicate volcanic activity. According to one set of legends, the dormant volcano Halla-san (1,950 m) on Quelpart Island became active and exploded in 1002 and 1007 A.D.

Other, less convincing legends suggest volcanic activity at Mt. Paektu (2,744 m) in 1597 and 1702 A.D. Data for 1702 indicates that the mountain did explode, resulting in the deposition of whitish volcanic ash.

Korea has no active volcanoes at present, and this, together with the low frequency of earthquakes, signifies the dissimilarity of Korean and Japanese geology.

Korean records show that earthquakes have occurred on 1,661 days of the 2,000 years since the era of the Three Dynasties; of these, approximately forty earthquakes were more or less violent and resulted in the destruction of some buildings or injury of people (WADA, 1912).

The actual number of earthquakes in Korea may be larger than the above figure, for it is not improbable that two or more earthquakes occurred on the same day, records of earthquakes may have been lost, and all earthquakes were not necessarily recorded. Nevertheless, it is certain that the frequency of earthquakes in Korea is far less than in Japan. In fact, I experienced only one earthquake in Korea during my twenty-eight years there, which I experienced at Changgi, Yongil-gun, on the eastern coast of North Kyŏngsang-do.

Mineral resources: Korea's mineral resources differ from those of Japan. She lacks, first of all, oil fields and sulphur deposits; and she is comparatively rich in anthracite but poor in brown coal. The country is extremely poor in resources of tin, manganese, antimony and mercury.

Korea is rich, however, in tungsten, gold, magnesite, apatite, graphite, mica, barite, fluorite, alunite, talc, cyanite (together with sillimanite and andalusite), and rare-element minerals (monazite, zircon, allanite, beryl, various lithium minerals). Especially noteworthy are the rich deposits of magnesite and tungsten; numerous deposits of crystalline and earthy graphite, of which total annual production has often been the highest in the world; and extensive placers of heavy minerals which rare generally rich in monazite and zircon in close association with fergusonite, samarskite, columbite, gold, etc. There seems to be no great difference between Korea and Japan in ore reserves of the other important minerals.

Finally, it must be noticed that most of the important mineral deposits in Korea are believed to have originated in the later Mesozoic, namely the period of acidic rocks of the Bukkokuji group or earlier. In this regard, Korea seems similar to Manchuria and other East Asiatic continental areas, but different from the Japanese archipelago and the Philippine Islands, where minerals of Cenozoic origin are dominant.

Comparison with South Manchuria and North China, with Special Reference to Pre-Cambrian Stratigraphy in Korea

Geological maps of East Asia illustrate the striking differences in Korean and Japanese geology, as stated above, and the many similarities between Korea and South Manchuria or North China. Such a distinct contrast, revealed in the geology on both sides of the Tsushima Strait, seems to be due largely to the unique situation of Japan on the periphery, and consequently the unstable portion, of the Asiatic continent, while Korea and its adjoining lands, including South Manchuria and North China, are more or less away from the peripheral zone of the continent.

The most obvious similarities are shown by the five major units of the stratigraphic columns common to these continental areas, *i.e.* the thick sediments of the Upper and Lower Paleozoic and the Upper and Lower Proterozoic, of which the Upper Proterozoic is separated into two parts by a clino-unconformity. The sediments of these major units in Korea are so similar in rock sequence, lithological nature, and fossils to corresponding sections in South Manchuria or North China that they may be interpreted as portions of a common and widespread sedimentation which successively prevailed over these areas.

Geologists have proposed diverse terms, however, for these stratigraphic units, and such a diversity of terminology has seemed unavoidable because of inconclusive field observations.

For uniformity of terminology, the writer has selected tentatively terms from those already proposed for the above five stratigraphic units, as follows:

Heian system (Middle Carboniferous—Triassic)
Chōsen system (Lower Cambrian—Middle Ordovician)
Sinian system (Upper Proterozoic) } Shōgen system or Sinian system
Huto system (Upper Proterozoic) } in a wide sense
Wutai system (Lower Proterozoic)

Of these, the term Heian was proposed by R. Kodaira (1924) and Chōsen by K. Inoue (1907); both are well known among Japanese geologists who are interested in the Paleozoic stratigraphy of East Asia. The Sinian is here taken in a strict sense and applied to the Kuken series of the Shōgen system; the Huto (B. Willis and E. Blackwelder, 1907) for the Shidōgū and Chokken series of the Shōgen system; and the Wutai, an old term proposed by F. von Richthofen (1882), for all metamorphosed sedimentaries represented by the Matenrei system in the northeastern part of North Korea, the Yokusen system diagonally traversing South Korea, and the Jōsuiyō series scattered in the western part of N. P'yŏngan-do.

The Rensen system, a term proposed by S. Kawasaki[4] for the oldest complex of

[4] The term was probably first used in the explanatory text for the geological map of Korea shown at the memorial exhibition of the fifth anniversary of the new administration of the Government-general of Chōsen (in Seoul) in 1914.

crystalline schists in Korea, is being tentatively retained. S. NAKAMURA and S. MATSUSHITA (1940) proposed another term, the Keirin system, for the Korean complex which includes all pre-Shōgen metamophosed sedimentaries, and determined its age as Archean. Aside from the chronological interpretation put forth by the two authors, the term may be conveniently used for any complex of metamorphosed sedimentaries in Korea which cannot be differentiated into Upper and Lower Proterozoic and the Rensen system.

According to some authors, the Shōgen system is divided by a stratigraphic hiatus in its upper portion. If the hiatus is as great as S. MATSUSHITA (1947) insists, the system should be divided into two parts as he has already done. MATSUSHITA proposed that the Sinian in a strict sense be used for the upper part and that the old term, Huto, proposed by B. WILLIS and E. BLACKWELDER in 1907, be used for the lower part.

One of the striking phenomena of East Asian stratigraphy is the fact that Middle Carboniferous sediments rest disconformably upon Middle Ordovician limestone throughout the area. In Korea, however, the existence of Silurian terrain has been suggested since 1934, when S. SHIMIZU, K. OZAKI and T. OBATA (1934) reported the unexpected discovery of fossils from limestone pebbles of the basal conglomerate of the Lower Jurassic Daidō series near Kyomip'o, Hwanghae-do.[5] From these fossils, the authors have identified eighteen coralline species and four species of cephalopods, and contend that the fauna suggest the Silurian period.

A paper by T. YAMAGUCHI (1951) reports the discovery of doubtful fossils from a thin bed of arenaceous slate and limestone in Kŭmch'ŏn-gun, Hwanghae-do. According to him, the collection contains a form comparable to *Monograptus priodon* BRONN. and some forms which can be assigned to a certain species of *Cypridea*, and the meager collection as a whole suggests the Silurian. The fossil-bearing bed is intercalated in a thick series consisting largely of phyllites with or without pebbles, ottrelite-bearing clay slate, quartzite and limestone. Except for the fossils discovered by YAMAGUCHI, there has been no age measurement available for the thick series, although it was formerly assigned to the Kyūzan formation of the Heian system because of its inferior anthracite seams (GEOLOGICAL SURVEY OF CHŌSEN, 1928), and later to an upper part of the Shōgen system because of its lithological and stratigraphical resemblances to the latter (S. MATSUSHITA, 1941). According to YAMAGUCHI therefore, the Kyūzan formation or a part of it is probably Silurian and the upper portion of the Rensen system, discussed by S. KAWASAKI (1916), is younger, for that segment of the Rensen system rests, showing no evidence of tectonic contact, upon the fossil bearing bed of the Kyūzan formation.

Taking all these matters into consideration, geologists must revise the stratigra-

[5] The authors had considered the conglomerate with the fossiliferous limestone pebbles as Silurian sediments, but, soon after the publication of their paper, T. KOBAYASHI visited the locality and affirmed the younger age of the conglomerate. (KOBAYASHI, T., Is the limestone conglomerate at Kyomip'o Gotlandian sediments?: *Jour. Geol. Soc. Japan,* v. 47, p. 362.)

phic interpretations already reported concerning the Sinian and the Rensen systems in the area around Kŭmch'ŏn-gun. Limited by the present state of knowledge, however, the writer hesitates to follow YAMAGUCHI in considering the entire Kyūzan formation Silurian, although he cannot necessarily deny the probability of Silurian terrain in Kŭmch'ŏn-gun.[6] As for YAMAGUCHI's chronological conclusions on the Rensen system, which consists essentially of highly metamorphosed crystalline schists intricately injected by grey granite-gneiss, the present writer adheres to a quite different view.

Another question for future study concerns the existence of Devonian sediments in Korea, which was suggested by a few forms of corraline fossils reported by H. YABE and T. SUGIYAMA (1939) from Ch'ŏnsŏng-ni, Sunch'ŏn-gun, South P'yŏngan-do, where both the Heian and the Chōsen systems are exposed side by side but separated by a narrow area with no outcrops of bedrock. The fossils were reported to have come from a limestone block on the ground. In this case also, the limestone strata from which the fossils were derived have not been disclosed.

In South Manchuria a bed of limestone conglomerate over 10 m thick has been found between Middle Ordovician limestone and the Middle Carboniferous Penshi series in disconformity to both series (NODA, 1952). In Shantung province, North China, a similar bed disconformably rests on the Middle Ordovician Chenan limestone (NODA, 1952). No fossils have been discovered as yet, however, from these beds.

As to the stratigraphic correlation of the Korean Pre-Cambrian beds with those in South Manchuria, differing views have been published and many questions remain as yet unsolved. However, it seems reasonable to correlate three sub-divisions of the Korean Sinian system, *i.e.* the Kuken, the Shidōgu and the Chokken,

[6] The fossil bed in question is found in a broad shear zone trending from east to west. In the Chŏngok district in the southern part of Yŏnch'ŏn-gun, a little to the south of the shear zone, there is Lower Jurassic shale with plant fossils, together with conglomerate. According to my observations, the Jurassic beds are intercalated as more or less narrow bands in the complex of mica-schists which belong to the Upper Rensen system described by S. KAWASAKI. The Jurassic beds are generally sheared and often phyllitic, the plane of foliation being parallel to the general trend of the Jurassic bands and to the foliation of the mica-schists. Tectonic contact between the Jurassic bands and the mica-schists is often verified, but the exact position of the contact is often obscure because of the complicated phyllitic structure of both the Jurassic bands and the mica-schists.

That the mica-schists are quite different in age from the Jurassic beds was suggested to me at Munsan, about 25 km sw of the Chŏngok district. At Munsan, there are similar Jurassic beds containing plant fossils with a marked basal conglomerate, and the beds rest with profound clino-unconformity upon a complex of mica-schists apparently similar to those in the Chŏngok district. Is there no room for doubt about the occurrence of the fossil bed reported by YAMAGUCHI?

Another point which needs attention is that there is no possibility of assigning the Rensen system to an age younger than the fossil bed reported by YAMAGUCHI or the Kyūzan formation intercalating the fossil bed. The major portion of the Rensen system is intimately intruded by the gray granite-gneiss, and gneisses quite similar to it are discordantly covered by the Lower Paleozoic Chōsen system or the Upper Proterozoic Shōgen system, in various places of Korea. YAMAGUCHI, however, did not state in his paper that the gray granite-gneiss or the portions of the Rensen system invaded by gneisses are younger than the fossil bed.

with the Nanshan, the Kuantung and the Tahoshangshan of the corresponding South Manchurian section.

The Matenrei system, a representative complex of the Korean Wutai system, may safely be correlated with the Liaoho system of South Manchuria and the Wutai system of North China, and its three sub-divisions, the upper, the middle and the lower, investigated by Y. KINOSAKI (1932, 1938) with the Kaiping, the Tashihchiao and the Hsiangshuitzu series of the Liaoho system in South Manchuria.

The South Manchurian Hsiho series has been correlated with the Tahoshangshan by S. MATSUSHITA (1952) and R. SAITO (1952). There are, however, some doubts about the stratigraphic interpretation of the Hsiho on the opposite side of Chasŏng district in Korea beyond the upper reaches of the Yalu River; in the adjacent Kanggye and Huch'ang districts, the Chōsen system, with fossils, rests directly upon the erosion surface of granite-gneiss and crystalline schists without any intervening Sinian sediments. Similar beds in the Chasŏng district, which are no doubt a continuation of the so-called Hsiho series on the opposite side of the Yalu River, have been compared with the Chōsen system by K. NAKAMURA (1942) and T. KOBAYASHI (1952). It seems more probable that the series under consideration in these districts correspond either to the Chōsen system, as NAKAMURA and KOBAYASHI insist, or to a part of the Wutai system which was not intensely metamorphosed, as in the case of the Jōsuiyō series of the Korean Wutai system along the lower reaches of the Yalu River.

Pre-Cambrian Granites in Korea

There are more difficult and important problems in the chronological interpretation of Pre-Cambrian granites in Korea.

S. NAKAMURA proposed the term "Kokulian granite" for Korean pre-Sinian granites except the Seikoshin gneiss in Hamhŭng district, South Hamgyŏng-do, which is clearly later than the Kokulian in origin. The granite has gray to dark gray feldspars with large crystals of grayish microcline sporadically scattered in the rock and often has garnet, cordierite, graphite or tourmaline as important accessories; its quartz is commonly gray, sometimes rose and occasionally tinged with violet. The rock generally contains many accidental xenoliths, mostly of sedimentary origin, and exhibits a more or less distinct banded flow structure.

Such granites are discordantly covered by Lower Cambrian beds of the Chōsen system in various places in Korea and have been well known among Korean geologists under the name of "gray granite-gneiss," the typical granite being the Kankō gneiss which the writer (1926) discovered in the Hamhŭng district, South Hamgyŏng-do.

The Kokulian granite has been often correlated with the Kungchangling granite of South Manchuria or the Taishan granite of North China. But it is highly probable that granites quite different in age have been imprudently grouped together under the term Kokulian granite. The author is of the opinion that the granite should be classified into at least two large groups: the younger (Proterozoic) intruded into the Wutai and the Rensen systems but the older (Archean?) intruded into only the Rensen system and may be discordantly covered by the Wutai, although the chronological as well as stratigraphical relationship between these two groups has not actually been verified.

Other Pre-Cambrian granites in Korea which may belong to the younger group are the tourmaline granite and the schistose granite of P'ungsan-gun, South Hamgyŏngdo described by Y. KINOSAKI (1938) and the red granite described by S. KAWASAKI (1916); the latter includes Koho granite, Ryūyōri granite and Meisen schistose granite, all discussed by Y. KINOSAKI (1932), together with the schistose granite of the Ch'ilbo-san district reported by the author (1925). All of these examples were found within or adjacent to the extensive terrain of the Matenrei system, and in places piercing the latter or enclosing xenoliths of crystalline schists which are more or less lithologically similar to the Matenrei system.

Of the granites enumerated above, some types described by Y. KINOSAKI do not differ essentially from the Kankō gneiss of Hamhŭng district, while the others differ by having reddish instead of gray to dark gray feldspars.

Classified with those granites is the Ritsura granite described by S. MATSUSHITA (1943) in the central part of Hwanghae-do, which is covered unconformably by the Shōgen system.

Examples of the older group of granites are found intricately intruding into the Rensen system. In my study, however, the granite presumably of the older group could not be distinguished in lithological character from the gray granite-gneiss of the younger group. The areal distribution of the older granites, therefore, has remained quite uncertain.

One more example that suggests Pre-Cambrian igneous activity in Korea is the nepheline syenite of P'yŏnggang district in the northern part of Kangwŏn-do.

The extensive terrain extending from Kŭmch'ŏn district of Hwanghae-do easterly to Kŭmhwa district, Kangwŏn-do, throughout P'yŏnggang district, is occupied largely by thick beds of mica-schists, phyllite, limestone and dolomite, with intercalating manganese beds. These beds lack fossils but probably belong to the Shōgen system as previously designated by S. NAKAMURA. The strata are undoubtedly intruded by masses and dikes of nepheline syenite with more or less distinct gneissic structure. The Pre-Cambrian origin of the syenite may be suggested by the fact that no examples with the gneissic structure seen in the nepheline syenite are known among the rocks intruding the Paleozoic or later strata in Korea. In short, if the thick beds truly belong to the Shōgen, as is highly probable, the writer does not hesitate to designate the age of the nepheline syenite as Pre-Cambrian. However, so far as the stratigraphic hiatus in the upper part of Shōgen system is taken into consideration, the age of the syenite may not be settled, because the relation between the syenite and the upper part of Shōgen system has not been clarified. In this paper I have tentatively considered the syenite to be of an age corresponding to the interval in the upper part of the Shōgen system, viz., between the Kuken and Shidōgu series.

In gneissic structure, the syenite is comparable to the Seikoshin gneiss which is clearly younger than the gray granite-gneiss (Kankō gneiss) in the Hamhŭng district.

Pre-Cambrian granites are known as Kungchangling and Tuimenshan granites in South Manchuria, and Taoke and Taishan granites in North China. At present there seems to be no doubt that the Kungchangling and Taoke granites originated later than the Tuimenshan and Taishan granites.

Kungchangling granite has been correlated with the Taishan granite by S. Matsushita (1952). R. Saito (1952), however, classified the former into a younger, Hsienglushan granite and an older, Hsiaolikou granite and correlated them with the Taoke and Taishan granites of North China.

Provisional conclusions about the chronological interpretation of granites in Korea, South Manchuria and North China are shown in the following table.

Upper Proterozoic	Sinian system in a narrow sense (Kuken series of the Shōgen system in Korea)
	Nepheline syenite and Seikoshin gneiss of Korea; Kungchangling granite in part, namely Hsienglushan granite of South Manchuria; Taoke granite of North China
	Huto system (Shidōgu and Chokken series of the Shōgen system in Korea)
Lower Proterozoic	Kokulian granite in part (Kankō gneiss), Red granite and Ritsura granite of Korea; Kungchangling granite in part, namely Hsiaolikou granite of South Manchuria; Taishan granite of North China
	Wutai system (Crystalline schists series of the Matenrei, the Yokusen and the Jōsuiyō in Korea)
Archean	Kokulian granite in part of Korea; Tuimenshan granite of South Manchuria; "oldest gneissose rocks of North China"
	Rensen system

Synopsis of the Geological Systems of Korea

Subdivision and geological age			Distribution, kind of dominant rocks and thickness	Mineral resources and miscellaneous remarks
Quaternary system		Alluvial series	Sand, gravel, clay and peat, forming alluvial plains and terraces; talus and fan deposits; some besaltic lavas of Cheju-do. Very extensive in distribution, but thin in thickness, generally 30 m or less, except the basaltic lavas.	Placers of gold, magnetite, illmenite and some special heavy minerals, dominated by monazite and zircon; quartz sand and ballstone (for ball-mills), etc.
		(Para- or Clino-unconformity)		
		Pleistocene series	Terrace deposits with mammalian fossils at Tonggwanjin, Chongsŏng-gun, N. Hamgyŏng-do; basaltic lavas and gravel beds on the Kaema plateau in S. and N. Hamgyŏng-do, Koksan-gun, in Hwanghae-do, and Ch'ŏlwŏn district in Kangwŏn-do; basalt flows on the Tertiary sediments in Changgi district, N. Kyŏngsang-do; trachyte flows on the coast of Myŏngch'ŏn district, N. Hamgyŏng-do, and Hamhŭng district, S. Hamgyŏng-do; shell beds (SEIKIHO formation), trachy-andesite and basalt of Cheju-do etc.	Gold placers, diatomite and peat.
		(Unknown relation)		
Tertiary (?) system			Diatomite deposits of Anbyon, S. Hamgyŏng-do,[7] and Ch'ŏlwŏn, Kangwŏn-do; lignite beds of Kowŏn-gun and Chongp'yŏng-gun, S. Hamgyŏng-do.	Diatomite and lignite.
		(Unknown relation)		
	Upper	Shichihŏsan (Ch'ilbo-san) series *Pliocene?*	Alkaline liparites, alkaline trachyte, basalt, tuffs, gravel beds, etc., the majority of which belong to the Shichihŏsan group in N. Hamgyŏng-do and Tōryūsan group in S. Hamgyŏng-do. Alkaline volcanics of Paektu-san may also belong to the series.	Moonstone in an alkaline rock as a semiprecious stone. The alkaline volcanics are highly variable in petrological nature, the comenditic ones, however, being most common.
		(Clino-Unconformity?)		
	Upper	Ennichi (Yonil) series.[8] *M. Miocene*	P'ohang district, N. Kyŏngsang-do. Upper: Shale and siltstone, rich in animal and plant remains. Lower: Conglomerate, sandstone and shale, conglomerate being dominant. Thickness: 600 m or less	Fossils are especially abundant in the Upper, dominant ones being marine molluscs and plants, the majority of the latter being more or less comparable to living species of the warm temperate zone of eastern Asia.

Tertiary System		Epi-Chōkian interval (Stage of peneplanation) —(Clino-unconformity)—	Strata of the Upper series are in general nearly horizontal or dipping at a very low angle and rarely faulted, while the Middle and Lower series are much disturbed by faults (mostly normal faults), warping and insignificant foldings, the strata generally being tilted at angles of about 20° or less. In some places the sediment of the Middle series is accompanied by flows of basaltic and some other volcanic rocks. Clino-unconformity is clearly observable between the Shichihōzan and Meisen group in North Korea, and between the Ennichi and Chōki series in South Korea.		The main part of the crustal movement which disturbed the older series probably began in the Oligocene. It may represent the Nanling movement, a part of the Himalayan movement in Korea. The Korean movement, however, seems to have a more intimate genetic relationship to the Ōyashima movement of Japan, which is also a part of the Himalayan movement.
	Middle		N. Kyŏngsang-do	N. Hamgyŏng-do	
		Chōki[9] (Changgi) series *Miocene～ Oligocene*	Bonkokuri (P'omgong-ni) group: Andesite, liparite, parlite, tuff, conglomerate, sandstone and shale; volcanic rocks being dominant. —(Clino-unconformity)— Chōki group: Conglomerate, sandstone, shale, various tuffs, coal, diatomite and interstratified basaltic flows; rich in plant remains, the flora being the Arctic Miocene type, somewhat modified; poor in animal remains which are represented by *Vicarya callosa* JENKINS and some other molluscan remains yielded from definite horizons. Thickness (except the basaltic flows): about 1,400 m.	Meisen (Myŏngch'ŏn) group Conglomerate, sandstone, shale, siltstone, coal and interstratified basaltic flows; rich in animal and plant remains, the former being represented by forms of marine molluscs and the latter by a flora which consists largely of forms of Arctic Miocene flora mixed with those comparable to living species of a temperate zone. Thickness: about 1,800 m. —(Clino-unconformity)—	Coal and diatomite The Chōki group covers a strikingly uneven surface of rocks of the Bukkokuji group, while the basement of the Ryūdō group referred to below is exceedingly flat. The flora of the Chōki series is especially rich in remains of beech (*Fagus*), containing various forms of the genus.

			Ryūdō (Yong-dong) group: Upper: Thick accumulation of basaltic lavas and basaltic tuffs, tuff breccia, and thin beds of sandstone. Lower: Shale, sandstone, conglomerate and coal; rich in plant remains. The fossils flora is of the Arctic Miocene type. Thickness of the Lower: 600 m or less.	Coal and clays ("Gairome" and "Kibushi"), the coal being important in the northeastern part of Korea.
	Lower	(Unknown relation) Hōzan (Pongsan) series *Upper Eocene*	Hwanghae-do Conglomerate, sandstone, shale and coal; rich in animal and plant remains, the former being represented by fresh water molluscs and some mammalian species and the latter by flora of the Arctic Miocene type. The Tertiary beds constructing the Anju coal-field of S. P'yŏngan-do may belong to this series. Thickness: over 350 m.	Coal of the Hōzan (Pong-san) series with that of the Anju coal field are important in the coastal regions facing the Yellow Sea.
Epi-Bukkokujian interval (Stage of epeirogenic movements and widespread peneplanation-Peitai stage)	(Unknown relation)	The crustal movements are considered to have begun at the beginning of the Rakutō series and lasted in the block movements closely accompanied by widespread eruption of the comagmatic acidic rocks of the Bukkokuji group, the last phase of the movements being the Bukkokuji disturbance. The disturbance was preceded by two phases of subsidence of regional or isolated basins, the Rakuto and Shiragi phases respectively. During the Shiragi phase an enormous amount of intermediate or rather basic lavas were poured out. The Bukkokuji phase was followed by a stage of peneplanation, the remnant of the peneplain being observable in very limited patterns on the Kaema plateau and on tops of high mountains in various places in Korea.		The phases of the crustal movements may represent the East Asiatic Yenshanian movement in Korea and its prolongation. The last phase, viz., the Bukkokuji disturbance, may be correlated with the North American Laramide Revolution.
		Bukkokuji (Pulguk-sa) series *Eocene?~ Uppermost Cretaceous*	Bukkokuji group: N. and S. Kyŏngsang-do, N. and S. Chŏlla-do N. Ch'ungch'ŏng-do, N. and S. P'yŏngan-do, etc. Granite, grano-diorite, diorite, liparite, feldspar porphyry and various dike rocks; granite, liparite and feldspar porphyry prevail; liparite and feldspar porphyry are generally dark gray, dark brown or dark green in colour and often show flow structure, and are grouped under the name of black felsophyre.	Various kinds of deposits of gold, tungsten, molybdenum, lead, zinc, copper, fluorite, alunite, etc. are found in close association with the intrusives of this group, the age of the Bukkokujian igneous activity being the most important metallogenetic epoch in Korea.

		The granite piercing the Taishū group may also belong to this group.	
		(Intrusive contact)	
		Taishū group: Tsushima (Japan), S. Cholla-do (?), S. Kyŏngsang-do (?) Shale, mudstone and sandstone, often with ripple marks and sun cracks; molluscan (mostly fresh water species) and plant remains (mostly dicotyledonous) are sparingly preserved. In Korea, it is often accompanied by tuffs. Thickness: over 600 m in Tsushima.	The chronological relationship between the Bukkokuji and Taishū groups seems to be more intricate than is shown in this table. In other words, the two groups seem to be partly contemporaneous and stratigraphically inseparable with each other.
Keishō (Kyŏngsang) system *Eocene?*~ *L. Cretaceous* or *U. Jurassic*	(Para-unconformity?) Shiragi (Silla) series *U. Cretaceous*	N. and S. Kyŏngsang-do, N. and S. Chŏlla-do, N. and S. Ch'ungch'ŏng-do, Hwanghae-do, S. P'yŏngan-do, etc. Shale, mudstone, sandstone, conglomerate, tuff, tuff breccia and andesite; often reddish, purplish or greenish; ripple marks and sun cracks are very common; generally poor in fossils, but a rich dicotyledonous fossil flora was yielded from a black shale in the upper part of the series; animal remains are represented by non-marine molluscs and *Estheria*. Thickness (except andesitic flows): over 3,000 m in N. Kyŏngsang-do.	The series has a thick bed of conglomerate at the base and is accompanied by thick accumulations of andesitic lavas, intercalated, or constructing the top of the series. Various terms for the series in various districts in Korea have been suggested, for instance, Upper Daidō formation or Taihō (Taebong) system in the districts along the Taedong-gang, Chin-an series in N. Chŏlla-do, and Eidō series, excluding its lowest subdivision, in N. Ch'ungch'ŏng-do.
	Rakutō (Naktong) series *L. Cretaceous* or *L. Cretaceous*~ *U. Jurassic*	N. and S. Kyŏngsang-do, N. Ch'ŭngch'ŏng-do, N. P'yŏngan-do. Shale, sandstone, conglomerate and inferior anthracite, with a striking bed of basal conglomerate; shale and sandstone, often reddish. Except for the reddish beds, the series is rich in remains of non-marine molluscs and plant fossils; ripple marks are seen in places. Thickness: over 3,950 m in N. Kyŏngsang-do.	The series is divided into two red and two blackish formations in alternation, with a blackish formation at the base. The basal formation is especially rich in remains of plants (Nakong flora) and non-marine molluscs, and corresponds to the Naktong (Rakutō) series, in a strict sense, by H. Yabe.
Epi-Daidoan interval	(Clino-unconformity)	The strata of the Keishō system are generally tilted at low angles, less than 30°, or nearly horizontal, but show no marked folding; while the Daidō system is strongly disturbed by conspicuous foldings and reverse faults or over-thrusts. The orogenic movements which disturbed the Daidō system were great and widespread, and were preceded by phases of subsiding movement of basins where the Daidō sediments were laid down.	The disturbance has been known under the name of Taihoan by E. Konno and may be chronologically correlated with that of the Ōga phase in Japan. It is interpreted as the first orogenic phase of the East Asiatic Yenshanian movement in Korea.

Daidō (Taedong) system *M. Jurassic*∼ *L. Jurassic*	Daidō series	N. and S. Ch'ŭngch'ŏng-do, Kyŏnggi-do, Kangwŏn-do, Hwanghae-do, N. and S. P'yŏngan-do, S. Hamgyŏng-do. Shale, sandstone and conglomerate in alternation; sandstone and shale most prevailing; often with anthracite seams intercalated; rich in plant remains. Thickness: about 2,650 m in S. Ch'ŭngch'ŏng-do.	Anthracite seams are workable in places, but not important in Korea. The series in the districts along the Taedong-gang has been called the Lower Daidō formation.
Epi-Heian interval	(Clino-unconformity)	The orogenic movement which resulted in this clino-unconformity is known as the Shōrin disturbance. The disturbance does not seem to differ in any essential characteristic structure from the Taiho disturbance, but is far smaller in scale than the latter. However, it is noteworthy that Korea has not been extensively covered by marine water since this disturbance.	The disturbance is thought to have begun in a later stage of the Heian system. It may be chronologically correlated with the Akiyoshi disturbance in Japan.
Heian (P'yŏngan) system[10] *Triassic*∼ *M. Carboniferous*	Green series *Triassic*	S. P'yŏngan-do, Kangwŏn-do, N. Ch'ŭngch'ŏng-do, N. Kyŏngsang-do and S. Hamgyŏng-do. Sandstone, shale and conglomerate; sandstone, dark green to dark gray, rarely reddish, prevails. The Red formation, well known as the Taishiin series in the P'yŏngyang coal field, S. P'yŏngan-do, has been often correlated to the Green series, but the stratigraphic relationship between them is quite uncertain. The Red formation rarely contains silicified wood. Thickness: over 1,000 m in S. P'yŏngan-do (over 1,700 m in the Taishiin series)	
	Kōbōsan (Kobangsan) series *Triassic* or *Up. Permian* (or *Permo-Triassic*)	S. P'yŏngan-do, Kangwŏn-do, N. Ch'ŭngch'ŏng-do, N. Kyŏngsang-do and S. Hamgyŏng-do. Sandstone, shale, conglomerate and anthracite; sandstone and shale prevail; rich fossil flora of a Mesozoic type has been yielded. Thickness: 350–500 m in S. Pyŏngan-do; 700 m in Kangwŏn-do.	Anthracite
	Upper Jidō (Sa-dong) series *L. Permian* (*Artinskian*)	S. Pyŏngan-do, Kangwŏn-do, N. Ch'ŭngch'ŏng-do, N. Kyŏngsang-do and S. Hamgyŏng-do. Sandstone, shale and anthracite. The shale is generally carbonaceous and in cases strikingly aluminous; rich in plant and animal remains. Thickness: 30–100 m in S. P'yŏngan-do.	Anthracite of this series is very important in Korea. Aluminous shale is also important as a fire clay.
	Lower Jidō series *L. Permian* (*Sakmarian*)	S. P'yŏngan-do, Kangwŏn-do, N. Chŭngch'ŏngdo, N. Kyŏngsang-do and S. Hamgyŏng-do. Shale, sandstone, hornstone, limestone and anthracite; shale and sandstone are generally carbonaceous; rich in plant and animal remains. Thickness: 100–150 m in S. P'yŏngan-do.	Anthracite

		Epi-Kōten interval	(Para-unconformity?)	The para-unconformity is suggested paleontologically, but has not been stratigraphically verified as yet.	
		Kōten (Hongjŏm) series *M. Carboniferous* (*Muscovian*)	S. P'yŏngan-do, Kangwŏn-do, N. Ch'ŭngch'ŏng-do, N. Kyŏngsang-do and S. Hamgyŏng-do. Sandstone, shale, hornstone, conglomerate and limestone; limestone prevails; sandstone and shale are often reddish; rich in animal remains (marine), but exceedingly poor in plant remains. Thickness: 250–300 m in S. P'yŏngan-do.	
Epi-Chōsen interval. (Stage of widespread epeirogenic movement and peneplanation—Rakurō stage)	(Para-unconformity)		The para-unconformity was long believed to be so great as to indicate the age of dry land ranging from the U. Ordovician to the L. Carboniferous. However, the existence of the Silurian limestone was suggested in 1934 from the derived fossils discovered in the basal conglomerate of the Jurassic Daidō series in Hwanghae-do, and then coralline fossils, probably indicating the Devonian, were unexpectedly discovered in a limestone block on the ground in Sunch'ŏn-gun, S. P'yŏngan-do, although the limestones from which the above fossils were derived have not actually been disclosed as yet.	Doubtful fossils which suggest the Silurian have recently been discovered in a thin bed consisting of arenaceous clay slate and limestone in Kŭmch'ŏn-gun, Hwanghae-do.
Chōsen (Chosŏn) system *M. Ordovician~ L. Cambrian*	Great Limestone series	Bantatsu (Mandal) series *M. Ordovician*	N. and S. P'yŏngan-do, Hwanghae-do, Kangwŏn-do, N. Kyŏngsang-do and S. Hamgyŏng-do. Limestone, mostly massive; rich in animal remains, predominantly remains of cephalopods and molluscs. The uppermost portion lacks fossils. Thickness: about 600 m in S. P'yŏngan-do.	Limestone is important as a raw material for cement manufacturing and some chemical industries in Korea. Paleontologically the series corresponds to T. Kobayashi's Toufangian series (Caradocian—Llandelian)
	Great Limestone series	Sozan (Ch'osan) series *L. Ordovician~ M. Cambrian*	N. and S. P'yŏngan-do, Hwanghae-do, Kangwŏn-do, N. Kyŏngsang-do and S. Hamgyŏng-do. Limestone, siliceous limestone, dolomite, shale and clay slate; more or less impure limestone prevailing. The limestone is thinly bedded, often carbonaceous and variable in lithological characteristics, including oolitic, cryptozoon (*Collenia?*) and vermicular limestones; the base consists of a thin but persistent bed of black shale (Rinson shale) rich in Middle Cambrian fossils. In general, the series is fairly rich in remains of Crustacea and others. Marine algae is known as a representative plant remains. Thickness: 900 m in S. P'yŏngan-do.	Paleontologically the upper and middle parts of the series correspond to T. Kobayashi's Wolungian (Skiddavian) and Wanwanian (Tremadocian) series, respectively.

	Yōtoku (Yangdŏk) series *M. Cambrian~ L. Cambrian*	N. and S. P'yŏngan-do, Kangwŏn-do, Hwanghae-do, N. Kyŏngsang-do and S. Hamgyŏng-do. Sandstone, shale, clay slate, quartzite and thin beds or lenses of limestone; shale prevails and is often sandy, rarely dark reddish; the base consists generally of quartzite, variable in thickness; shale, sandstone and limestone lenses are often rich in remains of Crustacea and Brachiopoda. Thickness: 400 m in S. P'yŏngan-do; 550 m in Kangwŏn-do.	
(Para- or Clino-unconformity)			
Sinian system *Upper-Proterozoic*	Kuken (Kuhyŏn) series	S. P'yŏngan-do, Hwanghae-do, Kangwŏn-do? and S. Hamgyŏng-do? Clay slate, shale, phyllite, pebbly phyllite (tillite?), quartzite and limestone; shale and phyllite dominates. Clay slate and shale often blackish. *Collenia* limestone is found in the basal horizon in some places. Thickness: 1,500 m in Hwanghae-do.	Insignificant iron formations in Kangdong district, S. P'yŏngan-do; marble, rosy or reddish orange, in Sŏngch'ŏn district, S. P'yŏngan-do; manganese deposits in Anhyop and Kŭmhwa districts, Kangwoň-do.
(Unknown relation)			
Sinian intrusive rocks		Nepheline syenite of P'yŏnggang district, Kangwŏn-do and hornblende-biotite granite (Seikoshin gneiss) of Hamhŭng district, S. Hamgyŏng-do.	Sodalite in the syenite (sub-precious stone)
(Intrusive contact? Para- or clino-unconformity between the Kuken and Shidōgu series)			
Huto system *Upper-Proterozoic*	Shidōgū (Sadangu) series	S. P'yŏngan-do, Hwanghae-do, Kangwŏn-do? and S. Hamgyŏng-do? Essentially limestone and dolomite with thin beds of clay slate intercalated; thin beds of *Collenia* limestone are found at the middle and uppermost horizons. Thickness: 2,000–2,400 m in Hwanghae-do; 1,500 m in S. P'yŏngan-do.	Marble
	Chokken (Chik-hyŏn) series	S. P'yŏngan-do, Hwanghae-do, Kangwŏn-do? and S. Hamgyŏng-do? Clay slate, phyllite, mica-schist, quartzite and limestone, with conspicuous beds of quartzite generally at base. Thickness: 3,100–3,800 m in Hwanghae-do; 700 m in S. P'yŏngan-do.	
Epi-Kokulian interval (Stage of peneplanation?)	(Para or clino-unconformity)	The interval is suggested by observations in Sŏngch'ŏn-gun and Sangwŏn district of Chunghwa-gun, S. P'yŏngan-do, where the Chokken series rests directly upon a complex consisting of mica-schists or gray granite-gneiss.	In the chronological column of Korea, the interval may occupy a very wide range.

Lower Proterozoic granites		A part of the Kokulian granite or the gray granite-gneiss: tourmaline granite and schistose granite of P'ungsan-gun in S. Hamgyŏng-do, and Kankō gneiss of Hamhŭng district in S. Hamgyŏng-do. Red granite: Ryūyori (Yongyang-ni) granite of Tanch'ŏn-gun in S. Hamgyŏng-do, Meisen (Myŏngch'ŏn) schistose granite of the northwestern part of Myŏngch'ŏn-gun, N. Hamgyŏng-do, and schistose granite of the Ch'ilbo-san district in Myŏngch'ŏn-gun, N. Hamgyŏng-do. Ritsura granite in the central part of Hwanghae-do.	Crystalline graphite and micas (phlogopite is most important), chiefly in North Korea. Pegmatite dikes of Red granite often contain zircon and allanite, and dikes of gray granite-gneiss in Yongch'ŏn-gun, N. P'yŏngan-do contain large crystals of monazite.
(Intrusive contact)			
Wutai system *Lower Proterozoic*	Jōsuiyō (Sangsuryang) series[11]	Ch'angsŏng-gun, Sakchu-gun and Ŭiju-gun, N. P'yŏngan-do. Sandstone, hornfels, clay slate, mica-schist, epidote schist, limestone, dolomite and quartzite; base unknown. Thickness: over 4,800 m in Ŭiju-gun.	Crystalline graphite and sillimanite.
	(Unknown relation. Almost contemporaneous?)		
	Yokusen (Okch'ŏn) system[12]	N. and S. Ch'ŭngch'ŏng-do and N. Chŏlla-do. Upper: Sandstone, hornfels, phyllite, mica-schist, conglomerate, quartzite, hornblendite, limestone and iron formations. Of these, phyllite is most common. A thick bed of phyllite contains sparingly angular or subangular pebbles of quartzose rocks and seems comparable to tillite in its rock nature. Middle: Amphibole schist, limestone, mica-schist, phyllite and hornfels; limestone and amphibole schist being dominant. Lower: Sandstone, hornfels, metamorphosed clay slate and quartzite; the metamorphosed clay slate is often accompanied by deposits of earthy graphite. The base is not known. Thickness: very thick.	Earthy graphite and iron.
	(Unknown relation. Almost contemporaneous?)		
	Matenrei (Mach'ollyŏng) system[13]	N. and S. Hamgyŏng-do. Upper: Mica-schist, limestone, dolomite and various gneisses, the mica-schist being dominant. Middle: Limestone, dolomite, magnesite and mica-schist; limestone and dolomite prevail. A *Collenia* limestone is found intercalated in a middle horizon. Lower: Mica-schist, graphite schist, quartzite and dolomite; the mica-schist prevails; base unknown. Thickness: over 9,100 m.	Magnesite deposits, very large in scale; crystalline graphite; apatite. The large scale iron formation of Musan, N. Hamgyong-do is thought to be of the system, but is quite uncertain.

Ep-Archean interval		The interval has not been actually verified.	
Archean granites		A part of the Kokulian granite in the terrain of the Rensen system at least.	At present, it can not be differentiated petrographically from the grey granite-gneiss of the Lower Proterozoic age.
	(Intrusive contact)		
Rensen (Yonch'ŏn) system *Archean*		Kyŏnggi-do, S. Ch'ŭngch'ŏng-do and Kangwŏn-do. Upper: Mica-schist, phyllite and micaceous hornfels. Lower: Mica-schist, amphibole schist, hornblende pyroxene hornfels, quartzite and siliceous limestone, together with iron formations. Base unknown. Thickness: very thick.	Iron and sillimanite (cyanite).

7) According to B. V. Skvortzov, the diatom remains of Anbyŏn suggest the Upper Pliocene.
Skvortzov, B. V., 1936, The Neogene diatoms from the Ampen district, S. Kankyō-do, eastern coast of Chōsen: Bull. Geol. Surv. Chōsen v. 12.

8) The boulder deposits (Shinkō formation) unconformably resting upon the Chōki series (Chōhōri formation) in Sinhŭng district, S. Hamgyŏng-do, probably belong to the Ennichi series and may represent an early stage of it.

9) The major part of the Tertiary formations along the Tuman-gang, N. Hamgyŏng-do, are divided by a distinct unconformity into the Yūsen (Yusŏn) and Kōei (Haengyŏng) formations, which may be correlated with the Ryūdo and Meisen groups. Formations which may belong to the Chōki series commonly have coal seams and are found also in the Sinhŭng district (Chōhōri formation) of S. Hamgyŏng-do, the Tonch'ŏn district in the northern part of Kangwŏn-do, and the Samch'ŏk district in the southern part of Kangwŏn-do.

10) The Heian system in Korea corresponds to the South Manchurian type of Upper Paleozoic system of Manchuria. Another type of Manchurian Upper Paleozoic, the North Manchurian type, is represented in Korea by a thick series of shale and sandstone in the Tuman-gang river basin, and considered to be an extension of the Tuman formation, one of the North Manchurian Upper Paleozoic series.

11) Originally crystalline schists in the Ch'angsŏng and Sakchu districts were included in the series by Sh. Nakamura (Mineral Resources of Chōsen, v. 1, 1915). In comparison, the crystalline schists of neighboring Ŭiju district (E. Takahashi, Ŭiju sheet, scales 1:200,000, 1940) are not so intensely metamorphosed, but are considered part of the terrain of crystalline schists extending from Ch'angsŏng and Sakchu districts.

12) The Yokusen system comprises various metamorphosed sedimentaries as shown in the table and occupies an extensive belt, trending northeasterly through Okch'ŏn district in South Korea. A certain portion of the strata included in the Okch'ŏn series may belong to the Heian system, as pointed out by N. Kobatake (N. Kobatake: Considerations on the Yokusen [Okch'ŏn] system, *Sci. Rep. South Branch School, Ōsaka Univ.*, no. 1, 1952), and in other cases it can hardly be differentiated from the Cretaceous Shiragi series which suffered metamorphism through contact with the granite which invaded the series (Shimamura, S., Geol. Atlas of Chōsen, no. 5, 1925). However, the pre-Sinian age of the essential portion of the complex is suggested by the fact that the complex is invaded in some places by gray granite-gneiss (Nakamura, S., Mineral resources of Korea, v. 8, 1925).

13) According to Sh. Nakamura, it is highly possible that the Matenrei system in part in the northern part of S. Hamgyŏng-do belongs to the Chōsen system. The question, however, has remained unsolved.

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Geology of South Korea
with Special Reference to
the Limestone Plateau of Kangweondo

Teiichi Kobayashi

Introductory Note

South Korea has an intimate tectonic relationship with North Korea, South Manchuria, and North China, all of which belonged to Hwangho province in the Palaeozoic era. It is recognized, however, that the faunal aspect of South Korea is intermediate between those of the Hwangho Basin as well as the Yangtze Basin covering Central and South China. The Okch'eon geosyncline which occupied the northeastern part of the Yangtze basin crosses South Korea diagonally. The Yeongnam land on its southeast side extended into Fukien, and the Kyeonggi land on the other side into Shantung. Along the south side of this land the Okch'eon sea was sometimes confluent with that of the Hwangho Basin. Therefore, the stratigraphy of South Korea is of more than local value. In fact a key to the Ozarkian problem was found in South Korea because in the Ordovician period the Hwangho Basin formed a large zoopalaeogeographic province with North America and the Arctic region whereas the Yangtze Basin was united with Europe and Australia.

Tsushima Strait, separating the peninsula from the Japanese islands, lies on the tectonic boundary between the continent and the islands. In the Cretaceous period there was the Tsushima basin around the strait, and the Kyeongsang group deposited there is a link in geology between Japan and Korea. The Cretaceous and later formations are, however, blankets on the fundamental frame of the geological architecture which was instituted by the older Mesozoic Songnim and the younger Mesozoic Taebo disturbance. This framework was precisely analyzed in the Kangweondo limestone plateau which occupied the northeastern part of the Okch'eon zone. There is a remarkable imbrication which is in some ways similar to the structure of the Scottish highlands and the Appalachian mountains, but the Okch'eon imbrication has its own characteristics. The eastern part of the plateau is essentially different from the western part, because the former belongs to the Yeongnam massif.

The igneous activity accompanied by the Taebo disturbance, especially the batholithic invasion of the Chugoku granite, extensively consolidated Eastern

Asia. Subsequently its fragmentation took place, one product being the Korean Peninsula. As shown by its backbone range close to the Japan Sea, the peninsular outline was introduced by faulting and asymmetrical upwarping. The fault mesh in the former stage of fragmentation was analyzed in great detail in the eastern plateau. The backbone range was previously thought to have been introduced by faulting, but later investigation has shown that the present topography depends chiefly upon the geanticlinal upheaval after the faulting. The faulted blocks are beheaded by the high peneplane which was named Roppyakusan or Yukpaeksan after its clear-cut remnant on Mt. Yukpaek in the eastern plateau. The two cycle mountains of Korea are typically shown in cross section through the plateau whence the high and low planes have been traced into Manchuria and Japan by later researchers. As seen in the topographic map the Korean peninsula together with the Ryukyu Islands forms the periphery of the East China Sea. The tectonic elements of this arc are aligned *en échelon*. In Kyushu the arc joins with the arc of Japan in the shape of a T.

Thus South Korea, and the limestone plateau of Kangweondo in particular, provides one of the crucial points in the geologic history of East Asia. The more important subjects to be dealt with in the plateau are as follows:

1. the development from the Okch'eon geosyncline to the orogenic zone;
2. the fragmentation of the Yeongnam massif into blocks;
3. another fragmentation along the Korean arc subsequent to the late Mesozoic granitization.
4. the topographic development of the two cycle mountains.

Special attention is paid to (1) the growth of embryonic folding, (2) differential deformation with regard to the competency of formations in the Okch'eon zone and (3) the remarkable *Schuppenstrukturen* at the two southern corners of the Chungbongsan block in the eastern plateau. In addition there are several topics of special interest. In regard to tectonic considerations it is especially noteworthy that (1) the limestone plateau covers the geosyncline and a part of the Yeongnam massif and (2) the Cambro-Ordovician Korean group and the P'yeongan group, from Moscovian to Lower Triassic, are separated by parallel unconformity where the former consists largely of limestone whereas the latter is mostly terrigenous. Hence the two are quite different in plasticity. The Triassic embryonic folding brought forth Bangsong lake in the Okch'eon zone. The Bangsong series is a lacustrine sediment and the variation of its basal conglomerate enables one to explore the palaeogeography in great detail through lattice analysis. Mt. Taepaek is one of the highest summits in the backbone range. The standard sequences of the Korean and P'yeongan groups were established in its vicinity. While the facies and thickness change greatly towards the west in the geosynclinal zone, the change is slight toward the east. Accordingly, these sequences make it easy to decipher the faulted mosaic along the coast of the Japan Sea. The high Yukpaeksan plane cuts this mosaic. The marginal peneplanes, broad in the west but very narrow in the east, reveal a strong contrast. They are the two principal topographic factors controlling the life and culture of this nation.

The principal aim of this paper is to describe the geology of South Korea with special reference to the Kangweondo limestone plateau and to discuss the history of its tectonic development. I began this study in 1926 and made studies on the stratigraphy of the Korean group, the palaeontology of the Ordovician nautiloids, and the geomorphology of Korea until 1931, when I went abroad.

After my return home in 1934 I busied myself in the tectonic research of West Japan, but in 1938 began to resume my investigations on the continent. I made surveys of the plateau with Messers. Ichiro YOSHIMURA (1938), Yoshiyuki IWAYA (1939–40), Kiyohiko AOTI and Tsuneo HUKASAWA (1940), Sadataka HISAKOSHI (1941) and Kunio KOBAYASHI, Taro YOSHIKAWA and Hisashi YOSHIDA (1942). The results of indoor and field work were reported by each participant and I myself compiled them in my progess report.

In 1950 the Committee for the Compilation of Geology and Mineral Resources of the Far East was established within the Geographic Society of Tokyo. One of the articles which I presented to the committee was *Geology of the Kangweondo Limestone Plateau and its Relation to the Geology of the Neighbouring Areas* which was printed in 1952. *Geology of South Korea* in which this article constitutes the second chapter was published in 1953 in the faculty journal of the University of Tokyo as Part IV of the Cambro-Ordovician Formations and Faunas of South Chosen.* It has been revised for inclusion in this volume.

Here I wish to record my most cordial thanks to all of the persons and scientific organizations in Japan and foreign countries for giving me facilities and assistance during these forty years, without which this study could not have been accomplished.

Note: Stratigraphic Terms are written according to the old romanization in text-figures 8, 9, 11 and 18 and geological maps I and II, but according to the new romanization in the other illustrations, tables and text.

Old romanization	**New romanization**
Bansho series	Bansong series
Beiho slate	Myobong slate
Bukkokuji igenous rocks	Pulgoksa igneous rocks
Bunkoku beds	Mungog beds
Chikunsan shale	Chikunsan shale
Chosen group	Jeseon or Korean group
Daido series	Daedong series
Doten quartzite	Dongjeom quartzite
Eiko beds	Yeongheung beds
Gakoku beds	Wagok beds
Girinkitsu beds	Euirimgil beds
Greenstone series	Nogam series
Heian system	Pyeongan system
Jido series	Sadong series

Kasetsu group	Hwajeol group
Kobosan series	Gobangsan series
Koten series	Hongjeom series
Kyeongsang group	Gyeongsang group
Makkol limestone	Makkol or Maggol limestone
Masari beds	Machari beds
Naktong series	Naktong series
Samposan beds	Sambangsan beds
Seison shale	Sesong shale
Seizen limestone	Jeongseon limestone
Shiragi series	Silla series
Shiun beds	Chaun beds
Shobo schist	Songbong schist
Sohsan quartzite	Jangsan quartzite
Taiki limestone	Daegi limestone
Tomkol shale	Dumugol shale
Tonden slate	Tunjeon slate
Tsuibon limestone	Tuwibong limestone

I
A Geological Sketch of Korea and Environs

1. Research in the geology of Korea

Not only Korea but Eastern Asia as a whole may be said to be a new world geologically. It can boast of no long history of research in modern geology as can Europe, where studies have been going on since the Renaissance. The first scientific observation of Korea was made by O. C. Gottsche when he made an eight-month journey there in 1884. Among the Japanese, N. Kaneda was the first to study Korea's geology (1891). Koto's *Orographic sketch* (1904) and *Journey through Korea* (1909–10), Yabe's descriptions of the *Mesozoic Naktong flora* (1905), fusulinids (1906), and *Gigantopteris* (1908), and K. Inouye and his associates' *Geology and mineral resources of Korea* (1907) were published with a geological map of Korea in the following years.

After the annexation of Korea by Japan in 1910 Kawasaki, Nakamura, and Tamura carried out surveys of mineral resources throughout Korea. Then came studies on graphite and other minerals by Fukuchi, on the coal-field by Tokunaga, on the Permian coal-measures by Yabe and others. Geological surveys of the area were established in 1918 as part of the activities of the Government of Chosen, which published eighteen geological atlases of Korea (by 1937, scale 1/50,000) as well as many other publications. The coal-fields were surveyed by the staff of the Fuel Investigation Office and reports published after 1922. *Geology and mineral resources of Chosen* was compiled by Kawasaki in 1926 and a general geological map of Korea (scale 1/1,000,000) published by the survey in 1928. Beside these there were many research reports chiefly by specialists from the universities including KONNO's and NAKAMURA and his students' Geology of the P'yeongyang coalfield, MATSUSHITA's Pre-Cambrian Sangweon system, KOBAYASHI's Cambro-Ordovician Korean (Chosen) system, KOBAYASHI and his students' Geology of Kangweondo limestone plateau and so forth. KOBAYASHI summarized the tectonic development in his *A sketch of Korean geology* (1933). Many results of investigations of geology and mineral resources by 1945 were compiled in *Geology and Mineral Resources of the Far East* (in Japanese), Volume One, Korea, some articles of which are translated into English and contained in the present volume. For detailed accounts of the history of the research the reader is referred to TATEIWA's *History of Geologic Research in Korea* in the aforementioned Japanese edition.

2. Outline of geomorphology of Korea and environs

Korea is a peninsula of the Asiatic continent, with an area of 220,379 square kilometers, *i.e.* a little smaller than the main island of Japan. KOTO (1904) divided Korea into three parts: the *Gaima* (or *Kaema*) *Plateau* to the north of the line drawn between the east and west Korean bays, the *Hanland* to the south of the Weonsan—Seoul rift valley and *Palaeo-Korea* between them. The backbone range is close to the Sea of Japan. The Tsushima Strait separates the peninsula from Japan's Kyushu and Chugoku regions. The boundary between China and Korea is demarcated by the course of the Yalu River and the Touman River with Mt. Paektu between them. There is, however, no distinct difference in orography between its two sides.

The mountainous land in North Korea and East Manchuria is detached from the Sikhota Alin Range by the narrow lowland of Lake Khanka. It is separated from the north Manchurian highland by the Sungari River. Its western side is sharply defined by the Liao tectonic line. Farther beyond lies the central Manchurian basin.

The ENE trend called *Sinische Richtung* by RICHTHOFEN (1881) controls the orography and hydrography of this mountainous land. The southern scarp of the Kaema plateau, the southern coasts of Shantung and Korea, and the northwestern coasts of Kyushu and Chugoku have a similar trend. In Central and South Korea, however, the NNW trend called *Korean direction* by KOTO is distinct as indicated by the coast line of the Japan sea and the Taepaiksan range along the coast. From Taepaiksan, however, the Sopaiksan range runs across South Korea diagonally. Because a NE trend is prevalent in South China, the term *Sinian direction* was given by PUMPELLY (1886) and adopted by KOTO in his Korean orography. The Ch'aryeong range and Yeongsangang River are on this trend. The NNE trend is also important as indicated by the rift valley between Weonsan and Seoul, the Masigyeong range and the Kongju range on its two sides, and by the Kilchu-Myeongch'eon graben.

These are all very important trends controlling the land relief and river system.

Some of the reliefs depend on faulting, others on warping or flexure. Their original forms are, however, generally strongly dissected. Still others may be erosion scarps. The E-W direction is very important for the geologic structure of North Korea, but is less significant in topography, although it is still revealed to some extent by differential erosion. Peninsular Korea including Palaeo-Korea and Hanland is outlined by the Korean arc on its east side. The volcanic zone comprising Mt. Paektu and Ullŭngdo and Cheju islands describes another arc parallel to but outside of the preceding.

3. Tectonic lineament of Korea and environs

During and before the Palaeozoic the larger part of Korea was inseparably related to South Manchuria and North China, but the extreme northeastern area of Korea is quite different from Korea proper. It may be combined with the Chientao area of Manchuria to the north and the Suifun area of Ussuri to the east into the Suifun-Touman area. The Mongolian geosyncline is thought to have been connected there with the Chichibu geosyncline of Japan. Embraced by these geosynclines there was a vast terrain for which I proposed the name *Koreo-Chinese Heterogen*.

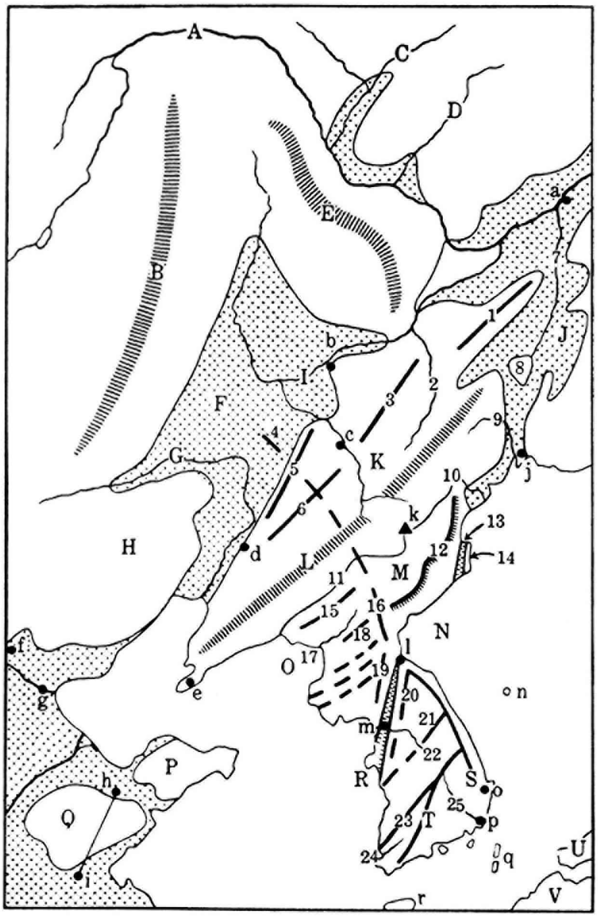
The Pre-Cambrian basement is exposed at some places but none is wide enough to be called a shield.

Among these massifs there were some geosynclines and basins of different magnitudes, the basins belonging possibly to quasikratons. The terrain is not a simple kraton, geosyncline, or a quasikraton, but a heterogenous aggregate varying in places in plasticity or rigidity. Hence the name, Chinese Heterogen, previously suggested (Kobayashi, 1950).

The Chinese Heterogen can be divided by the Tsinling-Seoul line (Kobayashi, 1930) into two major provinces, called Hwangho and Yangtze (Kobayashi, 1952). The Pre-Cambrian history of the Hwangho province best known in the zone through Wutaishan, and Liao-Kaema land, may be summarized in the following manner: (1) the Wutai cycle of sedimentation; (2) the Taishan igneous cycle; (3) the Huto cycle of sedimentation; (4) the Taoke igneous cycle; (5) the Sinian cycle of sedimentation.

The sedimentary basins in Hwangho Province are collectively called the Hwangho Basin. The Cambro-Ordovician Korean system is in most places underlain by the Sinian system unconformably and overlain by the P'yeongan system also paraunconformably. There is, however, a tremendous hiatus between the Korean and P'yeongan systems, related to the time interval from late Ordovician to early Carboniferous.

The Kyeomipo limestone conglomerate near Kyeomipo, south of P'yeongyang, which was once thought to be a Silurian deposit (Shimizu, Ozaki, and Obata, 1934), is in fact the basal conglomerate of the older Mesozoic Daedong series and the Silurian fossils are *rémaine* in the conglomerate (Kobayashi, 1935). Some Devonian-type corals were reported at Cheonseongni to the northeast of P'yeong-



a Chabarowsk
b Harbin
c Kirin
d Shenyang
e Dairen
f Peking
g Tienshin
h Ihsien
i Weihsien
j Vladivostok
k Paektu (Hakuto) volcano
l Weonsan (Genzan)
m Seoul (Keijo)
n Ullung-do (Utsuryo island)
o Kyeongju (Keishu)
p Pusan (Fuzan)
q Tsushima islands
r Cheju-do (Saishu island)

1 Wantashan range
2 Mutanchiang river
3 Laochangkuang Sueiling
4 Hei-Liao divide
5 Taheishan range
6 Sahaliang-ling
7 Ussuri river
8 Lake Khanka
9 Suifun river
10 Touman river
11 Yalu (Oryokko) river
12 Hamgyeong (Kankyo) range
13 Myeongch'eon (Meisen) graben
14 Ch'ilbosan (Shichihosan) horst
15 Kangnam (Konan) range
16 Nangnim (Rorin) range
17 Ch'ongch'eongang (Seisenko) river
18 Myohyang (Myoko) range
19 Masigyeong (Basokurei) range
20 Kwangju (Koshu) range
21 Ch'aryeong (Sharei) range

A Amur River
B Great Khingan range
C Seja River
D Bureja River
E North Manchurian highland
F Central Manchurian plain
G Liao River
H Jehol
I Sungari River
J Khanka-Suifun lowland
K East Manchurian mountainous land
L Changpaishan (Chohakusan)
M Kaema plateau
N East Korean bay
O West Korean bay
P East Shantung
Q West Shantung
R Weonsan-Seoul (Genzan-Keijo) rift valley
S Taebaegsan (Taihakusan) range
T Sobaegsan (Shohakusan) range
U Chugoku
V Kyushu

Fig. 1. Orographic Map of Koreo-Manchuria.

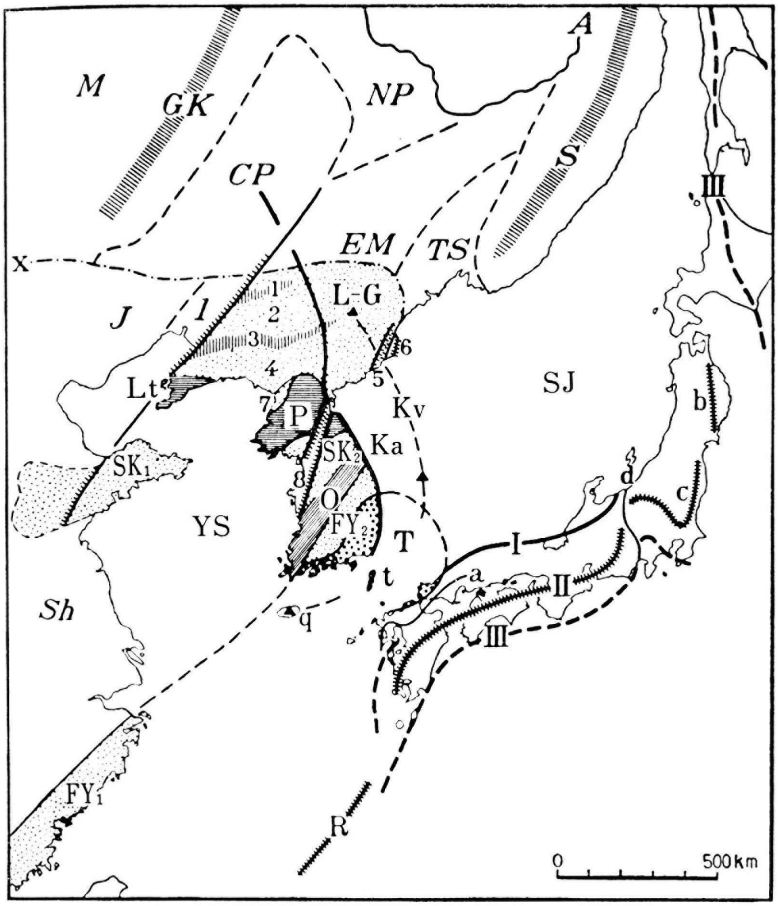
yang (Yabe and Sugiyama, 1939), but their stratigraphic position is still obscure.

In Yangtze Province the Pre-Cambrian sequence is not so well known as in Hwangho Province, but there is a more continuous display of Palaeozoic formations without such a Middle Palaeozoic break as seen in the Hwangho Basin. Furthermore, the marine facies is predominant until the Triassic, but the sea never flooded the Hwangho Basin after the early Permian transgression.

In South Korea there are the Korean and P'yeongan systems separated by the Middle Palaeozoic hiatus as usual in the Hwangho Basin, but the rock facies of the Korean system and its fauna, especially the Ordovician ones, are more related to those of the Yangtze Basin than to those of the Hwangho Basin. The marine fauna in the lower P'yeongan system also appears intermediate between those of the two basins.

The tectonic lineament of Korea which I proposed in 1933 needs little emendation, but if its surrounding areas are brought into the picture, some modifications are advisable. It has been confirmed that the Yeongnam land extends into Fukien and the Kyeonggi land into eastern Shantung (Kobayashi, 1943). The P'yeongbuk Kaema land is perhaps better combined with South Manchuria, but there were two zones of depression which wedged themselves into this land from the west. In the northern, *i.e.* the Tiehling zone there are the Sinian and Huto systems and in the southern, *i.e.* the Taitzuho zone there are not only these two but also the Korean and P'yeongan systems. The Pre-Cambrian Taoke igeneous activity and related deformation processes were strong in the northern zone, but less so in the southern zone and almost negligible in the P'yeongnam geosyncline still more to the south. There the Huto and Sinian systems form the Sangweon system, of a tremendous thickness attaining 7,000 m or more. The sub-Cambrian discordance is also weak or indiscernible. Incidentally, more than half of the North Korean terrain which was referred to the Korean system in the 1928 map is now known to belong to the Sangweon system. In the Okch'eon geosyncline in South Korea, on the other hand, the Sangweon system is completely missing and the Korean system directly rests on the Pre-Cambrian basement.

The Korean system was first divided into the lower or Yangdeok series and the upper or Great Limestone series. A revised classification exists for each region, as described in detail in my recent paper (1966). The P'yeongan system used to be classified in Korea into four series, namely Hongjeom, Sadong, Gobangsan and Greenstone. In the standard stratigraphic classification in the Hwangho basin, however, the Sadong series is better split into two parts, because the lower Sadong is generally marine and the upper Sadong non-marine. Therefore I recommend the application of the Taiyuan series to the lower Sadong and the Shansi series to the upper Sadong. The Hongjeom series contains a Moscovian marine fauna. No Uralian fauna is yet known in the Hwangho basin. Nevertheless the Hongjeom and Sadong series appear to be continuous at least in the P'yeongnam and Okch'eon geosynclines. The Taiyuan series contains a marine Sakumarian fauna. Accordingly the Shansi series is Middle Permian, the Gobangsan Upper Permian



A	Amur River
CP	Central Manchurian plain
EM	East Manchurian mountains
FY_{1-2}	Fukien-Yeongnam (Reinan) land
GK	Great Khingan range
J	Jehol
Ka	Korean arc
Kv	Peri-Korean volcanic chain
LG	Liao-Kaema zone
Lt	Liaotung
M	Mongolia
a	Motoyama metamorphic zone
b	Kitakami mountains
c	Abukuma mountains
d	Itoigawa-Shizuoka tectonic line
I	Axial zone of the Akiyoshi mountains
II	Axial zone of the Sakawa mountains
1	Tiehling zone
2	Shenyang (Fengtien, Mukden) zone
3	Taitzuho zone
4	P'yeongbuk (Heihoku) zone
NP	North Manchurian plateau
O	Okch'eon (Yokusen) zone
P	P'yeongnam (Heinan) zone
R	Ryukyu arc
S	Sikhota Alin Range
Sh	Shankiangan basin
SJ	Sea of Japan
SK_{1-2}	Shantung-Kyeonggi (Keiki) massif
T	Tsushima basin
TS	Touman Suifung area
X	Northern boundary of the Koreo-Chinese Heterogen
l	Liao tectonic line
q	Cheju-do (Saishu, Quelpart) volcanic island
t	Tsushima Islands
III	Axial zone of the Oyashima mountains
5	Kilchu-Myeongch'eon (Kishu-Meisen) graben
6	Ch'ilbosan (Shichihosan) horst
7	P'yeongweon (Heigen) massif
8	Weonsan-Seoul (Genzan-Keijo) rift valley

Fig. 2. Tectonic Map of Korea and Environs.

and the Greenstone series lower Triassic. A tentative correlation of the P'yeongan system is shown in Table 1.

Table 1. Tentative Correlation of the Pyeongan System in the Hwangho Basin.

Age	Hwangho Basin				Phase of Disturbance
	Korea	S. Manchuria	N. China		
Ladinic					Songim (Shorin)
Anisic Skytic	Greenstone or Nogam		Shichienfeng		(Misaki) Tate-Suwan
Tatarian Kazanian	Kobosan or Gobangsan	Saichia	Shihhotzu		Usuginu-Tungwu
Kungurian Artinskian Sakmarian	Jido or Sadong	Liutang	Shansi	Yueh- menkou	
		Huangchi	Taiyuan		pre-Usuginu-Chaotsuo Sakamoto-Kumming
Uralian Moscovian	Koten or Hongjeom	Penchi	(Chaotien) Penchi		

As mentioned above, the stratigraphic sequence of the Hwangho province before the Middle Triassic Songim deformation consists of the Wutaian, Hutoan, Sinian, Korean and P'yeongan systems. In the eastern part of the province the tectonic elements, positive and negative, were aligned alternately from north to south. They are classified as follows:

1. *Liao-Kaema land* in which there was (a) the Tiehling zone of depression in the north and (c) the Taitzuho zone of depression in the south, separated by (b) the Shenyang zone of elevation. To the south of the Taitzuho zone there was (d) the P'yeongbuk zone of elevation.
2. *P'yeongnam Geosyncline* which extended to the west into the western hills of Peking through the Liaotung peninsula.
3. *Kyeonggi land* extending into eastern Shantung.
4. *Okch'eon geosyncline* which is connected with the central and south Chinese basins in one way and intermittently with the *Shankiangan basin* (Kobayashi, 1941) to the south of the Shantung block.
5. *Yeongnam-Fukien land.*

In the Tiehling zone there is no Palaeozoic formation and in the Taitzuho zone there are many stratigraphic breaks and the Greenstone series is almost all missing. The sequence is most complete in the P'yeongnam geosyncline except the Greenstone series which is much thicker in the Okch'eon geosyncline where, however, the Sinian and Hutoan are missing. This geosyncline may have subsided more or less reciprocally to the upheaval of the Tiehling zone.

The fundamental problem is whether these lands persisted throughout the periods or were submerged under water, only the sediments having been eroded out.

In connection with this problem it should be noted that: (1) in Korea arkose material of the Sangweon system must have been supplied from land adjacent to the P'yeongnam geosyncline. There is neither the Korean nor the P'yeongan system on the massives in Korea. (2) In Manchuria there is the so-called Yungning sandstone which, according to SAITO (1938), is composed of deltaic sediments wedged in the Sinian formation. This delta must have expanded from the western part of the Liao-P'yeongbuk land. (3) The Okch'eon zone was land in the Sinian period. (4) There was the elevating Kyeonggi-Shantung axis between the P'yeongnam geosyncline and the Shankiangan basin. (5) At Kishan, farther west in Shansi, the Middle Cambrian formation similar to the Lower Cambrian Manto series in its lithic aspect lies on a gneiss basement. Therefore the basement must have been land until the early Cambrian period. (6) The *Cryptozoon* reef at the base of the Ordovician formation is extensive in the Taitzuho zone and the northern margin of the P'yeongnam geosyncline, as seen in the Wuhutsui basin and the Chinchou district in the Liaotung peninsula and in the Teokch'eon district in the northern part of the P'yeongan-namdo. The intraformational limestone conglomerates are also commonly seen in these places, but the *Cryptozoon* reef and the intraformational conglomerate is seldom seen in the central part of the P'yeongnam geosyncline. (7) The Cambro-Ordovician faunas in these depressions are similar to one another, but there are indigenous elements, *Coreanoceras* in the eastern P'yeongnam geosyncline and *Manchuroceras* in the Taitzuho depression for instance. The Wanwanian fauna (KOBAYASHI, 1933) of the latter depression is quite characteristic. The Cambro-Ordovician faunal aspect of the Okch'eon geosyncline is quite distinct from that of the Hwangho basin in many respects. Such an endemism may be due to isolation by a peninsular projection or intermittent land barrier. (8) In the P'yeongan system it is sometimes seen that the conglomerate wedges are inserted near the margin of some coal fields. These facts as a whole suggest that elements bearing positive and negative tendencies were aligned alternately from north to south, although it is probable that the positive elements were covered to some extent by thin blankets of sediments.

4. The Songnim and Taebo disturbances and related granitization

The aforementioned tectonic lineament of the Hwangho province was maintained through the Palaeozoic, but strongly deformed during the Mesozoic era. The Mesozoic basins are therefore distributed without any relation to the previous land masses and zones of depression.

In calling it Yenshan, WONG (1927) paid attention to the late Mesozoic crustal deformation. The name, *Yenshan movement,* however, has been used in various ways since its denomination. In the meantime the Taiho (Taebo) movement was proposed by KONNO (1928) for the late Mesozoic disturbance in Korea. Therefore the

Yenshan might be used as a collective term for the late Mesozoic disturbances in the Hwangho province or the Chinese Heterogen and the Taebo for the paroxysm at the Jurasso-Cretaceous transition.

The older Mesozoic disturbance in the province was first proven at Songnimni near Kyeomipo, south of P'yeongyang, where the older Mesozoic Daedong series dipping northwest was found to lie on the Ordovician limestone dipping southeast (Kobayashi, 1930). Because of this clino-unconformity the older Mesozoic disturbance was named "Shorin" (Songnim). Subsequently evidence of this disturbance was seen in the Wafangtien coal field at the neck of the Liaotung peninsula and later in the P'yeongyang coal field. The folding and thrusting of the P'yeongnam geosyncline was first attributed to the Taebo disturbance, but later it was found that this geosyncline had been deformed primarily by the Songnim disturbance and that the Taebo deformation was a secondary one in which the already complicated structure was deformed by interformational sliding, up-thrusting and normal faulting.

Because the Mesozoic strata on the continent must be classified before any tectonic analysis, I have taken up the study of the non-marine Mesozoic formations in Eastern Asia and the fossils contained therein, carrying on this project in collaboration with Suzuki, Takai and several others since 1942. The classification thus obtained is shown in Table 2.

Table 2. Tentative Classification of Non-Marine Formations in Eastern Asia and Fossils Contained Therein.

Age	Formation	Fauna			Flora
		Mollusca	*Estherites*	Fish	
Cretaceous	Sungari	Sungari	*mitsuishii*	*Sungarichtys*	Gyliak
	Silla	Kyöngsang	*kyöngsangensis*	*Manchurichtys*	
	Naktong				Toyora
Jurassic	(Fuhsin) Jehol	Jehol	*middendorfii*	*Lycoptera-Asiatopsis*	
Up. Trias.	Daedong	Daedong (Daido)	*coreanica*		Mine

As discussed elsewhere, the Akiyoshi cycle of orogeny disturbed not only the Chichibu geosyncline, but also the Mongolian geosyncline, although in the earlier phases of the cycle the disturbance was stronger in the latter, and in the later phase, in the former geosyncline. As discussed in detail (Kobayashi, 1952) the climate of the Hwangho basin changed from a warm, humid one in the Shansi epoch when coal measures were deposited, to one of high aridity in the Greenstone epoch after a warm but fairly arid climate in the Gobangsan epoch when the *Gigantopteris nicotianaefolia* flora flourished. This change must have been due to a pre-orogenic upheaval of the geanticlinal axis on the inner side of the Chichibu geosyncline which extended from Japan to Tonkin. In the late Permian period the sea retreated completely from the Mongolian geosyncline. Though the early Triassic sea lingered on in Transbaikalia and southern Ussuri, the vast terrain of Eastern Asia became an arid land.

The Akiyoshi orogenic cycle was accompanied by the batholithic invasion of the Mongolian granite with the result that the Angara Urkraton was fused with the northern part of the Chinese Heterogen through the Mongolian orogenic zone. (Kobayashi, 1942). Therefore the basins where the Daedong group was deposited are distributed independently from previous tectonic lineament, as shown by the Tsetsenwan series in Outer Mongolia, the lower Algatchi in Transbaikalia, the Mongugai in Ussuri, the Daedong in Korea, the Peipiao coal-bearing in Jehol and the Tatung in Inner Mongolia, the Mentoukou in the western hills of Peking and so forth. The post-orogenic conglomerate series in the Kuznetsk basin is probably a Daedong member far in the interior.

The Daedong group of floras on the continent were first thought Liassic or even Dogger. The Mongugai flora of Ussuri, the Nariwa and other similar floras of Japan and the Hongay flora of Tonkin, which belong to the Daedong group and which all lie in the Akiyoshi orogenic zone were referred to Rhaetic. But in fact the Nariwa plant beds are located beneath the shell beds containing upper Noric *Monotis ochotica,* as shown some years ago (Kobayashi, 1938). Later investigations have shown that the Mine group of floras in Eastern Asia to which all of them belong, is mostly Carnic or Noric and partly Ladino-Carnic or Rhaeto-Liassic. The Dipteridaceae are well represented in the floras of the Akiyoshi zone, especially in its southern part, because plants flourish best in a warm humid climate and the zone belonged to the monsoon region. Because the inland climate was unsuitable, the floras of the Mine group on the continent in which the Dipteridaceae declined were thought to be Liassic or even younger, but really they are not much younger than those in the Akiyoshi orogenic zone as proven by the estherians and by stratigraphic facts (Kobayashi, 1942).

It took me years to confirm the age of the Mine group of flora, but when it was finally established, it was seen that there is a great homotaxism between the floras of the Rhaeto-Liassic aspect on the Atlantic and Pacific sides of the Eurasian continent. Although the Greenstone series is barren of fossils, it is superjacent to the Upper Permian Gobangsan series. In the northeastern part of the Okch'eon zone it is a prorogenic or Flysch type of sediment of a tremendous thickness, resembling the Skyto-Anisic Inai series in Japan and its equivalent near Vladivostok in lithic aspect. Therefore I have become convinced of the Middle Triassic age of the Songnim disturbance. In other words, the Songnim phase is approximate to the Akiyoshi phase in age, if not exactly contemporaneous.

The Middle and Upper Jurassic Jehol series which was deposited widely farther inland is frequently rich in volcanic and pyroclastic rocks. If a small lake near Ŭiju at the month of the Amnok-kang is excluded, Korea was entirely land at the time. With the exception of the bathyal sediment in the Shimanto geosyncline all of the Jurassic sequences in Japan are bisected by discordances, although the ages of the discordances are somewhat different in places. As discussed later the discordance separating the Mongugai from the Nikan series in Ussuri undoubtedly indicates a phase of the Middle Jurassic Hida interorogeny. The Nikan series is an approximate equivalent to the Tetori series in the Hida plateau in Central Japan, although the Middle Jurassic may be absent in the Nikan, hence the Upper Cretaceous in the Tetori series. The two represent continuous limno-paralic deposits from Middle Jurassic to Middle or Upper (?) Cretaceous.

In the Cretaceous period there was the Tsushima basin to the west of the Tetori and Nikan basins. The Kyeongsang group in South Korea is divisible into the Naktong below and the Silla series above, the two being approximate correlatives of the Inkstone and Wakino series in West Japan respectively. The last is disconformably underlain by the Toyonishi (late Malm to Wealden) and this in turn by the Toyora (Callovian to Lias) series also disconformably. The Sakawa cycle of orogeny attained its paroxysmal phase in the inner side of the arc of Japan at the transition (Oga phase) from the Toyonishi to the Wakino epoch, although it commenced in the late Toyora epoch.

Neither the Jehol nor the Naktong series is well developed in the P'yeongnam and Okch'eon zones, but the Silla series covers the already folded formations inclusive of the Daedong. Therefore the so-called Taebo disturbance in Korea may have been of about the same age as the Oga phase in Japan.

In Japan the great Sakawa orogeny from late Jurassic to middle Cretaceous is now well ascertained to be classifiable into the Oga orogeny from late Jurassic to Wealden in the inner side of West Japan, the Neocomian Oshima orogeny in North Japan and the Sakawa orogeny proper in the middle Cretaceous period, as demonstrated in my *Sakawa cycle*. The Jurassic Hida interorogeny and the Triassic Akiyoshi orogeny are also classified into a number of phases. Due to the Akiyoshi orogenic cycle in the Permo-Triassic period, possibly inclusive of the late Carboniferous, the inner side of the Chichibu geosyncline became the Akiyoshi orogenic zone or the Akiyoshi mountains. The outer side of the geosyncline developed into the Shimanto geosyncline. The inner side of this secondary geosyncline became the Sakawa folded mountains by the Jurasso-Cretaceous Sakawa orogenic cycle and its outer side developed into the third geosyncline called Yezo in the north and Nakamura in the south. Each of the orogenic cycles ended with a culmination, namely the Rhaetic Toyogatake culmination at the end of the Akiyoshi cycle and the Palaeocene Akitsu culmination at the end of the Sakawa cycle.

As the result of recent research in Central and North Manchuria tectonic phases of the Akiyoshi cycle analyzed in Japan are recognizable in some way in the eastern Mongolian geosyncline. It appears probable that the early deformation of the cycle was stronger there and the later one stronger in the Chichibu geosyncline.

The studies on the non-marine Mesozoic formations in Eastern Asia showed that the Songnim and Taebo disturbances in the Chinese Heterogen are respectively approximate to the Akiyoshi and Oga orogenies. But more intensive studies are needed before one can distinguish the phases of the tectonic development in the Korea-Chinese Heterogen and correlate them with those of the Japanese Islands. It is, however, certain that the major part of Yenshan movements belong to the Sakawa orogenic cycle, and it is probable that the paroxysm of the Yenshan movements *s. str.* corresponds approximately to the Oga phase of the Sakawa cycle.

A remarkable difference between the continent and the festoon islands is that the volcanism in the Hida interorogeny was weak in the latter but strong in the former where it took place almost continuously from late Triassic to late Cretaceous.

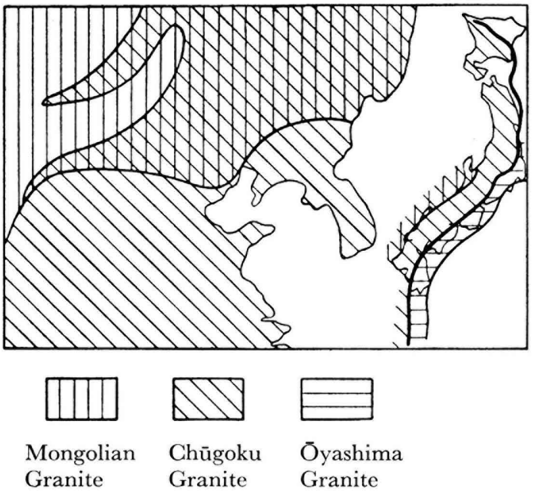


Fig. 3. Granitization of Eastern Asia.

The Sakawa orogenic cycle was accompanied by a batholithic invasion of granite. The term Chugoku granite batholith has long been used in Japan. Later the granite was called Pulguksa in South Korea, Ch'ienshan in South Manchuria and Yenshan in China. Therefore the Chugoku granite is adopted here as their collective term. The Sakawa cycle of orogeny was a strong one which extensively disturbed all Eastern and Southeastern Asia. The Amur geosyncline which was a relic after the Akiyoshi orogeny in the Mongolian geosyncline was also disturbed and intruded by granitic rocks (Kobayashi, 1942).

If the granites along the pliomagmatic zone of the Akiyoshi orogenic zone are excluded, the Mongolian granite batholith is restricted to the Mongolian zone. The Chugoku granitic invasion on the other hand extended as far as the Sakawa orogenic zone through Korea and China (P. Teilhard de Chardin, 1940). The post-Jurassic granite in Cambodia belongs most probably to this magmatism (Fromaget, 1941). The wave of warping which follows the Sakawa orogeny is intimately related to this plutonism. On the continent this warping took place without any relation to previous tectonic lineament and was associated with faulting. The great Khingan range and the Liao tectonic line crossing the Mongolian zone obliquely are products of the post-Sakawa warping and faulting. The Sungari series of late and (?) middle Cretaceous age is a filling in the central Manchurian basin and extends into the Seja-Bureja basin through the northern Manchurian highland.

5. The Touman-Suifun area in the Mesozoic and older periods

During the Palaeozoic era there were the Mongolian geosyncline on the north side and the Chichibu geosyncline on the southeast side of the Chinese Heterogen. The Cambrian fossils are known in the western part of the former geosyncline, but the oldest fossiliferous formation in its eastern part is the Ordovician *Lioclema* shale and sandstone in North Manchuria. In Central Manchuria the Silurian coralline limestone is the oldest (YABE and EGUCHI, 1943). In the latter geosyncline the oldest is the Middle Cambrian *Xystridura* shale in Hainan Island. The Silurian coralline limestone in Japan is now known in North Japan and in the outer zone of West Japan. The Silurian limestone facies is represented in the Lojaping series in the Yangtze basin. In the vast terrain of the Hwangho basin, however, there is a large middle Palaeozoic hiatus. North Korea is an exception where Silurian corals are contained in the older Mesozoic Kyeomipo conglomerate as *remanié fossils*, suggesting marine ingression into the P'yeongnam geosyncline from the east. The ingression was possibly repeated in the Devonian period, as suggested by Devonian corals at Ch'eonseongni (YABE and SUGIYAMA, 1939).

The Mongolian and Chichibu geosynclines were connected in the Touman-Suifun area where the Indo-Pacific fauna is known. *Neoschwagerina* reached Chabarowsk (AHNERT, 1928) and other elements of the fauna invaded farther into Mongolia (GRABAU, 1931). In the presence of Permian tuff this area corresponds better with West Japan than North Japan. With the retreat of the Permian sea the deltaic sediment containing the Gobangsan flora was deposited on the west side (KONNO, 1947). On the east side the Angara flora is contained in the coal-bearing Upper Permian. Therefore this is a crucial point in checking the relation between the two phyto-palaeogeographic provinces. In the inclusion of granitic rocks the fanglomerate in the deltaic facies belongs to the Usuginu type of conglomerate which is extensive in the Permian of Japan. The superjacent black shale facies may be comparable with the Toyoma slate on the Usuginu conglomerate (KOBAYASHI, 1952).

The Skyto-Anisic series near Vladivostok is also similar to the series in Japan in fauna and facies, but thinner here than in Japan. Furthermore it lies on granite, while in Japan it is generally underlain by the Permian disconformably (KOBAYASHI, 1942). The exotic granite boulders in the Permo-Triassic formations in Japan may have been derived from the pliomagmatic zone of the Akiyoshi axis (KOBAYASHI, 1952).

It was found recently that the Triassic formation of various stages are widely distributed in the Maizuru zone which extends from the north of Kyoto to the west of Osaka (NAKAZAWA, 1951). The *Claraia* limestone of Kurotaki and the *Meekoceras* limestone of Taho, both in Shikoku Island, are aligned in its extension. They as a whole indicate an embryonic syncline diagonal to West Japan. It is highly probable that the early and middle Triassic sea reached Vladivostok through this channel. The Ladinic is generally found detached from the Skyto-Anisic in Ussuri and Japan. In the early Carnic the Maizuru zone was an embayment and abundant *Palaeopharus* shows a faunal connection to the arcto-boreal side. The Carnic and older formations in the zone are all strongly folded. The Shidaka series to the west of Maizuru which was previously thought Jurassic, has been lately determined, with the find of *Myophoria*, to be a deposit of the metaorogenic or Molasse type immediately after the deformation (KAMBE, 1951). The Nariwa series to the west of Okayama which contains late Noric *Monotis ochotica* at the top is another metaorogenic deposit. At the western end of the main island (Yamaguchi Prefecture), however, the Ladino-Carnic Atsu series rests on the Akiyoshi folded mountains comprising metamorphic rocks. Therefore it is certain that the paroxysm of the Akiyoshi orogeny came earlier there than in the Maizuru zone.

The extensive distribution of *Monotis* shows flooding of the Noric sea over Northern Siberia, Amur embayment, Ussuri, Japan and so forth. The Triassic formations of Japan are devoid of volcanic material, but the tuff contained in the Mongugai series in Ussuri indicates volcanism behind the Akiyoshi mountains.

The Akiyoshi cycle of orogeny closed with the Rhaetic culmination of the Toyogatake phase. Subsequently the Liassic sea ingressed into the Akiyoshi land along the boundary between the zones of metamorphism and deformation from the west, as indicated by the neritic Toyora, paralic Yamaoku and limnic Yamamuro formations. Farther to the east in the southern Kitakami mountains a late Triassic embayment was slightly modified in the Liassic. On the outer side of West Japan which is farther apart from the Akiyoshi mountains the continental shelf was made narrower in the early Jurassic than in the later Triassic by the Toyogatake culmination (KOBAYASHI, 1948). Accordingly the neritic Lias or Dogger is delimited, though there is a continuous bathyal sediment off-shore in the Shimanto geosyncline which is a product of migration of geosyncline toward the south of the Akiyoshi mountains through the Permo-Triassic orogeny.

The Mongugai series is a formation, late Triassic to early Jurassic, in the depression behind the mountains and there is no Rhaetic discordance. Marine Jurassic fossils are reported from the Murawiow-Amurski peninsula and Askold island near Vladivostok. *Vaugonia* and *Biplices* among them suggest respectively early and late Jurassic ingressions.

The Jurassic sequence in Japan is bisected by the Hida discordance, but the age of this break is quite different at places. The Toyora from Liassic to early Malm reveals a cycle of sedimentation in an embayment. In the Hida plateau, Central Japan, the Kuruma basin became land and a new basin called Tetori was brought about on its west side. The lower Tetori series (or Kuzuryu division) contains a marine fauna including *Biplices* and *Seymourites,* the latter being a typical member of the Arcto-Boreal Callovian fauna. The limno-paralic middle Tetori, or Itoshiro division, is most extensive and yields the rich Tetori flora. The upper Tetori, or Akaiwa division, is composed mostly of deltaic sandstone, partly conglomeratic, and barren of fossil. Lately middle Cretaceous plants were discovered in the top, or Omichidani, division containing red tuff similar to the so-called Inkstone. The Tetori, Naktong, Ryoseki and Nikan floras are all similar to one another and are late Jurassic or early Cretaceous.

In northern Kyushu and its northeastern adjacence it is known that the Toyora series is discordantly overlain by the paralic Toyonishi, from upper Malm to Wealden, which is an orogenic sediment. Its transition to the limnic Wakino series was the paroxysm of the Oga orogeny. The Inkstone red tuffaceous formation superjacent to the Wakino is more extensive than the Wakino. These two correspond to the Naktong and Silla series in South Korea and the Kyeongsang group is their collective term.

The Nikan series in Ussuri consists of the arkose Nikan in the lower and the tuffaceous Nikan in the upper part. The arkose Nikan may be the correlative of the Naktong or the middle and upper Tetori series exclusive of the top division of the Tetori. The tuffaceous Nikan exclusive of its top is that of the Silla-Inkstone plus the top of the Tetori. The top division of the Nikan yields *Trigonia, Spondylus* and *Ostrea.* Judging from the Cretaceous palaeogeography of Japan and Korea it is quite improbable that the late Cretaceous sea ingressed into southern Ussuri from the south. Therefore there may have been a channel along the Sichota Alins.

In East Manchuria there are Jurasso-Cretaceous formations. Broadly speaking, the lower division containing the Tetori-Naktong type of flora (Moulin, Tunning, Lungching, etc.) may be correlated to the arkose Nikan and the upper division (Talatzu, Hwashan, etc.) to the tuffaceous Nikan. There the two parts are generally separated by a remarkable discordance and boulder conglomerate is fairly prevalent at the base of the latter. This deformation must be roughly in the Oga phase.

As mentioned above, the Touman-Suifun area records the history of the Akiyoshi cycle which took place behind Japan. During the Triassic and Jurassic periods the sea repeatedly ingressed as far as Ussuri. The fauna and flora there are intimately related to those of Japan. Furthermore it is certain that the Hida and Oga deformations took place there.

The Mesozoic and older history of the Touman-Suifun area is indeed intimately related to the inner side of West Japan, but is essentially different from that of Korea proper. Nevertheless it is a remarkable fact that the middle Triassic Akiyoshi orogeny was stronger in the P'yeongnam geosyncline than in the Okch'eon geosyncline, like the inner side of Japan where it was stronger than on the outer side, and the mountains introduced in North Korea and the inner side of Japan were secondarily deformed by the Wealden Oga orogeny.

Seeing that the distribution of the Triassic formation in the Sikhota Alin Range is restricted, it is probable that there was land, but the alignment of the Jurasso-

Cretaceous formations with the Palaeozoic formations along the axis shows that the folded mountains of the Sikhota Alin Range were not completed before the late Mesozoic orogeny. *Trigonia* from Suichan suggests the appearance of a channel in front which may have been the progenitor of the Japan sea.

6. Koreo-Manchuria after the Sakawa orogenic cycle

The Great Khingan range runs diagonally across the orogenic zone of Mongolia with a NNE trend, and is more gently inclined to the west than to the east. The central Manchurian basin is separated from the Seja-Bureja basin by the north Manchurian highland, but in the late Cretaceous period there was a twin basin where the Sungari series deposited (KOBAYASHI, 1942). Several patches of the series are scattered on the highland. The Seja-Bureja basin must have been produced after the Amur geosyncline became an orogenic zone. The Great Khingan range and the east Manchurian mountains must have been on the west and the east sides of the central Manchurian basin in the Sungari epoch.

The upper Sungari series inclusive of the Tsagoiana of the Seja-Bureja basin may be Cretaceo-Tertiary passage beds. The Taishu series on the Tsushima Islands is thought to be Dainan by TATEIWA (1934). But, intruded into by the batholithic granite, the vast terrain of Eastern Asia culminated and became land at the end of the Cretaceous period.

In Japan the Palaeogene is generally separated from the Cretaceous formation by disconformity except the Nakamura group along the Pacific coast of West Japan in which the boundary between the two systems is as yet obscure.

The Palaeogene sea ingressed into the Yezo and Nakamura geosynclines and also into the Palaeo-Shiranuhi bay to the west of Kyushu reaching the western extremity of Chugoku in the Oligocene inundation.

On the continent Oligocene and lower Miocene are most extensive among the Tertiary formations. Because the subsidence of the Tertiary basins began in late Eocene and lasted till the middle Miocene crustal deformation, the formations from middle Miocene to upper Eocene on the continent are collectively called here the older Tertiary group. It is extensive in the Seja-Bureja basin and occurs in the Itungho spatulate basin and the Fushun coal field on the west side of the Koreo-Manchurian mountainous land. In the Hanka lowland it is represented by the Hoeryong series in the Chientao and Touman area and the Posjet series in the Suifun area. In the Kilchu-M'yeongch'eon graben on the southeast side of the Kaema plateau there are the limnic Yongdong series, Yongdong alkaline basalt and the paralic M'yeongch'eon series in ascending order.

On the west side of peninsular Korea the Pongsan coal-bearing (upper Eocene) and probably the Anju series belong to the older Tertiary. On the east side there are small patches at Sigumni, T'ongch'eon and Kilchu in the last of which the Changii series is overlain by P'ongongri volcanics. The bases of the Yongdong and Changii series are fairly flat. There are weak discordances at the bases of the

M'yeongch'eon and P'ongongri. Deformation after their deposition was much stronger.

The P'ongongri and older formations are cut by faults of the Hansen system with a NNE strike and the downthrows on the east side. The Kaema plateau was raised to a great height by this movement. At Hapsu on the plateau but close to its rim the older Tertiary is in a basin 1,000 m above the sea. On the scarp of the plateau there is the Hamgyeong system of faults lying mostly in a NE to ENE direction, with their downthrows on the plateau side. During this deformation the Ch'ilbosan horst was separated from the plateau by the Kilchu-Myeongch'eon graben. The Ch'ilbosan volcanic series covers both the horst and the graben.

In the eastern part of the Kangweondo limestone plateau there is a zone of fault mesh which was produced by the block movement in the Cretaceo-Tertiary transition. But the land relief was leveled by erosion during the Palaeogene period. Its end product was the Yukpaeksan plane which was brought up by the middle Tertiary asymmetrical warping. There was however no strong faulting. The upper Miocene formation at Samch'eok, Yeonghae and Yeonil, on the east coast of the peninsula, begins with boulder conglomerates in the depressions in the already deformed terrain.

The Yukpaeksan plane is not a peneplane, but a plane of low relief varying in height to 500 m. It is probable that the top is the relic of the Eocene plane and the flat bottom is the Miocene plane. At all events the high rolling plane is extensive in Koreo-Manchuria and becomes higher near the coast of the Japan sea. In the Kaema plateau and east Manchuria the Yukpaeksan plane is widely capped by the middle Tertiary plateau basalt. In Chugoku the submergence of the plane invited the ingression of the Miocene sea.

In Koreo-Manchuria the younger Tertiary is less extensive than the older Tertiary and the Pliocene less than the Miocene. In Japan on the contrary the Miocene was a time of inundation. After the retreat of the Oligocene Ashiya sea there was a ditch from northwestern Kyushu to the Shinji peninsula where the limno-paralic sediments were deposited. Subsequently the Miocene sea ingressed from the south as far as the Kilchu-M'yeongch'eon graben, and an inland sea crossed Chugoku and Kinki.

Almost simultaneously with the middle Miocene deformation in Korea the limnic formation of the Shinji peninsula was strongly folded. Later the sea spread from the north; the Yeonil series near Kilchu is a sediment of that time.

By the embryonic folding in the transition from Cretaceous to Tertiary the Yezo geosyncline was differentiated into the elevating east side and the subsiding west side. In the latter the thick Palaeogene sediment was accumulated; later it folded and was thrust by the Neogene orogeny. In the transition from stable Palaeogene to mobile Neogene the northern wing of the Sakawa mountains in front of the Yezo geosyncline suffered fragmentation. As a result the Kitakami, Abukuma and other horsts were produced on the east side, and a chain of depressions on the west side, which are known by the name of the Uetsu subgeosyncline. A thick green tuff formation produced there was overlain by a thick oil-bearing Neogene in the subgeosyncline which was strongly deformed by the Diluvium.

As mentioned above, it is probable that there was a late Cretaceous channel on the east side of the Sikhota Alin Range, but after the retreat of this sea Japan became a maritime terrain of Palaeogene Asia. Whether or not the older Tertiary formations, like the Posjet, Hoeryong, Yongdong and Changii series all to the east of the Korean divide, are sediments in separate basins or marginal depressions of a large lake on the side of the Japan Sea, is indeterminable. But it is certain that there was a Sea of Japan during the Miocene. Its outline was different from the present one, especially on the side of Japan. But the outline at the end of Pliocene was quite similar to the present one, because the neritic Pliocene is distributed along the coast of North Japan. There is none on the coast to the west of Maizuru in Kyoto Prefecture, but the neritic upper Pliocene recurs in Cheju island to the south of the Korean peninsula. The shell bed at Ugolnaja, north of Vladivostock, may be of the same age or a little younger. Judging from the migration of mammals, however, the land connection through the Tsushima Strait or the East China Sea may have been maintained intermittently at least by the middle Diluvium.

It is difficult to date any phase of deformation without related formations. Seeing that Mesozoic formations are disturbed in the Hanka lowland, however, the progenitor of this depression must have existed in the early Triassic or at least in the late Triassic period. It was later developed as shown by the extensive distribution of the Jurasso-Cretaceous formations. The twin basins of Seja-Bureja and central Manchuria did not, however, exist before the Sungari epoch, because the Sungari series directly overlies the basement and the Amur geosyncline extended westerly into Transbaikalia through the Seja-Bureja tributaries until the early Cretaceous period.

The deformations which affected the Jurassic formations in Dalainor coalfield in Barga or in the Haokang coal field in northeast Manchuria are block movements. Insofar as Transbaikalia is concerned the deformation of the Amur geosyncline is of the German type as seen in Jehol. But because the *Schollenüberschiebung* is directed to the south or southeast in Jehol whereas it is to the north or northwest in Transbaikalia, the thrusting was probably caused by a grand geanticlinal upwarping of the broad central zone of Mongolia as suggested by TCHAYCHOVSKY (1935). The subsidence of the aforementioned twin basins and the upheaval of the Great Khingan range on its west side, and of the east Manchurian mountainous land on its east side took place after the early Cretaceous orogeny.

The Liao tectonic line which delimits the east Manchurian land may not be a simple fault but a series of parallel faults and flexures. In the Liaotung peninsula the Chinchou fault of this trend separates the folded Naknang group on the west side from the gneiss terrain on the east side. Likewise, a narrow graben of the same trend between I-hsien and Wei-hsien separates west Shantung and east Shantung. The increasing dip of the lower Sungari series, *i.e.* the Chuantou stage in the approach to the Taheishan range suggests a flexure. It is the forerange of east Manchuria, and behind it a spatulate basin of the Itungho is filled with the Palaeogene and probably also the Sungari series. But no Oligocene is known in the central Manchurian basin or in the north Manchurian highland. The Oligocene in the Fushin coalfield is cut by a fault at the northern end. The NE and ENE trends significant in the orography and hydrography indicate the blocking of the Koreo-Manchurian land.

In the topography of Korea and especially of Central and South Korea NNE and NNW trends are very significant. The Kilchu-Myeongch'eon graben and the Weonsan-Seoul rift valley are in the former trend. The Mukakusan fault (see Fig. 4) on the other hand is in the latter and traceable over 100 km, along which the Silla series is slipped down on the east side. The eastern coast of peninsular Korea runs parallel to it for a long distance, but in the south of the Yonggil bay it has a NNE trend. The Tsushima Islands are elongated in the same direction. The backbone range of the peninsula is warped up with the axis close to the Japan sea. From Taepaiksan the Sopaiksan range extends SW, with several parallel ranges and rivers on its northwest side.

In summarizing these facts it can be said that the strong faultings were at one time repeated somewhere in the interval from late Cretaceous to early Palaeogene, and in the middle Tertiary period at another time; hence the faulted mosaic was brought about. In Koreo-Manchuria some of the faults are normal but some others are reverse. They produced some grabens and horsts. In northern Kyushu and adjacent Chugoku the Palaeogene formations form basins or synclines with axes running in NW to NNW directions. Faults of the same trend are predominant there and these cut the Palaeogene (MATSUSHITA, 1950). It is remarkable that the western block is displaced to the south for a long distance along some of these faults. It is quite evident that there was a middle Tertiary faulting, but there may have also been pre-Miocene faulting, because the basement appears to be more displaced than the Palaeogene formations.

The block movement was accompanied by volcanic eruption. In the Kilchu-Myeongch'eon graben, the Yongdong alkaline basalts and the Ch'ilbongsan volcanics occurred respectively before and after the middle Tertiary faulting. The crustal movement after the Ch'ilbongsan volcanics was not so strong as that before them. On the Kaema plateau and the east Manchurian mountains to the north of it plateau basalt is extensive on the Yukpaiksan plane. The younger basalt flows fill the valley carving the high plane and carved by the present stream. The Weonsan-Seoul rift valley is also filled by basalt flows. Basalt patches aligned on the east and west sides of the Sikhota Alin Range are probably related to the Tertiary block movement.

In the Oki Islands in the Sea of Japan calci-alkaline rocks were effused earlier and alkaline rocks later in the Neogene and later period (TOMITA, 1936). In northern Kyushu and adjacent Chugoku middle Neogene and later basalt cones and flows are noted (MATSUMOTO, 1952) to be distributed in three equatorial rows *en échelon*, and the more northern ones are located more to the east. It was also noted by TSUYA (1934) that basaltic cones in Chugoku are distributed in the depressions of the Chugoku batholithic mass. The Hakusan volcanic zone runs to the west from Mt. Tateyama along the coast of the Japan Sea, but abruptly turns to the south in western Chugoku. These facts as a whole suggest the shifting of the western terminus of the Japanese arc to the south.

In the Kaema plateau there is alkali-trachyte of Mt. Paektu which was effused after the plateau basalt. It may be combined with the alkaline rocks on Ŭllungto and Cheju islands in the Peri-Korean volcanic zone.

7. The Peri-Tunghai tectonic zone and its *Flankenkettung* with the Japanese arc in Kyushu

As noted by KOTO, the tectonic development of the Korean trend is younger than those of the Liaotung and Sinian trends which are cut by the former. Through later investigations in Korea and Manchuria it has been well ascertained that the equatorial elements are as a rule older than those of meridional trend or those diagonal to the equatorial ones. More precisely, there was the Mongolian geosyncline between the Angara Urkraton and the Chinese Heterogen which was disturbed at first by the middle Palaeozoic orogeny on the northern side and widely oronized later by the Akiyoshi cycle of orogeny and the Mongolian batholithic invasion. Therefore the Mesozoic formations rest on either the folded or metamorphosed Palaeozoic Mammo group or the granitized basement (KOBAYASHI, 1942). The Amur geosyncline was a relic of the Mongolian geosyncline which was not completely oronized until the Sakawa orogenic cycle (KOBAYASHI, 1942). The P'yeongnam geosyncline and certain other depressions were strongly deformed by the Akiyoshi orogeny, but the deformation was incomparably weaker as compared with that of the Sakawa orogenic cycle through which the whole Chinese Heterogen was deformed and granitized by the Chugoku batholithic invasion. Faults, flexures or warpings rectangular or diagonal to the preceding equatorial lineament took place after Eastern Asia had thus oronized.

The Great Khingan range with its gentle back slope on the Mongolian side and Koreo-Manchuria with its slope on the side of the Yellow Sea and the central Manchurian plain are two of the *Landstaffeln* so-called by Richthofen. They are products of the post-Sakawa fragmentation or anoronization. SUESS's opinion that the architecture of Asia was instituted distally from the Angara Urkraton is however not erroneous, if one considers the oronization. The Cainozoic Oyashima disturbance was strong in the more distal part. Therefore SUESS's opinion is correct for the oronization of Asia and so is RICHTHOFEN's for its anoronization. The latter follows the former, and the latter begins earlier in the interior than in the periphery of the continent.

The peninsular outline of Korea is an outcome of such an anoronization. Its construction may have begun with the block movement along the Korean arc. But the two cycle mountains of Korea were introduced by upheaval after the Yukpaiksan peneplanation. The upheaval was most remarkable in the middle Miocene, but since then intermittent lesser upheavals were repeated some four times, as is discussed in detail below.

The Hei-Liao divide runs across east Manchuria. Another auxiliary axis of elevation on its northeast side is separated from the divide by the Kirin-Tanch'eon zone of depression. They are all parallel to the Korean arc. The coast line in Southeastern Korea and the Tsushima islands suggest a faulting of dominantly NNE trend. In northern Kyushu and adjacent Chugoku several facts concerning the fault system, the distribution of basalt and the volcanic zone suggest the *Blattverschiebung* of the western side to the south. The Palaeogene and Cretaceous formations in the Amakusa islands are folded with the main axis in the NE direction, but in central Kyushu the folding axis gradually becomes parallel to the zonal structure of the outer zone of West Japan.

To the south of the Sakawa mountains lies the Nakamura folded zone which was produced by the middle Tertiary Oyashima disturbance. The zone is abruptly bent to the south in southern Kyushu and extends to the outer chain of the Ryukyu Islands. It is intruded into by the Tertiary granite. Its exposures are aligned in parallel through Kyushu, Shikoku and Kii peninsula. The middle chain of Ryukyu is the extension of the Sakawa mountains, since there are Permian formation and late Mesozoic granite. The inner chain consists of volcanic isles which belong to the Kirishima volcanic zone. The rim of the east China shelf is deeply sinuated to the west of Kyushu. Because the sea repeatedly ingressed along this trend in the Mesozoic and later periods, the initial depression may have existed already in the Cretaceous or even in the Jurassic period.

As discussed in my *"Sakawa Cycle,"* the Ryukyu islands as well as the Pacific coast of West Japan suffered strongly from the middle Tertiary orogeny. This disturbance was accompanied by the Tertiary granitic intrusion. The outer chain of Ryukyu represents the axis of the Oyashima orogeny which extends through the projectiles of West Japan and runs into Central Japan. If the Peri-Tunghai arc is taken as a tectonic unit as was done by KOTO, its northern wing was anoronized and its southern wing oronized. RICHTHOFEN's *Flankenkettung* of this arc with the Japanese arc is made in Kyushu by the Nakamura folded zone and its Amakusa branch, between which the Sakawa mountains are wedged.

The Ryukyu arc inclusive of Kyushu, however, may have drifted to the south. The southern shifting of the western block and the related volcanism seen in West Japan must be due to drifting. As suggested by TOKUDA (1926) the festoon islands of Ryukyu and probably Japan slid or drifted toward the Pacific side. By its tension South Korea was cut by step-faults with their down throws on the side of the Tsushima Strait as shown by the Hansan fault system. The Tsushima Islands are horsts in the sunken Tsushima Strait.

II
Geology of South Korea

1. Outline of South Korea

The Okch'eon (Yokusen) orogenic zone runs across South Korea diagonally from Cheolla-namdo to southern Kangweondo, having a breadth of 40–50 km between the Kyeonggi (Keiki) massif on the northwest side and the Yeongnam (Reinan) massif on the other side, and the Tsushima basin lying farther to the southeast.

To the north of the *Kyeonggi massif* there is the P'yeongnam (Heinan) orogenic zone of North Korea. The massif is composed of the Yeonch'eon (Rensen) metamorphic system with the Kokulian granite intruding into it. These Pre-Cambrian rocks are exposed extensively, but near the coast of the Yellow Sea strips of older Mesozoic formations are found in the environs of Kŭmp'o and Namp'o. Cretaceous intrusive rocks are widely distributed but the extrusives are not so extensive in the massif. On the side of the Japan Sea there is a small older Tertiary basin at T'ongch'eon. The *Weonsan-Seoul rift valley* or the Ch'uga-ryeong graben in NNE trend runs from the eastern end of the P'yeongnam orogenic zone to the southwestern end of the Kyeonggi massif. The massif is bisected by this valley into the eastern and western blocks. Basalt is effused along this rupture. The *Okch'eon orogenic zone* can be divided into the northeastern and southwestern parts in the vicinity of Ch'ungju and Mun'gyeong. The limestone plateau of Kangweondo extends from the southwestern part of the Okch'eon zone to the Chungbongsan block. There is an extensive display of the great Cambro-Ordovician limestone formation. The Pre-Cambrian basement, however, is exposed at Chungbongsan and a few other places in the limestone plateau. While the Korean and P'yeongan systems are strongly disturbed in the Okch'eon zone, they are not much deformed on this rigid basement. The *Chungbongsan block* is a fragment of the Yeongnam massif which is detached by the Paekunsan syncline from the Taepaeksan block in the south. While there is no Palaeozoic formation on the *Taepaeksan block*, the Chungbongsan block is covered extensively by the Korean system, because the latter block has a subsiding tendency in contrast to the former. The Korean and P'yeongan systems are well developed in the Paekunsan syncline and its adjoining areas.

On the west side of the Chungbongsan block there is the older Mesozoic Bansong series which overlies the two systems generally with disconformity and extends far to the southwest into the Mun'gyeong district. These three formations are pre-orogenic. The middle Cretaceous Silla series on the east and southeast sides of the Chungbongsan block and the Samch'eok Miocene on the east side of the block are post-orogenic formations. Beside these there are various igneous rocks, mostly products of Cretaceous igneous activity.

The southwestern part of the Okch'eon zone is largely occupied by a complex of meta-

1. To'ngch'eon (Tsusen)
2. Ŭmgangsan (Mt. Kongo)
3. Weonju (Genshu)
4. Ch'ungju (Chiushu)
5. Kongju (Koshu)
6. Kunsan (Gunzan)
7. Yeongdong (Eido)
8. Cheonju (Zenshu)
9. Hwasun (Wajun)
10. Muan
11. Taebaegsan (Taihakusan)
12. Yeongyang (Eiyo)
13. Andong (Anto)
14. Ŭiseong (Gijo)
15. Teokyusan (Tokuyusan)
16. Yeonghae (Neikai)
17. Taegu (Taikyu)
18. Chinju (Shinshu)
19. Kyeongju (Keishu)
20. Pusan (Fusan)

a P'yeongweon (Heigen) block
b An'ak (Angaku) fault
c Yeseonggang (Reiseiko) valley
d Keump'o (Kimpo) graben
e Weonsan-Seoul (Gensan-Keijo) rift valley
f Namp'o (Rampo) faulted area
g Kongju (Koshu) graben
h Yeongdong, Chin'an and Ŭiseong (Eido, Chinan and Wajun) grabens
i Yeongyan (Eiyo) fault-angle basin
j Andong (Anto) upthrust
k Ŭeiseong (Gijo)wedge
l Ulsan (Urusan) zone

A P'yeongbuk (Heihoku) Gaima land
B P'yeongnam (Heinan) zone
C Kyeonggi (Keiki) land
D Non-metamorphosed Okch'eon (Yokusen) zone
E Metamorphosed Okch'eon (Yokusen) zone
F Chungbongsan (Chuhosan) block } Yeongnam (Reinan) land
G Taebaegsan (Taihakusan) block } Yeongnam (Reinan) land
H Teokyusan (Tokuyusan) block } Yeongnam (Reinan) land
I Tsushima basin

White Dots in Black: Basalt
Small Dots: Cretaceous and later sediments
Black: Older Mesozoic formation
White: Massif

Fig. 4. Tectonic Division of South Korea.

morphic rocks, called Okch'eon or other names. On the lateral sides of this part there are Cretaceous formations. In other words, there is a short strip of a Cretaceous formation at Kongju on the northwest side. Another Cretaceous formation on the other side forms a larger and much longer belt, or the spatulate basin so-called by Koto. The Cretaceous igneous group including the Pulguksa (Bukkokuji) granitic rocks is more extensive in this part of the Okche'on zone than in the limestone plateau of Kangweondo.

The *Yongnam massif* is divided into northeastern and southwestern parts by the Ŭiseong wedge of the Cretaceous Kyeongsang group. The above-mentioned Taepaeksan and Chungbongsan blocks are in the former part. The latter part is called here the *Teokyusan block* after Teokyusan 1,508 m above the sea. The Pre-Cambrian basement of this block is largely composed of grey granitic gneiss. It is intruded by granitic rocks. Furthermore there is a Cretaceous formation fringing the southwestern margin or filling the intermontane basins in some places.

As mentioned above, the Chungbongsan and Taepaeksan blocks are intervened by the Paekunsan syncline. This fragmentation began in the middle Triassic Songnim phase and was almost completed by the late Mesozoic Taebo disturbance. Subsequently the Japan Sea side of this region was deformed. The *Taepaeksan dislocation line* denominated by Koto (1903), however, is not a simple tectonic line but a zone of fault mesh. Because the dislocation of this zone is related to the deformations of Kyushu and the Ryukyu islands, KOTO (1916) proposed *Peri-Tunghai disturbance* as the collective term for the Mesozoic and later disturbances in these places which are aligned *en échelon* and form a grand arc as a whole. Tertiary formations of Samch'eok, Yeonghae and Kyeongju provide important materials for the study of this disturbance.

In the southeastern part of the Taepaeksan block lies the fault-angle basin of Yeongdong. Like the Ŭiseong wedge, there are the Naktong and Silla series. The two are combined into the Kyeongsang group, their approximate equivalents on the Japanese side being the Wakino and Inkstone series respectively. The depression where the Kyeongsang group is deposited is the *Tsushima basin* so-called by KOTO, the wedge of Ŭiseong being its northwestern projection.

Table 3. Stratigraphical Sequence of South Korea.

Geological age	Kyeonggi massif	Okch'eon zone	Yeongnam massif	Tsushima basin	Geological events
Pliocene				Seogwip'o	
Miocene			Samch'eok	Yeonil	2nd (Peri-Tunghai disturbance)
				P'ongongni	
	T'ongch'eon			Changgi	
Palaeogene					1st (Peri-Tunghai disturbance)
Cretaceous				Taishu	Chugoku granite
				Pulgoksa	
		Silla (Naktong) (Okch'eon Metamorphics)	Silla	Silla (Kyoen-gsang)	
				Naktong (Kyoen-gsang)	
Jurassic		(Okch'eon Metamorphics)			Taebo disturbance
Triassic	Daedong	Bansong (Okch'eon Metamorphics)			Songnim disturbance
Permian		P'yeongan (Okch'eon Metamorphics)			
Carboniferous		(Okch'eon Metamorphics)			
Devonian		(Okch'eon Metamorphics)			Epi-Naknang interval
Silurian		(Okch'eon Metamorphics)			
Ordovician		Korean (Okch'eon Metamorphics)			
Cambrian					Kokulian granite
Pre-Cambrian	Yeonch'eon		Taebaegsan		

2. The limestone plateau of Kangweondo and a history of its geological research

The so-called limestone plateau of Kangweondo lies mostly in southern Kangweondo, but a section lies in northern Kyeongsangdo. The great Cambro-Ordovician limestone formation forms an extensive limestone plateau there. But there are all kinds of formations in South Korea, the only exceptions being the Naktong, Changgi and P'ongongni series.

The geological outline of this region was first figured out by NAKAMURA in his survey of mineral resources (1924). Subsequently SHIRAKI surveyed the coal fields (1922, 1933, 1940). KOBAYASHI (1927–1949) made geomorphological and geological studies in cooperation with his students. In addition there are YAMANARI's survey of the Uiimgil and P'yeongch'ang sheet areas (unpublished), KOBATAKE's survey of Tanyang and Mun'gyeong coal fields (1930, 1942, 1947), NAKAZAWA's study of Ch'angni area (unpublished) and several others. As a result the geologic structure of about half of the plateau became well known.

The history of the plateau can be briefly summarized as follows:

(1) The Korean and P'yeongan groups of formations are deformed together with the older Mesozoic Bansong series in the Okch'eon orogenic zone and on the Chungbongsan massif. Various aspects of geologic structures and their mutual relations can be seen.

(2) Subsequent to the compressive deformation the Cretaceous Silla series was deposited in the eastern plateau. There arose a block movement which is related to Cretaceous igneous activity. As a result the Taepaeksan dislocation zone was brought about.

(3) Later the *Yukpaek* (*Roppyakusan*) *plane* was brought into being by the Palaeogene peneplanation. Still later, there took place an asymmetrical geanticlinal upheaval, causing the revival of erosion which dissected the high plane. New low planes produced on the east and west sides of the older one are respectively called the *Yeongtong* (*Reito*) and the *Yeoju* (*Rishu*) *plane*. The two cycle mountains of the Korean peninsula were thus introduced. The Neogene formation of Samch'eok is a deposit at the beginning of the later erosion cycle. The eastern plateau region is therefore the crucial point in deciphering the history of the topographic development of this region.

These subjects are dealt with in this chapter in great detail. There are important coal fields and various metal mines, but their description is omitted here.

3. Geological sequence of the Kangweondo limestone plateau

The Pre-Cambrian basement complexes are exposed in the Kyeonggi land on the northwest side of the Okch'eon geosyncline and in the Yeongnam land on its southeast side. The Yeonch'eon system and Taepaeksan series are the metamorphosed sedimentary rocks respectively of the Kyeonggi and Yeongnam massives.

Detached from the extensive display of the Pre-Cambrian complex in the Taepaeksan block, it is exposed fairly extensively around Chungbongsan and a few small patches are met with at Munŭngni and other places.

The Taepaeksan series in the Taepaeksan and Chungbongsan blocks is mostly composed of mica-schist, but limestone is contained in a small amount. These are two characteristics of this Pre-Cambrian formation. It is intruded by Kokulian granite and later by acidic dykes containing large crystals of tourmaline. In the vicinity of Choneogambong for example, the Cambrian basal conglomerate can be clearly seen to overlie the mica-schist. At Kuraeri, Sangdongmyeon, Yeongweolgun the strike of Taepaeksan series forms an angle of about 60 degrees with that of the Jangsan quartzite at the base of the Korean system. Clear-cut angular discordances can also be seen near Nokcheonri, Sangdongmyeon and Yeongweolgun. In other places the bedding planes of the superjacent Jangsan quartzite and the subjacent Taepaeksan mica schist are nearly parallel to each other. The Taepaeksan series in the south of Daegi, Sangdongmyeon, is not much metamorphosed.

The Pre-Cambrian complex around Chungbongsan is not well explored, but near Munŭngni it is known that the Jangsan quartzite of the Korean system overlies the wavy surface of the Pre-Cambrian basement which is composed chiefly of sericite schist and garnet granite intruding into it. The difference between the bedding plane of the quartzite and the schistosity of the schist is not large. To the west of P'yeongch'ang there is the Songbong schist formation in the basal part of the Korean system, composed mostly of mica-schist and quartz-schist, in addition to some marble. It overlies the southeastern rim of the Kyeonggi land which consists mostly of granitic gneiss but where the Songbong formation overlies the mica-schist member of the gneiss group, the boundary is as yet obscure because the difference in the bedding, schistosity or the grade of metamorphism appears slight.

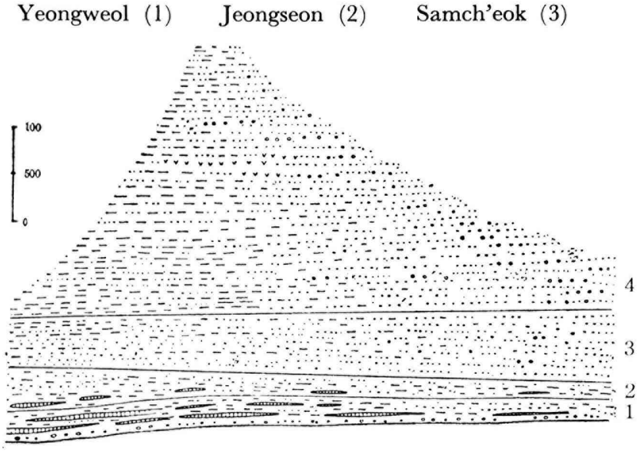
As in the other parts of Korea, the Korean system in the plateau used to be classified into the lower or the Yangdok series and the upper or the great limestone series, but this classification was abandoned and a new classification established in the vicinity of Taepaeksan (Kobayashi, 1930). There the Cambrian and Ordovician formations are about 850 m and 450m thick respectively. Later it was found that this standard sequence in the Paekunsan syncline, which is called the Tsuibon type, merges with that in the Okch'eon geosyncline (Kobayashi *et al.*, 1942). The stratigraphic classification of the Korean system is shown in Table 4 (Kobayashi, 1966).

It is noteworthy that the Dongjeom quartzite at the base of the Ordovician and the intraformational conglomerates above and below the quartzite and the Middle Ordovician Chikunsan shale, which are all generally seen in the Paekunsan syncline and on the Chungbongsan block, die out toward the geosynclinal zone. In the Yeongweol type of sequence in the axial zone of the geosyncline the base of the Korean system is not exposed, but it has been noted (1) that shales form a very thick early Middle Cambrian formation, (2) that black shales and cherty rocks occur in the late Middle and Upper Cambrian and (3) that the Dongjeom quartzite and the Chikunsan shale are replaced by calcareous facies. There is no sign of intrageosynclinal volcanism in the Korean system.

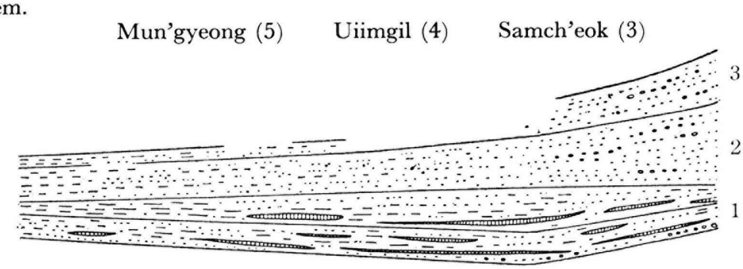
Table 4. Classification and Correlation of the Korean System in the Kangweondo Limestone Plateau (Thickness in meters).

Geological Age			Type Sequence	Tuwibong (Tsuibon)		Jeongseon (Seizen)	Mun'gyeong (Bunkei)	Yeongweol (Neietsu)	Pyeongchang (Heisho)
Ordovician			Toufangian	Girin Ls.	Tsuibon Ls. 50	Jeongseon Limestone	Totam (Todon) 300	Yeongheung (Eiko) 400	Upper Limestone
			Wolungian		Chikunsan Sh. 50–100				
				Chiktong Ls. 200–400			Cheongni (Teiri) 300	Mungog (Bunkoku) ±200	
			Wanwanian	Tomkol Sh. 150–250		(Haeungmak) Chaun (Shiun)			Tunjeon (Tonden) Phyllite
				Dongjeom Qu. 5–50					
Cambrian	Chaumitian		Fengshan	Chukryeon	Hwajeol 200		Seokkyori 200	Wagok 200–500	
			Daizan				Hanae (Kanai) 150	Machari 400	
			Changshan						Lower Limestone
	Fuchouan		Kushan		Seison Sl. 40–50				
		Changhia	Taitzu	Daegi Ls. 200–500		Daegi Ls.			
			(Mapan) Tangshih			Myobong Sl.	Masong 100	Sambangsan (Samposan) 750	Songbong (Shobo) Schist
	Mantoan		Shihchiao	Myobong Sl. 100–250					
			Sanshihlipu				Kurang +150		
			Bunsanri	Jangsan Qu. 40–200		Jangsan Qu.			

(1) Diagrammatic sections 1–3 showing the variations in facies and thickness of the P'eongan system.



(2) Diagrammatic sections 3–5 showing the variation in facies and thickness of the Hyeongan system.



(3) Index map showing the localities of the sections.

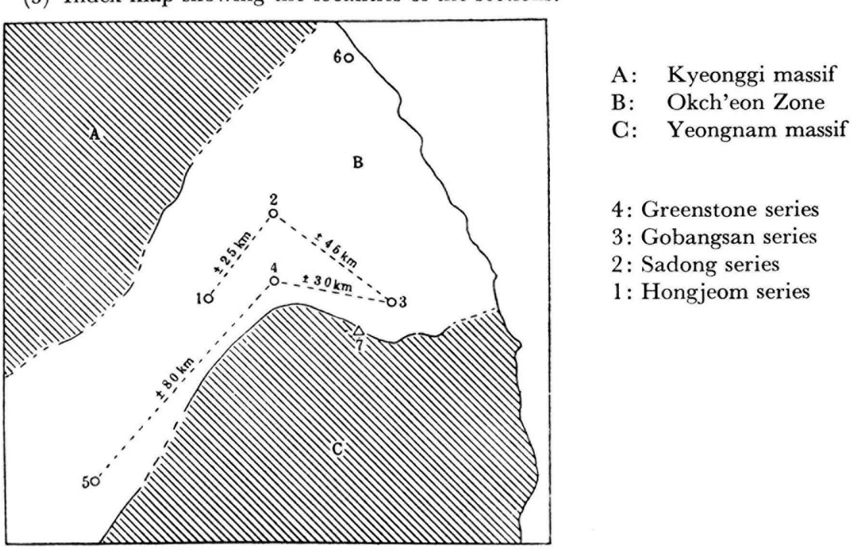
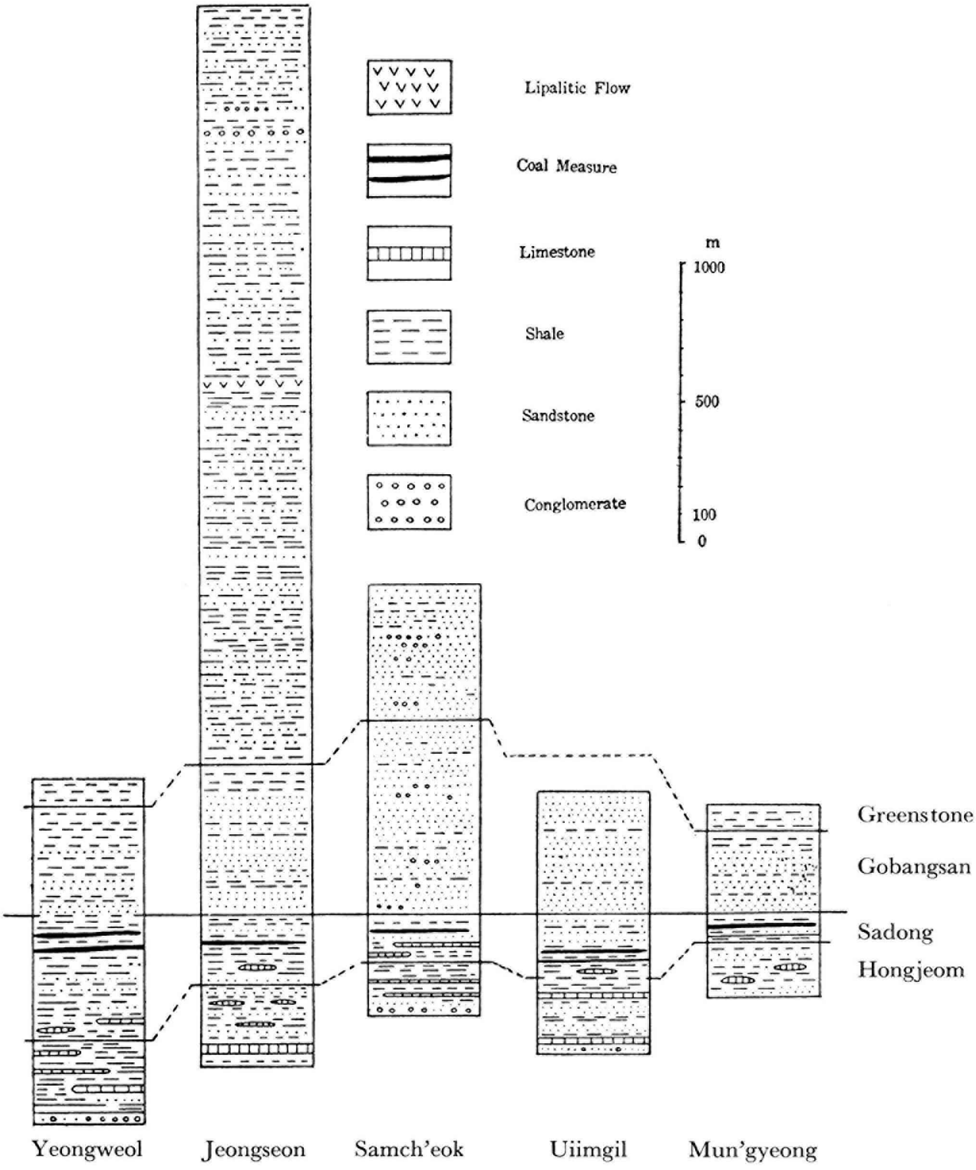


Fig. 5. Columnar Sections Showing the Variation in Facies and Thickness of the P'yeongan System and the Index Map Showing the Localities of the Sections.

(4) Columnar sections showing the variations in facies and thickness of P'yeongan group.



The Korean system is overlain by the P'yeongan system almost always para-unconformably (see Figs. 4–5 of Pl. II). At the clear-cut contact between the Korean and P'yeongan systems as seen at Dongjeom, Sangchangmyeon, Samch'eok-gun, and several other places, there appears to be some difference in the bedding plane at the point of actual contact, but no place is known where the base of the P'yeongan system lies on the Chikunsan shale. The Tsuibon limestone between them always measures 50 m or so. Therefore there is no uncertainty about the para-unconformable relation between the Korean and P'yeongan systems.

The P'yeongan system is classified into the Hongjeom, Sadong, Gobangsan and Greenstone (Nogam) series in ascending order. The *Hongjeom (Koten) series* here differs from that in North Korea in the frequent occurrence of conglomerate or conglomeratic sandstone in the basal part (see Fig. 6 of Pl. II). Several layers of limestone are intercalated in its lower part. The thickest limestone layer attains 60 m in thickness near Yeongweol. While sandstones and shales are variegated in this series, black color is predominant in them in the *Sadong (Jido) series* and especially in its upper part. The lower Sadong or the Taiyuan series contains limestone layers and lenses. The two series are especially thick near Yeongweol where limestone facies is well developed. The upper Sadong or Shansi series is the main coal-bearing formation. In marked contrast to the Sadong series cliff-forming light-coloured quartzite and quartzose sandstone are prevalent in the *Gobangsan (Kobasan) series*. Thin coal seams are found therein and shales are intercalated in these quartzose beds. The *Greenstone (Nogam) series* is a formation of tremendous thickness and consists in the main of frequent alternations of green or grey coloured sandstone and shale, but conglomerate and liparitic flows or tuffaceous beds are sometimes intercalated.

The Hongjeom series is 200 to 300 m thick, the Sadong 100 to 450 m thick, the Gobangsan 300 to 700 m thick and the Greenstone series is over 2,500 m in thickness in the vicinities of Kariwangsan and Pongdugonnisan. Although the Greenstone series is barren of fossil, the three others are fossiliferous. Plants were described by KAWASAKI (1927, 1934, 1939) jointly with KONNO (1932) in part. Foraminifers from the Hongjeom and Sadong series were studied by HATAE (1939), and a few naiads, a xiphosuran and a phyllocarid were described by KOBAYASHI (1933, 1937). The others have not yet been thoroughly investigated, but in a preliminary observation YOSHIMURA (1940) noted that the marine Hongjeom fauna is allied to those of the Penchi series in North China as well as the Weining series in South China and that its age must therefore be Moscovian. The marine fauna of the lower Hongjeom shows affinity to those of the Taiyuan series in North China and the Maping series in South China; its age is therefore Sakmarian. No Uralian fossil was found either in the Hongjeom or in the Sadong series. Nevertheless no stratigraphical break can be seen between the two series. The Sadong and Gobangsan floras are quite different from each other and different opinions have been expressed on their ages. My opinion is that the principal part of the Sadong flora is about Artinskian to Kungurian and that the Gobangsan flora is accordingly mostly Kazanian to Tatarian in age (1952).

The Hongjeom and the Taiyuan series are marine. Subsequent to the retreat of the Sakmarian sea the main coal measures were deposited, in a warm and humid climate, in the Shansi epoch. The Cobangsan series is a deposit in a warm and arid inland climate. The aridity became higher in the Greenstone epoch and the Greenstone series is a deposit in a barren land. The great thickness of the Greenstone reveals geosynclinal subsidence. The P'yeongan system is more than 4,000 m at its thickest and more than half of the thickness is occupied by the Greenstone series. Subsequent to its sedimentation the geosyncline suffered its primary deformation. In Korea there is no angular discordance in the Palaeozoic sequence which indicates either the Caledonian or the Variscan orogeny.

Through the deformation of the middle Triassic Songnim phase the Okch'eon geosyncline was differentiated into an embryonic anticline and a syncline respectively on its northwestern and southeastern side. These folds were gentle but probably in the form of an anticlinorium and a synclinorium. The depression of the latter was the Bansong lake where the Bansong series, a member of the Daedong group, was deposited. It consists of shale, sandstone and conglomerate in addition to some lava flows and thin tuff layers. Conglomerates are common in the lower part but recur near the top at in few places. Volcanic materials are found at Bansong, Sangdongmyeon, Yeongweol-gun and a few other places. Though there are andesitic or basaltic rocks, liparite is more common. Although there is some red quartzose sandstone in the Bansong series, sandstone is generally gray or bluish in color. Shales are commonly dark red and poor coal seams intercalated in them. Plant fossils occur in several places in the shale and sandstone and are described by KAWASAKI (1925, 1926, 1929). The flora is of the so-called Rhaeto-Liassic type and includes *Clathropteris meniscoides* as a member of the Dipteridaceae. Naiads from the Bansong series have not yet been closely studied.

Within the triangle with Jeongseon, Yeongweol and Uiimgil at its apices the Bansong series is 400 m at its thickest. Incidentally it overlies various formations from the Gobangsan series to the Tomkol shale. Clino-unconformity at the base of the Bansong series was observed at Namjeongni, Sangdongmyeon by YOSHIMURA (1940) and at Manjidong, Yeongweolmyeon by IWAYA (1952), but in most other places the base is marked off by disconformity. The basal plane is somewhat undulated at Want'aeksan and some other places, but it is generally even. The thickness of the basal conglomerate, the rock kind, shape and size of the boulders of the conglomerate and the relation of the conglomerate to its basement vary greatly within the triangular area. From these variations the following facts are deduced:

(1) The Korean and P'yeongan groups were gently warped up and down in the first Songnim phase.
(2) The P'yeongan group and the upper Korean group were extensively eroded, but the Korean group was capped by the P'yeongan at many places.

(3) Subsequently there took place a wide down-warping in the second Songnim phase through which the Bansong lake came into existence.
(4) Sediments transported from the surrounding mountains by rivers were deposited and the basal conglomerate was formed.

In the Tanyang district to the southwest of the triangular area the Bansong series is much thicker. According to KOBATAKE (1942) the lower conglomerate measures 350 m and the upper alternation of sandstone and shale 2,000 m at the thickest. In the Mun'gyeong district farther to the southwest the thickness of the lower conglomerate varies from 70 m to several hundred meters and that of the upper alternation attains 1,000 m.

Limestones are seldom found in the basal conglomerate of the Bansong series. Their occurrences are restricted to a few localities. All other materials of the series were derived from the P'yeongan group. No gneiss is contained in it. It is therefore certain that the mountains surrounding the Bansong lake were composed mostly of the P'yeongan group. While the lower conglomerate was supplied from the rugged mountains after the Songnim phase, the great thickness of the upper alternation shows the strong subsidence. The complex geologic structure was produced later by the Taebo disturbance.

The Silla series is a basin filling on the already deformed Okch'eon zone. It is distributed from the northeast side of Taepaeksan toward Samch'eok along the Japan Sea. In the southern part it is most extensive from Hwangjiri, in Sangchangmyeon, to Sodalmyeon and is divided by SHIRAKI (1940) into the lower or Cheokkakni beds and the upper or Kogi beds. The lower division is a red formation composed of conglomerate and sandstone, the former being more predominant in its lower part and the latter in its upper. Boulders in the conglomerate which were derived from its basement are round and commonly about 12 cm across. False bedding is frequently seen in the sandstone. Red shales are intercalated in the beds. At Hwangjiri there is a red conglomerate at the top of the division, the cementing material being tuffaceous. This division measures 250 m at the thickest, but its thickness at some places lessens abruptly to about 60 m. It covers a very uneven erosion plane of the Greenstone and older formations discordantly. The Kogi beds are mostly composed of white tuff and bluish white tuffaceous shale and attain a thickness of more than 250 m. At Simp'eori in Sodalmyeon there is a black shale layer near the base which yielded *Zamites* sp. The Silla series is undulated with a dip of 5 to 25 degrees, seldom inclining more steeply.

According to K. KOBAYASHI (1947), the Silla series in Millomyeon in the northern part is variable in facies. At Tomap'yeong there is white tuff in the lower part, coaly shale with coal seams in the middle, and alternations of tuff and dark green basaltic flow in the upper part. At Kwangch'eonni there are basaltic flows in the lower part and tuff and reddish purple conglomerate in the upper part. At Samgeori a basaltic flow lies on reddish purple conglomerate. It was further noted that the discordance at the base of the Silla series was not very angular there. The above mentioned basaltic rocks are mostly subaqueous lavas of olivine metabasalt.

Tomap'yeong liparite which intrudes into the Silla series contains numerous xenoliths derived from the basement formations including the basalt.

The Samch'eok Neogene extends farther to the northeast. On the west side of this basin it begins with talus debris covering a straight limestone cliff, but it overlies the Tomap'yeong liparite in the south and the Korean group on the southeast side with unconformity. The series in the southwestern part consists mostly of fanglomerate derived from the liparite, the gravels of which are largest at Sangt'otunni. Toward the opposite side it merges with alternations of sandstone and conglomerate. Clayey facies is developed farther to the northeast where diatomaceous earth is intercalated. This facies yields *Carpinus japonica* BLUME., *Quercus* cfr. *drymeia* UNGER. and *Trapa* cfr. *yokoyamai* NATHORST besides indeterminable *Acer, Fagus, Sequoia* and other plants and *Viviparus* and *Anodonta*. The age of the Samch'eok series may be late Miocene. There are coastal and fluviatile terraces of younger age.

Besides these there are various igneous rocks. Southwest of the Samch'eok district there is a granitic mass of Ch'eonŭnsa which is composed mainly of biotite granite. Similar granite in addition to granite-porphyry and quartz-porphyry is known to exist also to the north of Samch'eok and on the northwest side of the Chungbongsan block.

In the south wing of the Paekunsan syncline there is hornblende-biotite granite near Imongni, Sangdongmyeon. At Op'yeong, Sangchangmyeon to the east there is granite-porphyry intruding into the Korean system. Farther east there is a diorite mass to the south of Yeonhwabong which intrudes into the Jangsan quartzite and granite gneiss and forms contact deposits in the limestone above the quartzite. Granite-porphyry east of Myeonsan forms a long belt, and it was ascertained in its NNW extension that it intrudes into a fault. West of this zone there is white quartz-porphyry or liparite of Paekpyeongsan with a flow structure. Its distribution is related to that of the Silla series and its lithic aspect is similar to the liparite of Tomap'yeong. Quartz-porphyry of Poktoksan in Talteongmyeon is reddish gray and reveals a porphyritic structure. It intrudes into granitic gneiss and, in association with the Cheokkakni conglomerate, is cut by a N-S fault. Quartz-porphyry of Paekpyeongsan on the other hand did not suffer from any block movement.

In addition, biotite-hornblende granite is found south of Jeongseon, and biotite granite near P'yeongch'ang. Granitic rocks are more extensive in the Tanyang and Mun'gyeong districts. There are also various dykes of lamprophyre, felsite, quartz-porphyry, porphyrite, basalt and trachybasalt all of which came after the Taebo disturbance. The conclusion is warranted that a part of them, the quartz-porphyry of Poktoksan and Tomapyeong liparite, for example, are nearly contemporaneous with the Silla series. Judging from the general history of South Korea the majority of the acidic rocks are thought to belong to the late Mesozoic Pulgoksa igneous group, though there may be some Tertiary igneous rocks.

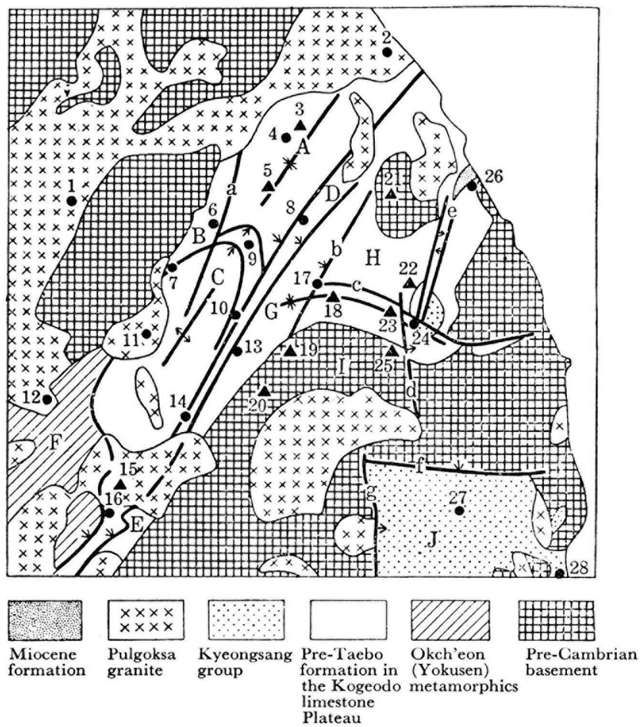
4. Geologic structure of the Kangweondo limestone plateau

The Okch'eon orogenic zone is, as mentioned already, divisible into two parts near Ch'ungju and Mun'gyeong, namely, the metamorphosed southwestern part and the non-metamorphosed northeastern part. While the late Mesozoic granitic batholith is extensive in the former, the exposure of the batholith is restricted in the latter. There is a great limestone formation in the latter and on the Chungbongsan block. Accordingly karst topography is well developed in the limestone plateau. The Okch'eon zone in the western part of the plateau is about 40 km in breadth from northwest to southeast and reveals a typical imbricated structure. In the eastern limestone plateau the breadth measured from north to south is expanded toward the east, because the southern margin of the limestone plateau swerves toward the east and then toward the southeast. In the northeastern terminal part the P'yeongan system forms a large synclinorium of Pongdugonni where the best display of the Greenstone series is seen. On the southeast side of this synclinorium there are some domes, the largest being the Chungbongsan dome where the Pre-Cambrian basement is extensively exposed. A gentle brachyanticline through Hwaamni and Munŭngni has a northeast axis. The *Jeongseon imbricated zone* is located on the south side of the Pongdugonni synclinorium and on the west side of the Chungbongsan dome and of the brachyanticline of Hwaamni and Munŭngni.

To the west of this imbricated zone there is the *Yeongweol anticlinorium* which terminates near Sambangsan in the north. On the northwest side beyond this anticlinorium there is the *P'yeongch'ang zone*. The Yeongweol anticlinorium is highly complicated by numerous thrusts. It is limited by the *Kongsuweon thrust* on the southeast side (see Fig. 2 of Pl. II). The zone between this thrust and the *Teokp'ori thrust* which is the most complicated, is the Jeongseon zone which expands northeasterly but narrows in the other direction.

Between Tanyang and Mun'gyeong there is the granite mass of Toraksan and Chuhŭsan. Though interrupted by them, the correlation of the tectonic elements on the two sides of the mass may be ascertained with some degree of certainty. The middle zone of Mun'gyeong district which is called here the *Mun'gyeong zone* is considered to correspond to the Jeongseon zone. The Mun'gyeong zone is thrust upon by the Okch'eon metamorphic group of the northwestern zone and thrusts itself upon the *Sin'giri zone* on the southeast side. The pre-Taebo formations in the last-mentioned zone is as a whole monoclinal toward the northwest and in most places separated from the Pre-Cambrian rocks of the Yeongnam massif by the *Cheomch'on fault*.

In the Tanyang-Yeongch'un district the monoclinal Korean system lies on the Pre-Cambrian basement discordantly. This is undoubtedly the extension of the Sin'giri zone which, however, virgates into a series of folds and thrusts to the north of Madaesan. An eastern branch of this virgation is the Paekunsan syncline, the axis of which is in its western half convex toward the north with Tuwibongsan (Tsuibonsan) as its front, but in the eastern half the convexity is on the other side



1 Weonju (Genshu)
2 Kangnŭng (Koryo)
3 Palwangsan (Hatsuosan)
4 Puksilli (Hotokonri)
5 Kariwangsan (Kariosan)
6 P'yeongch'ang (Heisho)
7 Chuch'eonni (Shusenri)
8 Jeongseon (Seizen)
9 Ch'angni (Sori)
10 Yeongweol (Neietsu)
11 Chech'eon (Teisen)
12 Ch'ungju (Chushu)
13 Yeongch'un (Eishun)
14 Tanyang (Tanyo)
15 Chuhŭlsan (Shukitsusan)
16 Mun'gyeong (Bunkei)
17 Uiimgil (Girinkitsu)
18 Tuwibong (Tsuibon)
19 Madaesan (Bataisan)
20 Sobaegsan (Shohakusan)
21 Chungbongsan (Chuhosan)
22 Unbongsan (Yohosan)
23 Hambaeksan (Kanpakusan)
24 Hwangjiri (Kochiri)
25 Taebaegsan (Taihakusan)
26 Samch'eok (Sanchoku)
27 Yeongyang (Eiyo)
28 Yeonghae (Neikai)

a P'yeongch'ang (Heisho) fault
b Maehwadong (Baikwado) tectonic line
c Chodongni (Chodori) tectonic line
d Hambaeksan (Kanpakusan) fault
A Pongdugonni (Hotokonri) synclinorium
B P'yeongch'ang (Heisho) zone
C Yeongweol (Neietsu) anticlinorium
D Jeongseon (Seizen) zone
E Sin'giri (Shinkiri) zone
e Osipch'eon (Gojusen) shattered zone
f N. Yeongyang upthrust
g W. Yeongyang fault
F Okch'eon (Yokusen) metamorphosed zone
G Paekunsan (Hakunsan) syncline
H Chungbongsan (Chuhosan) block
I Taebaegsan (Taihakusan) block
J Yeongyang (Eiyo) fault angle basin

Fig. 6. Tectonic Map of the Kangweondo Limestone Plateau.

and in the east of Hambaeksan the syncline is cut by the Hambaeksan fault. On the north side of this part of the large syncline there is the complicate *structural basin of Ungbongsan*. Its southern and eastern borders reveal a typical *Schuppenstruktur*. The Korean system there from to Samch'eok in the north is not much deformed. It is gently undulated and cut by faults.

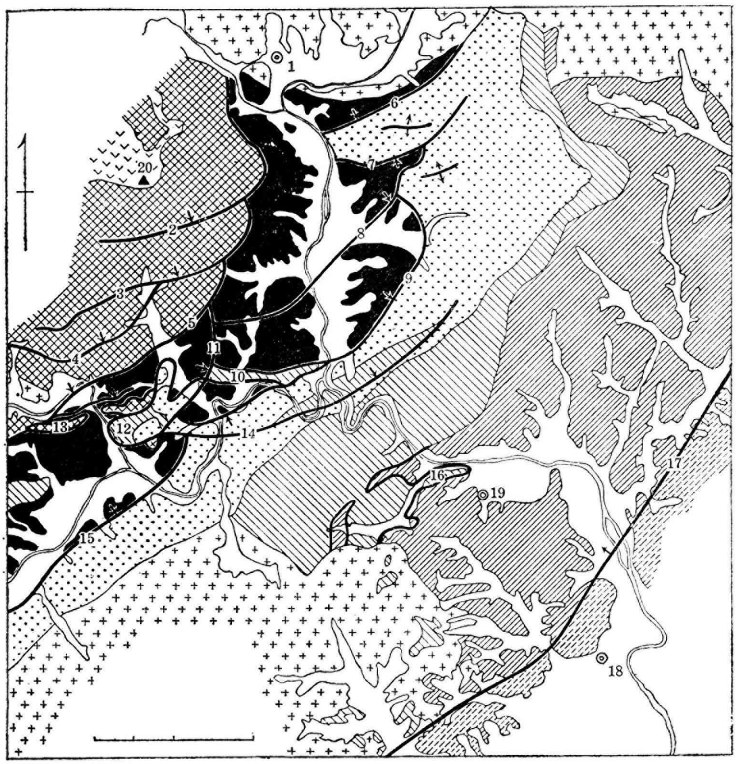
The block movement is very strong on the eastern side of the Hambaeksan fault. In the zone between this fault and the coast of the Japan Sea there are many faults in NE-SW, NNE-SSW, and N-S directions. Some faults run in an ENE-WSW or even E-W direction. The zone to the east of the Hambaeksan fault has thus suffered from the complicated block movement strongly. The faults are by no means all parallel to one another nor do they run along the Korean arc as noted by Koto. The Pre-Cambrian basement is exposed along the coastal line.

In the vast terrain on the west side of the Hambaeksan fault, however, most of the faults cutting the folds or thrusts are insignificant. However, there is a large fault running in a NNE trend to the east of P'yeongch'ang. The northern part of this fault forms the boundary between the P'yeongch'ang syncline on the west and the Chodongni basin of the Pongdugonni synclinorium *s. l.* on the east side, and its southern prolongation bisects the Yeongweol anticlinorium. On the northwest side of the fault are the Songbong upthrusts with an ENE trend. Beside those, faults running in a NW to WNW direction are found in some places. These are minor faults but the Chukyeong fault in the Tanyang district is a significant one. On the south side of the western Paekunsan syncline is the Oktong fault in the E-W direction.

The Korean and P'yeongan systems are widely distributed, but the Greenstone series is restricted to the northeastern and eastern parts of the plateau. The Bansong series occurs in the Jeongseon imbricated zone and its southeastern adjacence. The distribution of the Silla series is confined to the east side of the Hambaeksan fault, and the Neogene to the vicinity of Samch'eok.

a. Mun'gyeong (Bunkei) district (Figure 7)

This part of the Okch'eon orogenic zone is embraced by granite on the northern, western and southern sides. In the northwestern part of the district there is the Sangnaeri thrust group and the Seokhyeon thrust group on the other side. By these groups of thrusts the area is divided into three belts. The southeastern belt called *Sin'giri zone* consists of the Korean and P'yeongan groups and the Bansong series. The first of the three is overlain by the second para-unconformably and the second by the third disconformably. These formations are monoclinal in general, but near the Mun'gyeong coal mine, the structure is complicated at some places in the northwestern part of the belt. It is a remarkable fact that the Hongjeom series thrust itself on the upper Korean group over a distance of more than one km near Weondong. In the northern part of the zone the Korean group is found to overlie the Pre-Cambrian basement on the southeastern side, but in the southern part the two are separated by the Cheomch'on fault. The Taepaeksan series there



- Paekhwasan liparite
- Pulgoksa granite
- Daedong series
- P'yeongan group
- Okch'eon metamorphic rocks
- Korean system of Mun'gyeong type
- Korean system of Tsuibon type
- Taebaegsan series and Kokulian granite

1 Mun'gyeong (Bunkei)
2–5 Sangnaeri (Jonairi) thrust group
6 North Pongmyeong (Homei) thrust
7 South Pongmyeong (Homei) thrust
8 Oeoni (Gaiori) thrust
9 Seokhyeon (Sekken) thrust
10 Pongsaengdong (Hoshodo) strip
11 Northern part of Kaljonni (Katsudenri) thrust
12 Tot'amni (Todonri) basin
13 Klippe (?) of Ongnyeobong (Gyokujoho)
14 Sub-Soekhyeon thrust
15 Southern part of Kaljonni (Katsudenri) thrust
16 Weondong (Indo) thrust
17 Cheomch'eon (Tenson) fault
18 Cheomch'eon (Tenson)
19 Sin'giri (Shinkiri)
20 Paekhwasan (Hakkwasan)

Fig. 7. Geological Map of Mun'gyeong District.

consists mostly of biotite schist and quartz mica schist with thin layers of quartzite and crystalline limestone intercalated.

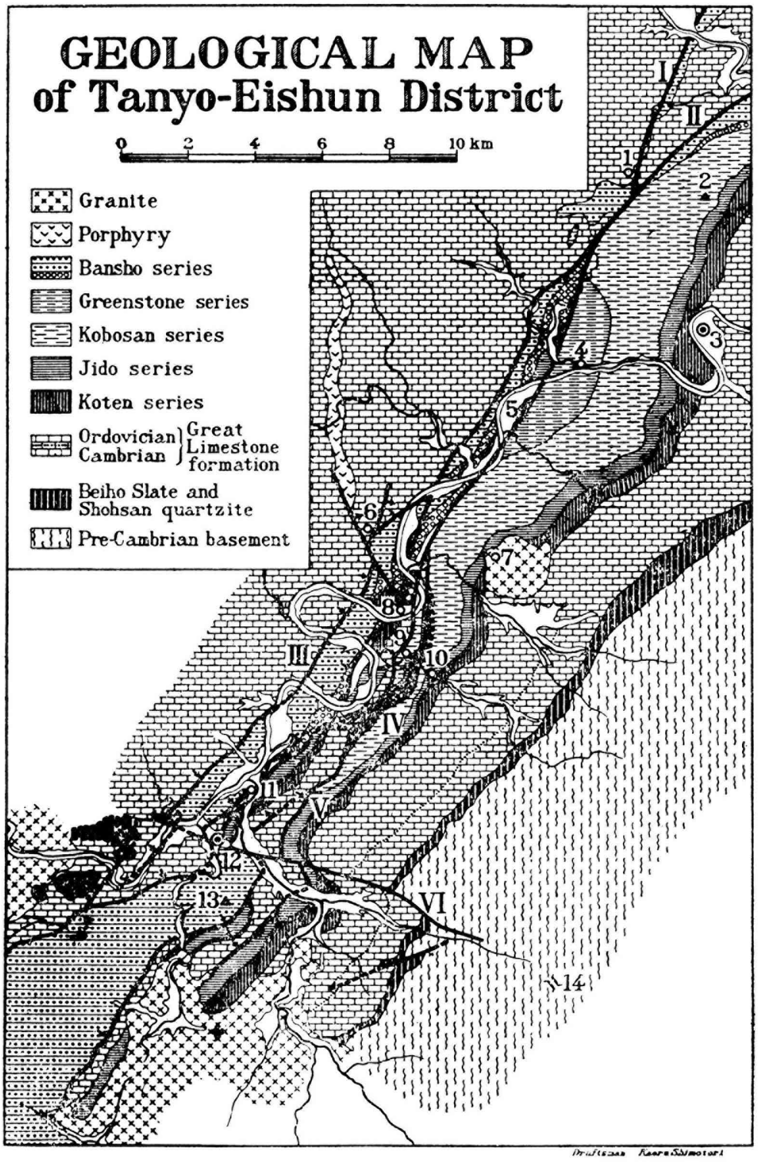
The middle belt is the *Mun'gyeong zone* which is mostly composed of the Korean group, but there are in addition a small brachysyncline of the Bansong, Sadong and Gobangsan series near Tot'amni, a narrow strip of the Greenstone series of Pongsaengdong and a few other strips of the Ongnyeobong formation of unknown age. In the so-called Pongsaengdong quartzite formation red or dark brown slate and dark brown, partly green, sandstone are leading members, only a relatively small amount of quartzite being found. SHIRAKI (1934) considered the formation to be Upper Cambrian, but KOBAYASHI and AOTI (1942) are of the opinion that it belongs to the Greenstone series (inclusive of the T'aejaweon series in North Korea), if not to the Bansong series. The Ongnyeobong quartzite formation which SHIRAKI referred also to Upper Cambrian is composed chiefly of red shale and partly of red or dark blue sandstone. As it is similar to the Hongjeom series in its lithic aspect, it probably belongs to the P'yeongan group, if not to the Bansong series.

The *Paekhwasan zone* on the northwestern side is composed mainly of Okch'eon metamorphic rocks with sheets of gabbro among them. They are capped by the lava of Paekhwasan liparite. NAKAMURA took the Okch'eon for a Pre-Cambrian formation, but the thick limestone in the Okch'eon system can be referred to the Korean group, and its conglomerate-bearing formation to the Bansong series. Most of the remaining part of the formations can be regarded as the metamorphosed facies of the P'yeongan system. The Paekhwasan zone reveals an imbricated structure which is beheaded by a flat erosion plane which is in turn covered by the liparite flows of Paekhwasan.

b. Tanyang-Yeongch'un (Tanyo-Eishun) district (Figure 8)

Like the Mun'gyeong district, the Tanyang-Yeongch'un district is located on the southeastern side of the Okch'eon orogenic zone. In the northeastern extension of the Sin'giri zone the Korean system lies on the Pre-Cambrian basement. Near Kun'gan'u, west of Yeongch'un, the P'yeongan system comprises the Greenstone series at its top. These formations are monoclinal toward the northwest and thrust by the Korean system along the Teokp'ori thrust (*i. e.* KOBATAKE's Songhyeon thrust near Tanyang, 1930). Near the thrust the Hongjeom series thrusts itself on the Gobangsan, forming a small Kich'eonni thrust sheet. The Sadong on the Hongjeom series shifted itself by sliding along its basal plane and is overlain by the Gobangsan series. The Kich'eonni thrust sheet, however, tails out beneath the Teokp'ori thrust sheet.

The middle belt between the Songhyeon and Pyeolgongni thrusts consists mainly of the upper Korean system and the Bansong series and partly of the Hongjeom and Sadong series. At Tuamsam in the south of Tanyang the Sadong comes in direct contact with the Korean beneath the P'yeongsan system. This sliding line is traceable to the northeast of Tanyang and is called the Kosuri thrust by KOBATAKE.



1 Weolgok (Getsukoku)
2 T'aehwasan (Taikwasan)
3 Yeongch'un (Eishun)
4 Kun'gan'u (Gunkangu)
5 Hyangsanni (Kosanri)
6 Yeoch'eonni (Reisenri)
7 Yongsangni (Ryujori)
8 Teokch'eonni (Tokusenri)
9 Kosuri (Furuyaburi)
10 Kich'eonni (Kisonri)
11 Koch'eonni (Kosenri)
12 Tanyang (Tanyo)
13 Tuamsan (Togansan)
14 Chukyeong (Chikurei)
I Kongsuweon (Kosuin) thrust
II Teokp'ori (Tokuhori) thrust
III Pyeolgongni (Bekkokuri) thrust
IV Kich'eonni (Kisonri) thrust
V Songhyeon (Shoken) thrust
VI Chukyeong (Chikurei) fault

Fig. 8. Geological Map of Tanyang and Yeongch'un District.

Such sliding is frequently seen in the Jeongseon imbricated zone. Breccia occurs occasionally along the sliding plane; clayey rocks in a sheared zone become phyllitic. It is difficult to say whether the superjacent formation slipped up or down, when sliding occurred between the younger formation above and the older below. Therefore it is wise to distinguish such sliding from the thrusting of the older formation on the younger in general. To the west of Kosurihyeon sliding the thrusting of the Korean system upon the P'yeongan can be seen at Hyeonch'eonni and Kosuri. This is the principal thrust and an auxiliary one is found at Hyeonch'eonni within the Bansong series.

This Bansong series is thrust upon by the great limestone formation on the northwest side along the Pyeolgongni thrust in the northeastern terrain. West of Tanyang there are *Klippen* of quartzite of unknown age lying on the Pyeolgongni thrust sheet. The area farther west has not yet been surveyed in detail. The imbricated structure above mentioned is cut by the Chukyeong fault with a WNW trend, along which the southwestern block is shifted to the southeast.

The area between Songhyeon and Yeongweol has not yet been thoroughly investigated. But it is quite probable that the Pyeolgongni thrust joins with the Kongsuweon thrust. SHIRAKI's reconnaissance revealed that the Songhyeon belt tails out on the west side of T'aehwasan and then the Kongsuweon thrust occurs. The Songhyeon belt is mostly composed of the Bansong series and beneath it the Sadong series and the great limestone formation are exposed to a small extent. The imbricated structure is cut by a fault through Teokch'eonni and Yeonch'eonni. A large dyke intruding along the fault is prolonged for a long distance in the direction slightly west of north. In the eastern part of the district there is a granite mass of Yongsangni, Kakokmyeon, near the boundary between the P'yeongan and Korean systems.

c. Yeongweol (Neietsu) anticlinorium (Map 1)

The Kongsuweon thrust extends to the northeast from Weolgok, west of T'aehwasan. To the west of the thrust there is the Yeongweol anticlinorium which is about 27 km broad between Yeongweol and Chuch'eonni. Only the part of the anticlinorium to the north of the Hangang river has been thoroughly investigated.

The Hongjeon and Sadong series are found above the great limestone formation in its eastern wing but the rest of the anticlinorium is mostly composed of the great limestone formation, and the Sambangsan formation beneath the great limestone crops out in the north. The Bansang formation at Weolgok is an exceptional occurrence on the anticlinorium.

The anticlinorium is at present bisected by the P'yeongch'ang fault into the eastern-central and the western part. On the west side, the anticlinorium is limited by the Teokp'ori thrust near Chuch'eon. But when this thrust is traced to the northeast, the Yoengbongjong thrust appears beneath the Teokp'ori thrust sheet, which is cut by the P'yeongch'ang fault. Beyond this fault there is the Sangni thrust which describes the northern outline of the anticlinorium, and the anticlinorium

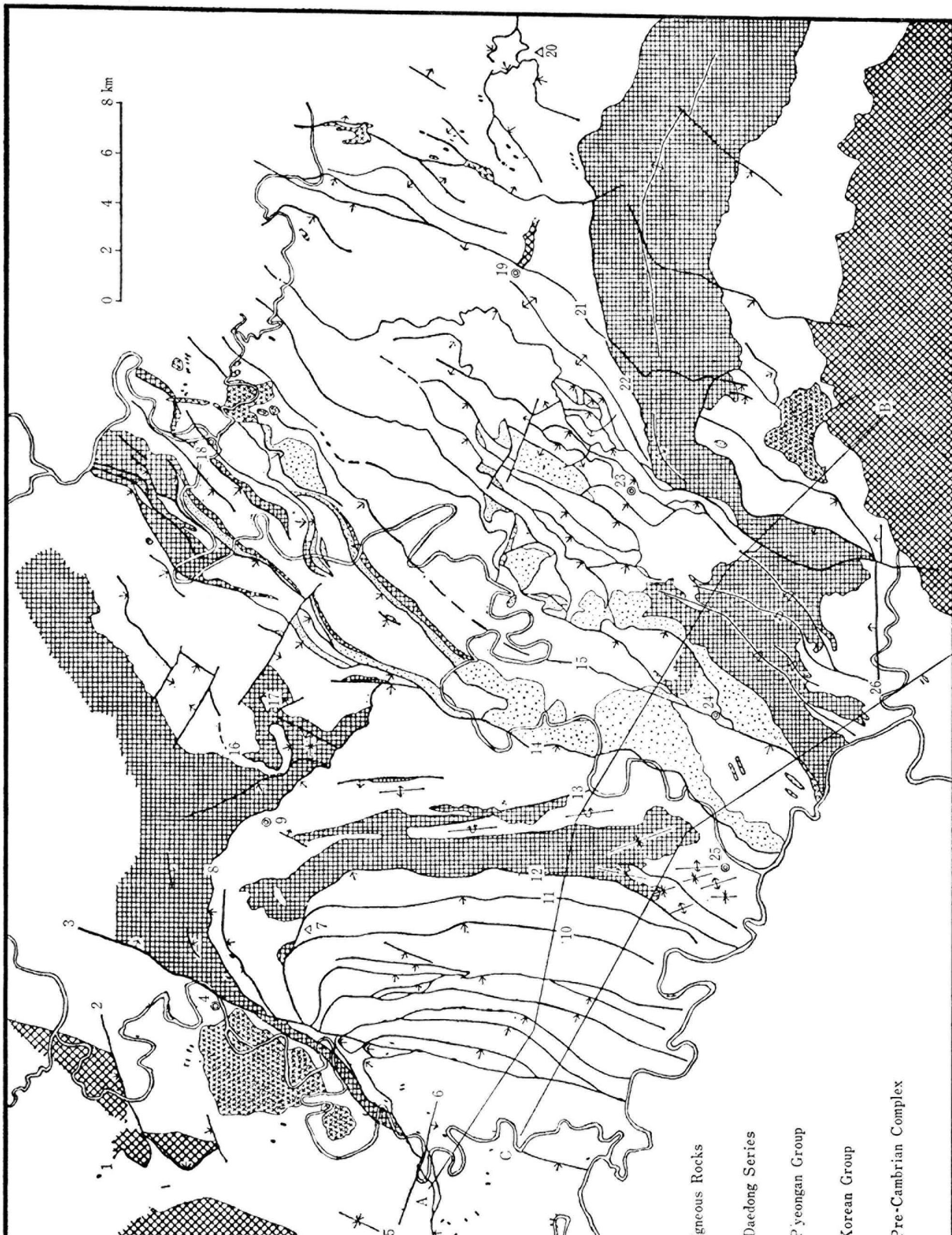


Fig. 9. Tectonic Map of the Western Part of the Kangweondo Limestone Plateau.

1. Chuchwari (Shuzari) thrust
2. Songbong (Shoho) thrust
3. P'yeongch'ang (Heisho) fault
4. P'yeongch'ang (Heisho)
5. Tun'jon (Tonden) synclinal basin
6. P'anunni (Banunri) fault
7. Sambangsan (Sanposan)
8. Sangni (Jori) thrust
9. Changni (Sori)
10. Namaeri (Nangairi) thrust
11. Mohari (Chikari) thrust
12. Mach'ari (Masari) thrust
13. Ryullichi (Ritsuriji) fault
14. Kongsuweon (Kosuin) thrust
15. Teokp'ori (Tokuhori) thrust
16. P'yeonganni (Heianri) thrust
17. Cheongsandong (Teijido) Klippe
18. Jeongseon (Seizen)
19. Mungogni (Bunkokuri)
20. Mt. Chomok (Roboku)
21. Surich'i (Suriji) tectonic line
22. Chodongni (Chodori) fault
23. Uiimgil (Girinkitsu)
24. Bansong (Bansho)
25. Yeongweol (Neietsu)
26. Oktong (Gyokudo) fault

itself is thrust *en bloc* upon the Chodongni basin on the north side. Among the thrusts within the anticlinorium the most important is the Machari thrust which cuts the eastern central part into inner and outer sections and runs along an arc inside the arcuate Sangni thrust. The outer part consists of the formations from the Sadong series to the Wagok formation which are folded and cut by thrusts at some places. The main coal measures of the Yeongweol coal field are found in the upper Sadong along the Machari thrust, which is compressed by thrusting, and form pockets in places. The P'yeongan system along the thrust is monoclinal but virgates toward the south into folds of different magnitudes, the western one being cut by the Nŭngdong thrust. To the east of the Yeongweol coal field there is a syncline with the Hongjeom series lying along its axis. Its two wings consist mostly of the great limestone formation. This syncline and the anticline on its west side are neither a simple syncline nor a simple anticline but rather a synclinorium and an anticlinorium by themselves and the principal axes of their folding are either vertical or inclined to the east. The synclinorium is cut obliquely by a hinge fault called Ryullichi.

The central part delimited by the Machari thrust on the northern and eastern sides, and by the P'yeongch'ang fault on the western side, is composed of a great limestone formation except for the northern rim where the Sambangsan formation exists. There is a series of thrusts with intervals of 500 to 1,000 m. The thrust planes are usually slanted steeply to the west or south.

It is probable that the Sangni thrust to the east of the P'yeongch'ang fault corresponds to the Yeongbongjong thrust to the west of the fault because the Gobangsan series of the Kariwangsan syncline extends to the southwest beneath the Yeongbongjong thrust sheet. The Machari thrust on the east side of the P'yeongch'ang fault virgates into a set of thrusts, called the first, second and third Cheonggok thrusts, each of which describes an arc. Inside the arc there are the Sambongsan formation on the outer and the great limestone formation in the inner side, as they are in the Machari thrust sheet. The great limestone formation extensive in the interior of the Cheonggok thrust is folded and probably thrust upon repeatedly, but the details of the structure are difficult to decipher because the formation is unfossiliferous.

d. P'yeongch'ang (Heisho) zone

Because the grade of metamorphism becomes higher farther in the west, the formations of this zone are barren of fossils. Accordingly their sequence and structure are not well known. It is, however, certain that there is a brachysyncline with the axis inclined southeasterly because the horseshoe-shaped Tunjeon phyllite zone is found to the north of Chuch'eonni. To the west of P'yeongch'ang it can be seen that the Pre-Cambrian basement is thrust on the Tunjeon phyllites on the west side along the Chuchwari thrust line. The Songbong schist on it dips to the east or southeast.

In this area this thrusting was followed by another through which the northwestern block was repeatedly thrust up on the other side along the Songbong thrust and also along an unnamed thrust south of Chuchwari, both striking ENE. To the northeast of Chuch'eonni there is the P'anunri fault with an ENE strike. There is a granite mass to the southwest of P'yeongch'ang but the relation of its intrusion to the thrusting or faulting is indeterminable because there is no place where any of the faults or thrusts is in contact with the granite mass.

e. Kariwangsan (Kariosan) and Chodongni (Chodori) basins

After his geological reconnaissance, NAKAMURA (1924) showed that the Greenstone series, *i. e.* his Pongdugonni formation, forms a large complicated syncline with Palwangsan as its center. This is the Pongdugonni synclinorium. The Palwangsan basin occupies the large central part, but little is known of this basin except its eastern and southern distal parts. To its southeast there is the Kariwangsan basin, and the Chodongni basin to the southwest of the Kariwangsan basin. The P'yeongan system forms the triangular Chodongni basin with Nambyeongsan as its northern apex and is thrust up by the Yeonsweol anticlinorium. The western edge of the triangle is delimited by the P'yeongch'ang fault except for its extreme southwestern part which extends beyond the fault toward Chuchwari, as mentioned above.

The Kongsuweon thrust marks the southeastern boundary of the Yeongweol anticlinorium, and the Mindunsan thrust which branches off from the Kongsuweon thrust marks the southeastern boundary of the Kariwangsan basin. Between this and the Sangni thrust there is a highly complicated structure near Changni. According to NAKAZAWA there is the P'yeonganni low angle thrust in the southern part of the Kariwangsan basin, to which the Cheongsandong Klippe belongs. In this vicinity there are NW faults by which the terrain is divided into small horsts and grabens.

f. Jeongseon (Seizen) imbricated zone

Between the Mindunsan-Kongsuweon thrust and the Teokp'ori thrust there are several thrusts virgating toward the northeast. In consequence the zone is divided near Jeongseon into several subzones. The complicated imbricated structure is found not only in the zone but also in the southeast beyond the Teokp'ori thrust as far as the vicinity of Uiimgil. It is a general tendency for these thrusting sheets to become isoclinal folds further to the south. It is often seen that the Bansong series is thrust up by the great limestone formation, but in the environs of Jeongseon the limestone formation thrusts itself sometimes upon the P'yeongan system. Where the calcareous formation is thrust upon these non-calcareous ones, the tectonic lines are clear and easily traceable.

Between the Taekp'ori and Maehwadong thrust the Bansong series overlies the P'yeongan system in the south and the great limestone formation in the north. This P'yeongan system is located in the western extension of the Paekunsan syncline and repeats isoclinal folding with a NE axis between the thrusts. These folds die out near the Hangang beyond which there is the monocline of the Sin'giri zone in the Yeongch'un district. Judging from these facts it is known that the western part of the embryonic Paekunsan syncline was isoclinally folded by the diagonal compression which formed the Jeongseon imbricated zone. To the south of the isoclinal zone the Korean system is cut by the equatorial fault of Oktong which in turn is cut by the Yaehwadong tectonic line (see Fig. 1 of Pl. II).

g. Paekunsan (Hakuunsan) syncline

The above mentioned isoclinal folding is confined to the west of the Maehwadong tectonic line. It is a normal fault in the south but soon becomes a thrust toward the north. To its east there are a few thrusts at intervals of 4 to 5 km. There the axis of the Paekunsan syncline describes an arc convex to the north. The granitic masses of Imongni and Op'yeong are located on the south side near the western and eastern ends of the arc. There is a fault on the north and west sides of the Imongni mass.

Between the P'yeongan and Korean systems on the northern wing of the syncline there is the Chodongni thrust which is cut by the Maehwadong and Surichi thrusts with a NE strike.

To the east of Op'yeong the axis of the syncline describes another arc convex to the south and its eastern side is shifted to the south for 3 to 5 km along the Hambaeksan fault. There the axis is inclined to the west. Accordingly the syncline narrows to the east at Myeonsan, but there is a subsided block farther to the east of Seokp'oni where the Korean system recurs. It is cut by faults on the northern and northwestern sides.

h. Chungbongsan (Chuhosan) block

The Pre-Cambrian complex of the block except for a small part has not yet been closely investigated. Near Uiimgil the Maehwadong thrust joins with the Chodongni thrust. The triangular corner of Uiimgil outlined by the two thrusts occupies the southwestern corner of the block. There can be seen a typical *Schuppenstruktur* of the Korean system which has been worked out by IWAYA (1940). The system, however, becomes gently undulated to the east where a gentle anticlinal axis runs through Hwaamni and Munŭngni. This principal axis is crossed almost rectangularly by auxilliary axes and the Pre-Cambrian rocks of Munŭngni are exposed at their intersection. The Surich'i tectonic line running along the principal anticlinal axis is a normal fault with the downthrow on its west side, but it becomes an upthrust toward the east in its southern part where it crosses the Paekunsan syncline. In the eastern wing of the above mentioned anticline there is a low angle thrust which is seen within the lower great limestone formation. To the north of Cheongansa there is a thrust toward the south within the P'yeongan system in the northern wing of the Paekunsan syncline. To the east of the Hambaeksan fault there is the Ungbongsan structural basin, and the *Schuppenstruktur* in its southeastern border is more typical than that in the Uiimgil area.

Like the Chodongni tectonic line to the west of the Hambaeksan fault, the Hwangjiri fault marks the boundary between the northern and southern terrains along which the northern block was thrust up towards the south in the Taebo disturbance. In this thrusting block, however, there was a ditch which later developed into the Osipch'eon shattered zone. There numerous small thrusts developed toward the ditch from the eastern and western sides, forming the *Schuppenstrukturen*.

i. Samch'eok—Kangnung (Sanchoku—Koryo) district

Between Samch'eok and Kangnŭng there are the great limestone formation and the P'yeongan system up to the Gobangsan series. The former formation is more extensive in the south and the latter system in the north. Near Okkye the great limestone formation apparently repeats its thrusts several times to the southeast or southwest. On the southeast of Kangnŭng the P'yeongan system is folded with northeast axes and cut by strike faults. Beside them there are significant faults with a northwest trend on the southwest side of Kangnŭng and with a NNW trend on the northwest side of Samch'eok. The terrain was intruded into by granite after the block movement. The formations are frequently metamorphosed and quartz-schist, clayslate and crystalline limestone are common among them. Beside quartz, sericite, biotite, muscovite, and plagioclase, staurolite, sillimanite, kyanite, garnet, cordierite, andalusite, almandite, hornblende, tourmaline and several other minerals are present in them in various combinations. While staurolite, sillimanite, kyanite, garnet and some others are products of dynamic metamorphism, andalusite, cordierite and a few others are products of thermal metamorphism. It is noteworthy that there took place such a high grade of regional metamorphism (SUZUKI, 1935). The bearing of this high metamorphism on the tectonics of the plateau is a subject for future study.

5. Songnim (Shorin) disturbance and Bansong (Bansho) lake (Fig. 10–14)

It was in the Songnim phase that the simple geosyncline of Okch'eon differentiated into embryonic folds. It formed a lake in the subsiding area where the Bansong series was deposited. Further complication was caused later by the Taebo disturbance. Because this structure is the final product of embryonic folding, the embryo is very important in understanding the later development. It is, however, very difficult to analyse the growth steps of the embryonic folding at the part where the Bansong series is missing.

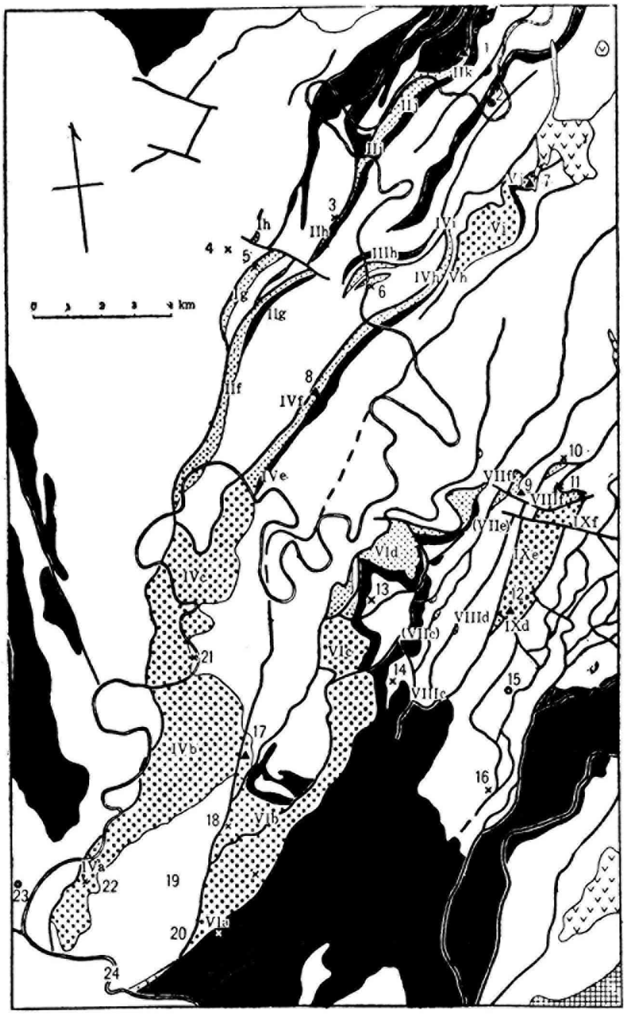
The series is aligned in several belts in the triangular area with Jeongseon, Yeongweol and Uiimgil at their apices. YAMANARI (1926) once thought that the belts of the series represented the valley fillings, but, as I have pointed out previously (1927), it is a lacustrine sediment, generally beginning with conglomerate, and followed by alternating sandstones and shales in which poor coal seams are intercalated. Subsequent to his preliminary survey I studied it in detail, first by myself and later jointly with YOSHIMURA, IWAYA and HISAKOSHI. As a result it was thoroughly proven that the lacustrine formation is inserted in the imbrication. Some nine or ten belts can be distinguished and are named from the northwest side as follows:

I.	Mudongji (Budochi) belt
II.	Pibongsan (Hihosan) belt
III–III'.	The northern and southern Kyulamni (Kiganri) belts
IV.	Sugalsan-Want'aeksan (Suikatsusan-Kwantakusan) belt
V.	Kŭiusan (Kiusan) belt
VI.	Bansong (Bansho) belt
VII.	Ungbong (Yuho) belt
VIII.	Kwangbangni (Kohori) belt
IX.	Songbong (Soho) belt

The belts are nearly parallel to one another and extend from northeast to southwest. For purposes of lattice analysis I have drawn on the geological map eleven lines (a-k) nearly perpendicular to the belts and schematized the detailed observations at their intersections. Because the sequences of the Bansong series at these points record the geological events which took place there, it is possible to figure out local variation in the events which occurred in the surrounding areas and affected the sediments.

The succession of the series and the relation to its basement can be observed precisely at the cross points in the lattice with special attention paid to the vertical and horizontal variations in the grain size of the sediments. The lateral variation in the grain size shows the source of the sediment, while its vertical variation indicates a change in the power of transporting material from the mountains to the lake, assuming that precipitation was constant through the Bansong epoch.

The series is about 400 m at the thickest part within the triangular area. In most places there is the basal conglomerate, and sandstone and shale beds above it. Conglomerate found at the point Vj at the top is an exception. Judging from the conglomerate the topography was very uneven in the early Bansong stage, but later the summit was dissected and probably the lake expanded. It is probable that the lake finally shrank and that erosion again took place. The Bansong series reveals a



1. Pibongsan
2. Jeongseon
3. Yangji
4. Majonch'i
5. Mudongji
6. Kyulamni
7. Kŭinsan
8. Sugalsan
9. Ungbong
10. Kwangbangni
11. Mach'aj'i
12. Songbong
13. Pyeongsan
14. Puksilli
15. Uiimgil
16. Hwarari
17. Wantaeksan
18. Bansong
19. Nanjeongni
20. Kongsuweon
21. Manjidong
22. Ch'ori
23. Yeongweol
24. Hangang

Igneous rock

P'yeongan group

Bansong formation

Pre-Cambrian basement

Korean group

Fig. 10. Tectonic Map of the Jeongseon, Uiimgil and Yeongweol Triangle Showing the Points in Lattice.

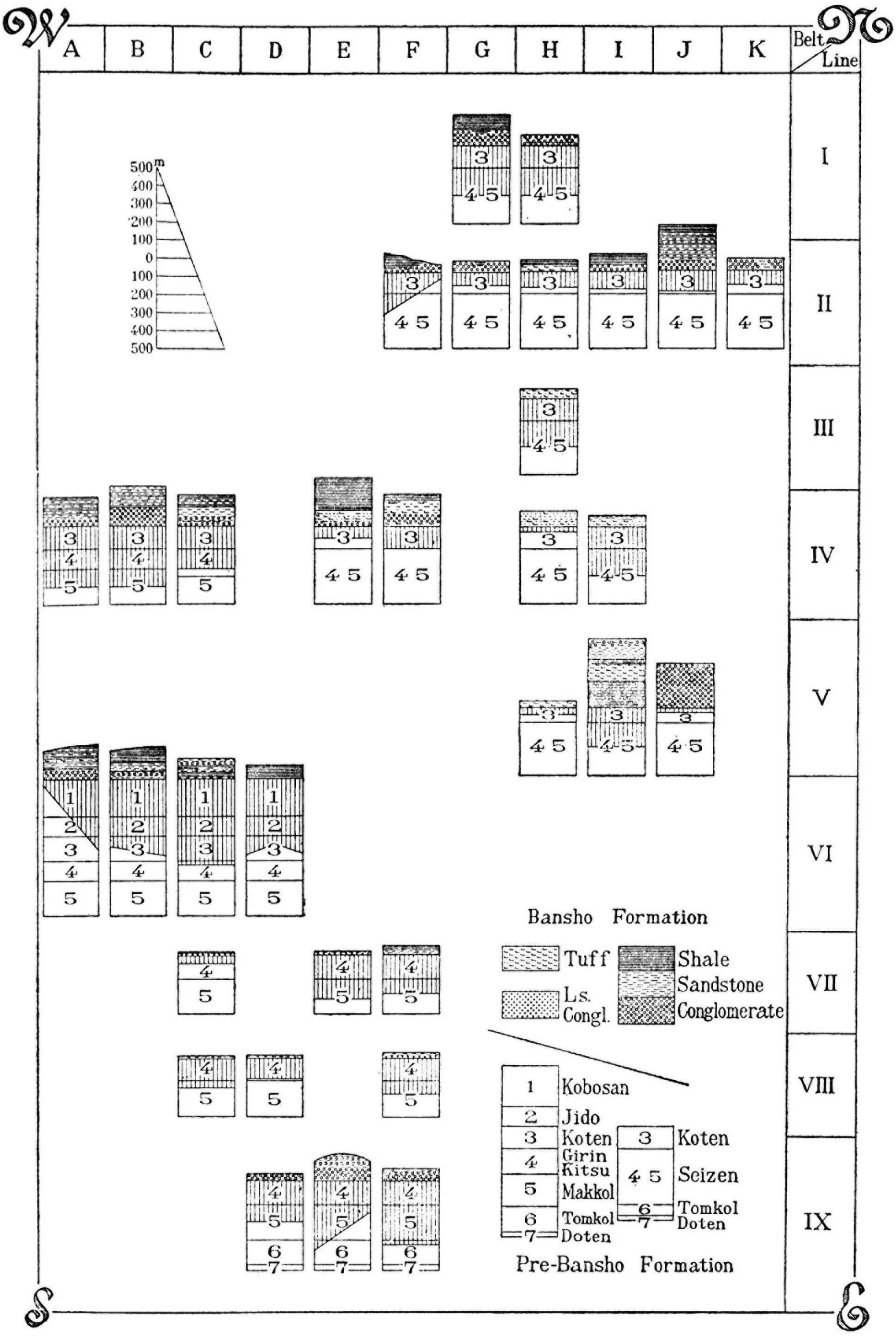


Fig. 11. Stratigraphic Sequences at the Points of the Lattice in Figure 10.

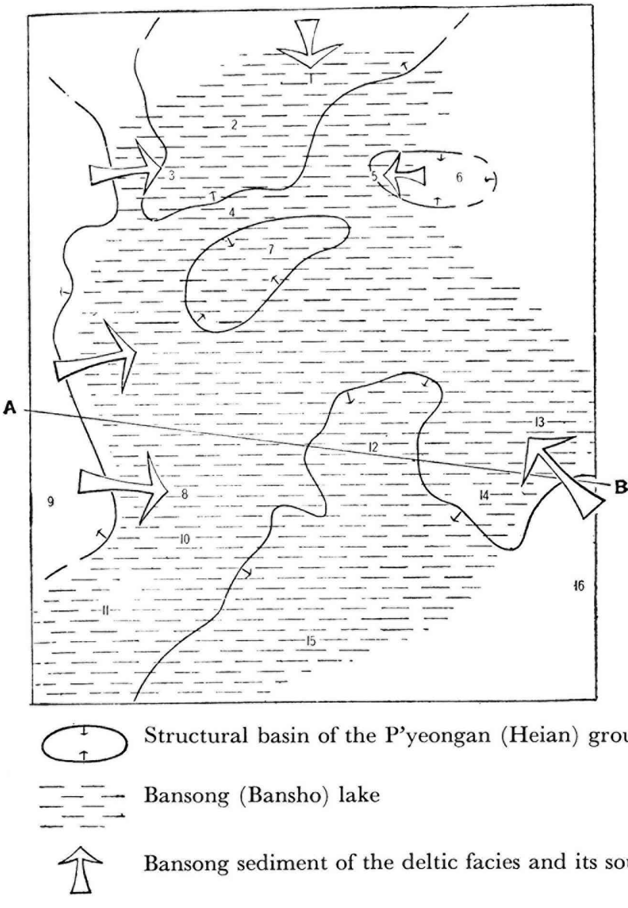
cycle of sedimentation, although it is difficult to say whether the coarse rocks were accumulated in the final stage or whether they were eroded out.

Lavas and tuffs some of which are basaltic or andesitic but others of which are liparitic were found in different horizons at several points, IIh, IIIh, IVf, h-i, Vh-i, VIa and IXg. The last two of these points are isolated and the center of the area where the volcanic material is mainly distributed is located somewhere between the points IIIg and IVg, although neither volcanic vent nor fissure has ever been discovered. A few xenolithes of purple shale which are thought to have been derived from the Hongjeom series, are contained in a liparitic flow at Yangsansa in the Pibongsan belt.

The conglomerate in the lower Bansong is thickest at the point Vj where it measures 140 m. The next thickest points are at IVb and IXe. The conglomerates at many other points are fairly thick, but absent at the points IIh, IIIh, IVh-i, VIc-d, VIIf and VIIIc-d. These places where the conglomerate is not found may reasonably be considered to have been either off-shore or the place which was flooded when the lake submerged. The increase in the grain size on the other hand indicates proximity to the land whence the sediment was supplied. In the Bansong belt for example the thin conglomerate in the south dies out toward the north. The conglomerate is very thick in the Songbong belt on its east side and also in the Want'aeksan belt on its west side. In the Kŭiusan belt the change from the thick conglomerate in the east to the fine rocks in the west is quite abrupt.

The reddish quartzite commonly seen in the Hongjeom series is the leading member of the southern conglomerate, while the northern conglomerate comprises fairly large amounts of white quartzite and quartzose sandstone typical of the Gobangsan series. Most of the large gravels in the conglomerate measure 20 to 30 cm in diameter, but those of 60 to 70 cm are not rare. Colossal boulders of more than one m are sometimes found near Mudongji, Want'aeksan and a few other places. On the north side of the Pibongsan belt there are also colossal boulders which are found in association with small ones a few centimeters in diameter. These are examples of typical deltaic facies. On the south side of the Pibongsan belt, however, the gravels soon become uniform in size, measuring 10 to 20 cm. The decrease in their diameter as a rule keeps pace with the increase in their rounding and sorting.

It is well known that while chemical dissolution is the most important factor in the erosion process of calcareous rocks, most of the others are mechanically disintegrated. The mode of disintegration is, however, different between sandy and shaly rocks and also between consolidated and unconsolidated rocks. The gravels and cementing material of the Bansong conglomerate distinguish the hard and the more easily disintegrated rocks of the mother land respectively. Angular blocks are contained in limestone conglomerate or breccia at Puksilli and Machachi and their sources must be close by.



Structural basin of the P'yeongan (Heian) group

Bansong (Bansho) lake

Bansong sediment of the deltic facies and its source

1. Pibongsan (Hihosan) delta
2. Cheongseon (Seizen) basin
3. Majon (Maden) delta
4. Kyulamni (Kiganri) anticline
5. Kŭiusan (Kiusan) delta
6. Kŭiusan (Kiusan) basin
7. Sugalsan (Suikatsusan) basin
8. Want'aeksan (Kwantakusan) delta
9. Yeongweol (Neietsu) syncline
10. Want'aeksan (Kwantakusan) anticline
11. Ch'ori (Shori) island
12. Pyeongsan (Heizan)
13. Songbong (Soho) delta
14. Puksilli (Hokujitsuri) island
15. Kongsuweon (Kosuin) basin
16. Paekunsan (Hakuunsan) syncline

Fig. 12. The Bansong Lake in the Early Stage and the Structure of its Basement in the Jeongseon, Uiimgil and Yeongweol Triangle.

A close examination of the lateral change in the grain size of the conglomerate and its components has shown that there must have been several mountain ranges as follows:

1) A precipitous mountain mostly of the Gobangsan series to the north or northwest of Pibongsan.
2) A high mountain composed of the Gobansan, Sadong and Hongjeom series close to the east or northeast of Kŭiusan.
3) A high mountain mostly of the Gobangsan series adjacent to the west of Majon pass.
4) A mountain chiefly of the Hongjeom series to the west of the southern part of the Want'aeksan belt which was especially high near Yeongweol.
5) Small islands of the great limestone formation near Ch'ori and probably at Puksilli.
6) A mountainous land composed of the Gobangsan, Sadong and Hongjeom series to the south or southeast of the Bansong belt was probably either far removed from the lake or not very high but occupied an extensive area.
7) A mountainous land composed of these three series in addition to the great limestone formation to the southeast of the Songbong belt.
8) Limestone cliffs near Machachi.

It is a remarkable fact that green siliceous sandstone typical of the Greenstone series has not been found in the Bansong conglomerate. The Bansong series overlies various formations from the top of the Gobangsan series to the Tomkol shale (see Table 4). The thickness of these formations inclusive of the two measures 1,300 to 1,500 m. Because the basement in the Bansong epoch was very gently undulated except in a few places where the clino-unconformity is found at the base of the Bansong series, the height from the bottom of the Bansong lake to the summits of the surrounding mountains was presumably about 1,500 m.

In the Songbong belt the base of the Bansong series is concealed by faulting. At some places the series became para-autochthonous because of its basal sliding. Except at Namjeongni and Manjidong where the clino-unconformable contacts were found by YOSHIMURA and IWAYA the series lies on the older formations disconformably at most places. At Want'aeksan and a few other places the base of the series is more or less uneven, but most other places it is even.

Because the P'yeongan system rests on the Korean para-unconformably, the two systems must have been almost horizontal by the time of the Songnim phase. Local folds through Namjeongni and Manjidong are exceptions and the basement of the Bansong lake was very gently undulated in the rest of the area. Where the Bansong series overlies the P'yeongan or the Korean system, the structure of the basement was a basin or a dome respectively. To the south of the folds there must have been a large basin of the P'yeongan system with the Gobangsan series at its center. This basin was probably separated from the Paekunsan syncline to the east by an anticlinal axis of Hwarari. To the northeast of the Namjeongni fold there was another basin of P'yeongsan composed of the Hongjeom series. This was probably separated by the Want'aeksan anticline of the upper great limestone formation from the synclinal basin of Sugalsan in the north which consists also of the Hongjeom series. The Hongjeom terrain near Jeongseon was, however, not a simple basin, because there was an anticline of Kyulamni composed of the great limestone formation.

It is certain that the Want'aeksan anticline extended to the southwest, running between the Yeongweol syncline on the west and the P'yeongsan and Kongsuweon basins on the other side. The limestone was exposed extensively also around Songbong and Ungbong.

Thus the basement of the Bansong lake was composed of several structural basins and domes aside from a few local sharp folds. The P'yeongan system was extensive on the north and south sides and the great limestone formation in the central and eastern parts. To the west of the Want'aeksan syncline there was the Yeongweol syncline composed of the P'yeongan system. In the central part of the Bansong lake the basement formations were well leveled.

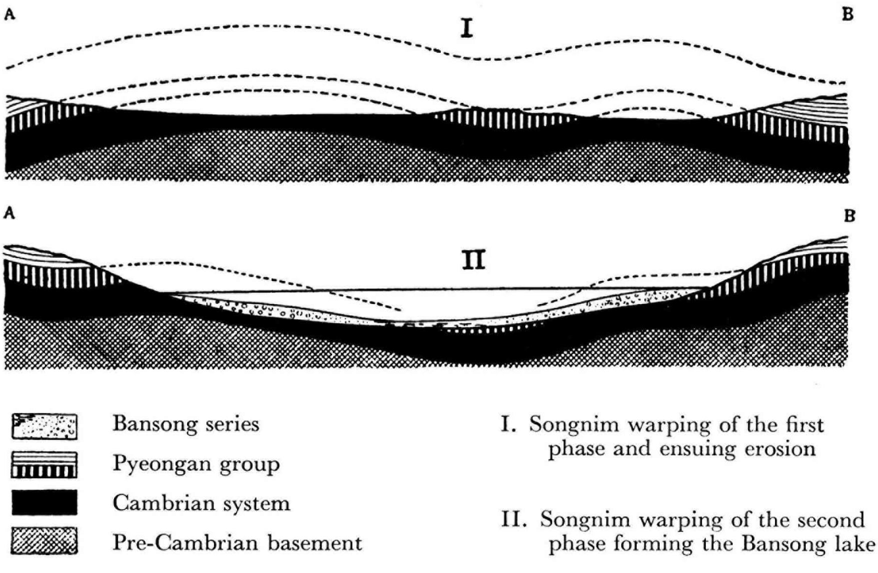


Fig. 13. Songnim Disturbance in the Western Part of the K ngweondo Limestone Plateau Analyzed into the Early and Middle Phases.

Because the structure of the basement disagrees with the outline of the Bansong lake and the series overlies the great limestone formation extensively in the central part, it is certain that the domes and basins in addition to gentle anticlines and synclines and local minor folds were formed in the early Songnim phase. Subsequently a gentle warping took place on a grand scale after which the Bansong lake was formed in the subsided portion. The lake was bordered by rugged mountain ranges on the northern, western and southern sides.

Assuming that this area was compressed to a half of its original breadth from WNW to ESE by the imbrication of the Taebo phases, the original structure of the Songnim deformation and the outline of the Bansong lake can be figured out by doubling the present breadth in the above mentioned direction (see text-fig. 12).

It seems to have been a tendency for the elevated or subsided part in the early Songnim phase to subside or be elevated to some extent in the next phase, more or less reciprocally. The Bansong lake is a product of down-warping in the latter phase, while its surrounding areas which were warped up became rugged mountains. Therefore the Bansong series begins generally with a conglomerate. At that time there were the Kŭiusan delta on the east side and the Majon delta on the west in the northern part. To the south of the latter delta there was the Want'aeksan delta. On the opposite side of the lake there was the Songbong delta. As a result of ensuing subsidence the lake expanded, while the land was dissected by erosion. The subsidence was accompanied by volcanic eruption. Toward the close of the Bansong epoch came the final warping through which the topography was somewhat modified and erosion revived.

The Bansong series is distributed in the Tanyang district beyond the Hangang river. According to KOBATAKE (1942), its lower part consists of reddish brown conglomerate in the lower 170 m and bluish gray conglomerate in the upper 180 m. The reddish brown conglomerate contains rounded boulders of over 30 cm in diameter. Most of them are white quartzite and quartzose sandstone which were derived from the Gobangsan series. Sandstone is the leading member in the bluish gray conglomerate; a small amount of limestone is contained in the conglomerate at Hyeonch'eonni. The upper Bansong series consists of alternations of sandstone and shale which can be divided into three parts. White or bluish gray, medium grained hard quartzose sandstone is the leading member in the lower 100 m or so; the middle 250 m is composed mostly of black shale in which several layers of sandstone and poor coal seams are intercalated. In the upper 60 m or so black shale layers are imbedded in white quartzose sandstone.

The total thickness of the series attains 750 m at the maximum. Its basement is mostly composed of the great limestone formation, but the Hongjeom and Sadong series lie on it at some places. The Bansong series is generally slipped along its base. To the south of the Chukyeong fault there is the sandstone and shale of the Bansong series at Yongdusan, some 2,000 m in its apparent thickness, where it rests on the great limestone formation at one place and on the Sadong series at another with the sliding plane at the base.

In the Mun'gyeong district to the southwest beyond the granitic mass of Toraksan and Chuhŭlsan, the Bansong series is mainly distributed in lunate form in the western part of the Sin'giri zone, though there is a detached occurrence at Tot'umni in the Mun'gyeong zone. In the Sin'giri zone it overlies the Hongjeom or Sadong series to the north of Chojongsan, but is on the Gobangsan series in the south. The conglomerate in the lower part varies in thickness, attaining several hundred meters on the west side of the Gobangsan series at Oeryongsan, but becomes thinner toward the southwest and northeast from this deltaic facies. It becomes thicker again near Ohangnyeong in the north. Boulders of the conglomerate are not well sorted; quartzite is abundant and ubiquitous; black shales are found near Seokhyeon; limestone is fairly common near Kaljonni. These various boulders are generally cemented with dark gray material.

The conglomerate beds are overlain by a thick sandstone and shale formation where sandstone is predominant in the upper part. The series to the east of Tot'umni overlies the Gobangsan series.

Fig. 14. Two Profiles Crossing Through the Western Part of the Kangweondo Limestone Plateau.

The chief distribution of the series is in the southeastern zone in the Mun'gyeong district, while it is in the middle zone in the Tanyang district. Farther to the northeast it occurs in several belts and extends beyond Jeongseon. The whole length from the northeastern end to the other measures some 100 km. The breadth is widest in the P'yeongsan-Yeongweol-Uiimgil triangle, being over 12 km from the Mudongji belt to the Songbong belt. Assuming that the breadth has been reduced by imbrication to a half of the original one, it must have been originally about 25 km. Considering the fact that the marginal deposit of the lake is now gone, the Bansong lake must have been no less than 30 km in breadth. The fossil lake thus figured may be as broad as Lake Biwa in Japan inclusive of its coastal plane, and its length corresponds to the distance from Lake Biwa to the city of Osaka. The height of the surrounding mountains in the early Bansong epoch probably exceeded that of the mountain ranges around Lake Biwa. Within the Bansong lake there were isles like Chikubushima in Lake Biwa, but they were composed of the great limestone formation. Judging from the deltaic sediments, the rugged mountains were mostly composed of the P'yeongan system with the Gobangsan series at the top.

Like Lake Biwa, the outline of the Bansong lake was most expanded in the northeast. It narrowed and possibly meandered on the other side, because its chief distribution is in the middle zone in the Tanyang district but in the southeastern zone in the Mun'gyeong district. The possibility of the meandering is also suggested by the geniculation of the zones between the two districts.

The Greenstone series exists in the Paekunsan syncline but not in its western wing. A small patch of the series beneath the Kongsuweon thrust, west of Yeongchien, is an exceptional occurrence in the Tanyang Yeongchun district. The reference of a few patches in the Mun'gyeong district to the Greenstone is as yet a matter of opinion. In the northeastern part of the Okch'eon zone there must have been the embryonic synclinorium of Pongdugonni, but the Greenstone series in its axial part was presumably separated from the Bansong lake by peripheral folds with the Gobangsan series at the top.

In short it may be said that the Greenstone series was not distributed so close to the Bansong lake that its boulders could be transported into the lake.

Then it is a fundamental question whether the Greenstone series was eroded out in the lake region before its appearance, or whether it was restricted in its accumulation to certain parts of the Kangweondo limestone plateau. Concerning this question one must take notice of a remarkable fact on the variation in facies and thickness. In the Korean system terrigenous rocks decrease and the thickness increases from the shelf sea on the eastern block to the axis of the geosyncline in the west. The change in sedimentation after the middle Palaeozoic land period is similar to that before it. The Hongjeom and Sadong series become thicker toward the geosynclinal axis where a limestone facies is well developed. But the thickness changes in the Gobangsan series in a different manner. It is thicker to the east of the Paekunsan syncline and in the northeastern part of the geosynclinal zone. In the Greenstone series the original thickness is indeterminable because it has been reduced by erosion, but it can be said in the Paekunsan syncline that it is thick in the east like the Gobangsan. Its extraordinary display in the northeastern part of the geosyncline is far more significant. It can also be noted that such a mode of distribution is not essentially different from that of the Songnim epoch. Furthermore it can be said that the above noted change from the Sadong to the Gobangsan epoch suggests a change in the direction of the subsiding axis.

In the Palaeozoic era there was the Chichibu geosyncline to the east of the Korean peninsular which was differentiating into an elevating anticline in its inner side and a subsiding syncline in the outer side in the Permian period. The differentiation can be especially well recognized since the middle Permian when the Usuginu conglomerate facies appeared. Subsequently in the late Permian the unfossiliferous and carbonaceous black mud facies of Toyoma is known to have accumulated in great thickness in the southern Kitakami mountains in northern Japan, in the Maizuru zone in western Japan and in the Chientao area in the southeastern extremity of Manchuria. Its distribution shows the subsiding axes *en échelon*. The Usuginu phase whence such a step in the tectonic development commenced in the Chichibu geosyncline corresponds approximately to the transition from the Sadong to the Gobangsan when the subsiding axes changed also in South Korea.

The Skyto-Anisic Inai series and especially its Anisic stage is very thick. It is represented by a thick marine slate formation in the southern Kitakami mountains, in the Maizuru zone and in the vicinity of Vladivostok. They show that the subsiding axes incised into the Akiyoshi geanticline *en échelon*. A similar axis of Pongdugonni must have existed in the northeastern terminus of the Okch'eon zone. The subsidence was much greater in the Inai epoch than in the Toyoma because the Inai series is much thicker than the Toyama. Likewise the Greenstone series is incomparably thicker than the Gobangsan. It is far in excess of 2,500 m and the Inai series is more than 3,000 m at its thickest.

Judging from the tectonic status prevailing in this part of Eastern Asia before the Akiyoshi-Songnim phase, it is presumable that the progenitor of the Pongdugonni synclinorium continued to subside to the west of the Akiyoshi geanticline. Such subsidence appears to suggest a reciprocal upheaval which formed the progenitor of the Yeongweol anticlinorium.

Although a conclusion is premature, there is evidence to support the contention that the embryonic folds were not the result solely of the middle Triassic Songnim disturbance, but that their preparation must have been gradually in progress since the Gobangsan epoch. Assuming such a pre-Songnim development, the Okch'eon geosyncline was also being differentiated at the time as was the Chichibu geosyncline, and the Greenstone series might not have been deposited uniformly through out the geosyncline. The subsiding areas became the synclines and the elevating ones the anticlines in the early Songnim phase. The embryonic folds were aligned *en échelon* between the Yeongweol anticlinorium and the Chungbongsan block. The structural basins of the P'yeongan system on the great limestone formation at Kŭiusan, Sugalsan and Pyeongsan reveal minor synclinal axes in the interspace. The Bansong lake was brought into being later by the extensive subsidence. Reciprocally the Yeongweol anticlinorium was warped up. The Bansong lake represents an embryonic syncline which developed later in the Taebo disturbance into the Jeongseon imbricated zone.

6. Kyeonggi (Keiki) land

The line between Haeju in Hwanghaedo and Mt. Kŭmgang in north Kangweondo marks roughly the southern border of the P'yeongnam orogenic zone and to the south the basement complex of the Kyeonggi massif is exposed. The massif is, however, bisected by the Weonsan-Seoul rift valley. The Pre-Cambrian Yeonch'eon system in the massif was named after Yeonch'eon-gun in Kyeonggi-do where its typical display is seen. It has not yet been thoroughly investigated, but it is evidently different from the Mach'eollyeong (Matenrei) system in the Kaema plateau in its lack of thick calcareous facies as seen in the middle part of the

Mach'eollyeong. YAMAGUCHI (1951) suggested Silurian or Devonian age for the Yeonch'eon system, but there is no conclusive evidence. Near Kŭmch'eon it is in contact with the Naknang (Rakuroan) complex in the southern rim of the Pyeongnam orogenic zone (KOBAYASHI, 1930). In the vicinity of Namp'o the system is composed of quartzite, schistose conglomerate, phyllite and mica-schist, the last two much more common than the two others (SHIMAMURA, 1931). It is extensively intruded into by the Kokulian granite. Gneissose granite or granitic gneiss is most extensive in the massif (Fig. 15).

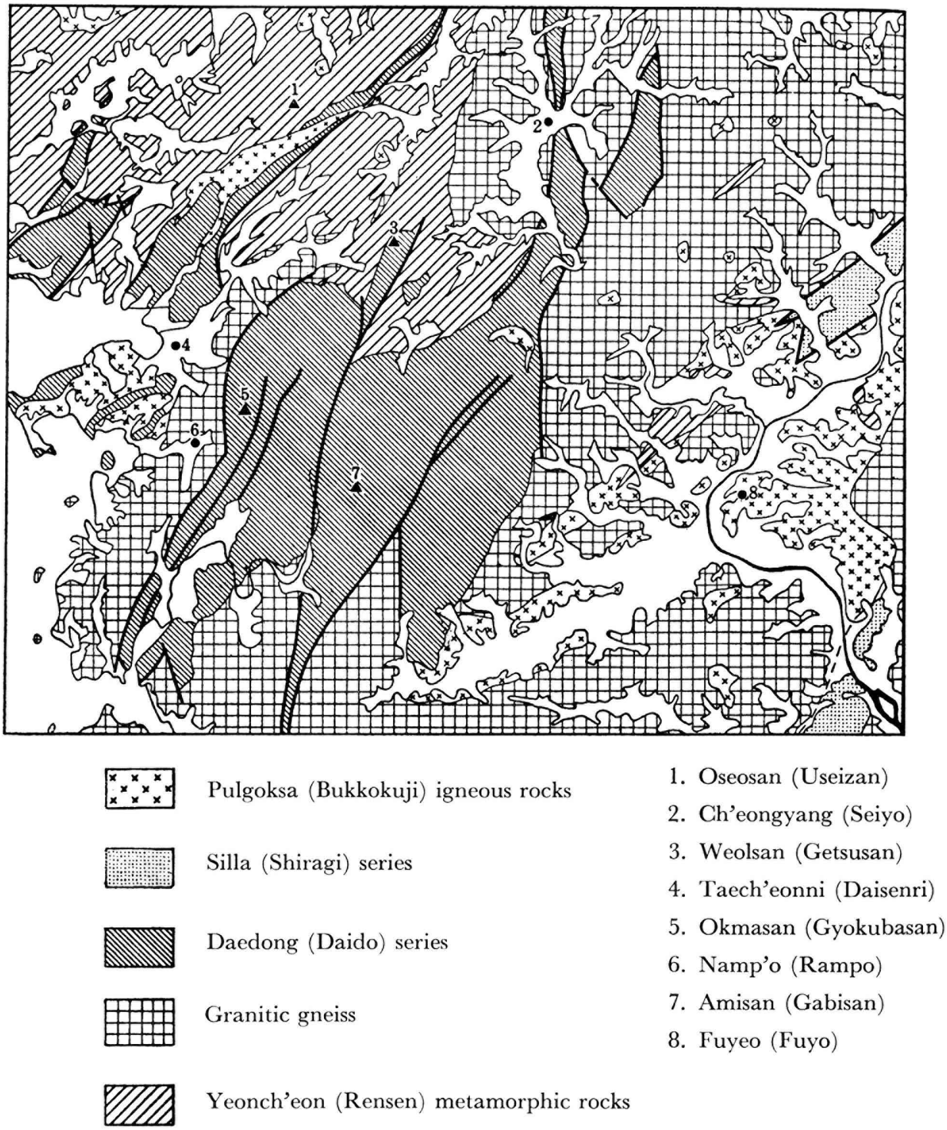


Fig. 15. Geological Map of Namp'o District.

There is none of the Sinian, the Korean or the P'yeongan system. The next younger is the older Mesozoic Daedong formation distributed in the narrow belts of Kump'o, west of Seoul, and of Namp'o in Ch'ungch'eongnamdo.

The Daedong formation of Namp'o was deposited in a basin behind the Ok-ch'eon orogenic zone. It lies on phyllites, crystalline schists and granitic gneiss. According to SHIMAMURA (1931) it can be classified in descending order as follows;

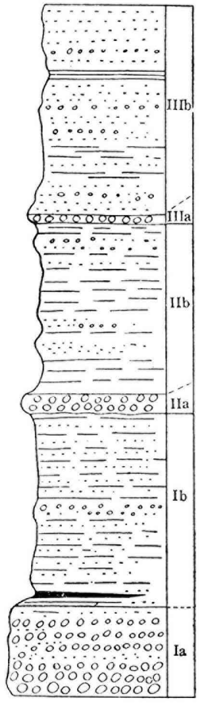


Fig. 16. Three Cycles of Sedimentation in the Daedong Formation in the Namp'o District.

IIIb. Okmasan (Gyokubasan) sandstone and conglomerate, 800 m thick.
IIIa. P'yeongni (Hyori) conglomerate, 30 m thick.
IIb. Paek'unsa (Hakuunji) black shale with sandstone and conglomerate, 650 m thick.
IIa. Kaehwani (Kwaikwari) conglomerate, 70 m thick.
Ib. Amisan (Gabisan) sandstone and shale with coal seams and basal conglomerate, 750 m thick.
Ia. Weolmyeongsan (Getsumeisan) conglomerate with some sandstone, 30-350 m thick.

The conglomerates of the beds Ia and IIa contain white quartzite, clayslate and granitic gneiss which are cemented with tuffaceous material. In the conglomerate of the bed IIIa, on the other hand, white quartzite boulders are cemented by quartz grains. Plant fossils and *Estherites* occur in the beds Ib and IIb. Such an old member as *Lobatannularia nampoensis* is contained in the Paekunsa flora. There are some species of *Estherites* common between the Amisan bed and the Tonjin formation of the Kump'o district. They are lower Noric *Estherites*, as pointed out by KOBAYASHI (1951).

The Daedong formation of Namp'o reveals three cycles of sedimentation (Fig. 16). Each of the cycles is represented by sediments over 700 m in thickness. The Bansong series on the other hand is a sediment of one cycle and its total thickness is much less than that of Namp'o in most sections. *Clathropteris meniscoides* is known to exist both in the Bansong and Paek'unsa floras. Though not yet quite definite, the Bansong series may be correlated with the middle Daedong formation of Namp'o.

Assuming this correlation, the lower Daedong of Namp'o is a product of the first Songnim phase and the middle Daedong that of the second in which the Bansong lake was produced and the Bansong series deposited. The upper Daedong of Namp'o is related to the third phase during which the Okch'eon zone was culminating until the Bansong lake disappeared. The background subsided reciprocally with this culmination and the upper division of Namp'o was accumulated there. These formations are cut by faults with NNE and NNW trends.

The Mesozoic formations in the Kump'o coal field to the west of Seoul are divided into the lower or the Tonjin series, about 800 m thick, and the upper or Munjusan series, about 850 m thick, by a weak discordance. The lower series consists mostly of sandstone and shale in alternation, partly tuffaceous, in which two anthracite seams are intercalated. Plant remains typical of the Daedong flora are contained in some horizons and *Estherites* in the upper part. Conglomerate is the leading member of the upper series, but thin layers of sandstone and red tuffaceous shale are found in it. It is certain that the lower series is late Triassic. Fragmentary plants from the upper series are enough to indicate its Mesozoic age. It is an orogenic sediment probably in the latter part of the Songnim disturbance, because the time interval and deformation indicated by the discordance are not so remarkable that it can be taken for a member of the Silla series. The two series form a structural basin elongated meridionally and cut by faults with the same trend. The Daedong formation of Namp'o was cut by faults with NNE and NNW strikes.

The Silla series of Kongju mentioned below is distributed on the border between the Kyeonggi massif and the Okch'eon orogenic zone. The middle Tertiary coal-bearing formation occurs at Tongch'eon north of Mt. Kŭmgang. Although the Pulgoksa granite intrudes into the massif widely, the late Mesozoic volcanics are not so extensive.

It is difficult to date the deformation of these Daedong formations because there is no younger formation in the vicinity. It is, however, noteworthy that the Daedong belts of Namp'o are located in the southwestern extension of the Weonsan-Seoul rift valley which is a graben and in which basalt is effused. On the east and west sides of the valley there are the Kwangju and Masing ranges and farther west there is the Yech'ong-gang along which basalt occurs. These mountains and valleys are all parallel to the Kilchu-Myeonch'eon graben and the Hamgyeong fault system. Therefore it is probable that the displacement has taken place along these parallel elements as it did in the Kilchu-Myeonch'eon graben in the middle Tertiary, although it is not improbable that the tectonic lines had already existed before then. In the Namp'o district the faults striking slightly west of north cut the NNE faults. The Kump'o graben runs meridionally; the middle Tertiary of T'ong-ch'eon, which is restricted to a very small area, is cut by minor faults of various directions.

7. Taebo (Taiho) disturbance

The structure of the Okch'eon orogenic zone is quite different from that of the Chungbongsan block and Paek'unsan syncline.

Because the embryonic folds of the principal tectonic elements such as the Pongdugonni synclinorium, Yeongweol anticlinorium and the Jeongseon imbricated zone are the outcomes of the Songnim deformation, the embryonic fold of the P'yeongch'ang zone may not be an exception.

These embryonic folds were greatly developed by the Taebo disturbance till the complicated folded structure of the Okch'eon zone was finished. Little is as yet known of the Pongdugonni synclinorium, but it is certain that the Chodongni basin which occupies its southwestern part was thrust upon by the Yeongweol anticlinorium from the south along the Sadong thrust. In the Yeongweol anticlinorium itself there is the Machari thrust by which the outer folded zone is separated from the inner imbricated part. In the outer zone the great limestone formation is capped by the Hongjeom and Sadong series, and their folding axes dip to the east or west. The inner part is exclusively composed of the Korean system, and to the east of Cheonggok-Kundŭngch'i thrust, thrusting is repeated toward the east. Judging from the virgation of these thrusts the more eastern one is as a rule earlier than the western. Namely, the Machari, Mohari and Namaeri thrusts were made one after another in the order mentioned. These thrusts are cut by the Sadong thrust. Therefore the Yeongweol anticlinorium must have thrust itself *en bloc* on the Chodongni basin after the imbrication within the anticlinorium.

Thus the folding developed into thrusting in the inner part which is composed of the incompetent great limestone formation, while the outer part where the formation is capped by the competent P'yeongan system was simply folded. Such a disharmonic folding between the two parts developed into the thrusting of the inner part on the outer zone along the already existing Machari thrust line. This thrusting *en bloc* is thought to have taken place simultaneously with or immediately after the Sangni thrusting.

The Yeongweol anticlinorium with its main axis through a point one-third of its breadth from the west is asymmetrical. On the northwestern side of the anticlinorium its inner part thrusts to the north on its outer zone along the Cheonggok thrust.

This zone thrusts on the southwestern wing of the Chodongni basin and the wing in turn on the P'yeongch'ang zone. Therefore the syncline indicated by the Tunjon phyllite in the P'yeongch'ang zone must have already existed before this thrusting. Because the Ongnyeobong and Hwabongjeong thrusts run parallel to each other, it is probable that the former thrusting was followed by the latter one.

As discussed in the preceding chapter, there was the embryonic Yeongweol syncline of the P'yeongan system on the west side of the Bansong lake. Judging from the material of the Want'aeksan delta, the Gobangsan must have been on the syncline at that time. Because the Korean system in the inner part of the Yeongweol anticlinorium thrusts on the Sadong series along the Machari tectonic line, the Gobangsan series was most probably absent in the inner part, but the series possibly existed in the outer until the Taebo epoch. The rigid Gobangsan series may have resisted the folding of the outer zone and the less folded outer zone resisted against the easily thrusting inner part. This must be the reason why the two parts made a differential movement along the Machari thrust. Assuming this interpretation to be correct, the embryonic Yeongweol syncline must have been brought into being in the Songnim phase.

When the Yeongweol anticlinorium developed, a series of parallel folds with a northeast strike were introduced on its east side. In this terrain also the tectonic development was disharmonic between the parts with and without the P'yeongan system. In the southern part of this terrain between the Teokp'ori and Maehwadong thrusts there are the Hongjeom and Sadong series in addition to the Gobangsan series at the western extremity. They repeat isoclinal folding in the western part of the Paek'unsan syncline. All of the isoclines dip to the northwest and many of these folds are closed. In tracing these folds along their axes the anticlines are seen to develop into thrusting sheets. Thus the folded terrain in the south merges with the imbricated terrain toward the north.

The folding axes are not always parallel to one another. Because the P'yeongan system is less developed, the great limestone formation was easily capable of folding. But the free folding was controlled by the competent Bansong series where it caps the incompetent great limestone formation. Therefore the former is frequently thrust onto by the latter from the northwest side. The great limestone formation reveals intraformational foldings at places where the Bansong is monoclinal (see Fig. 3 of Pl. II).

Because the Bansong series with the rude conglomerate at its base is more competent than the Hongjeom and Sadong, near Bansong that a brachysyncline of the Bansong series with its axis slightly north of east is observed to be bisected by an upthrust of its overturned northwestern wing on the other wing which is simply monoclinal in normal order and overlies the structural basin of the Gobangsan series. The above-mentioned zone of parallel isoclinal folding is located to the east of this Gobangsan basin.

A few words should be added here to explain how the northwestern wing of the Bansong brachysyncline thrust itself *en bloc*. On the northeast side of this wing the

Bansong series is thrust by the great limestone formation, while on its southwest side the formation together with the Hongjeom and Bansong series is repeatedly folded with the axis sharply oblique to the thrust. Thus in this arc the northeastern side was easily folded, while the other side was not so easily capable of folding. As a result the folding was confined to one side, and the folding oblique to the base of the Bansong series brought about the thrusting *en bloc*.

Not only near Bansong, but also at Puksilli and Soghangni to the east of Bansong thrust lines are sharply bent. On the southwest side of the bendings there is the above mentioned isocline of the P'yeongan system which has unquestionably resisted the folding. Because of this obstacle the thrusting took place on the north side of the isoclines. In farther north the great limestone formation forms an imbricated structure by parallel thrusts. The imbrication is regular and parallel to the Teokp'ori thrust except to the east of Yeongweol where the structure is cut obliquely by the Teokp'ori thrust. Therefore it is evident that the Teokp'ori thrusting lasted after the imbrication had been completed. Nevertheless the basal conglomerate of the Bansong series at this place is not much displaced along this thrust.

Between the Teokp'ori and Kongsuweon thrusts there is the Jeongson imbricated zone. At Ch'ori a strong intraformational folding is seen within the incompetent great limestone formation. The competent Bansong series on it is however monoclinal. The typical imbrication of the zone is seen to the northeast of Puryeong or its vicinity whence the thrust lines virgate, and about 10 thrusting sheets are aligned near Jeongseon. Resisted by the Bansong series of Kŭiusan, however, the parallelism of these thrusts is strongly disturbed. Incidentally the thrust line reveals an abrupt bending near Puryeong on the geological map, but it is due to topography and the thrust plane is simply inclined.

This imbricated zone extends from the west side of the Chungbongsan mountainous land to the southeast side of the Kariwangsan basin. The P'yeonanni thrust on its border is protruded to the southwest. The Cheongsandong *Klippe* of the great limestone formation on the P'yeongan system is a relic of this horizontal thrust sheet. Its mechanism and date are two questions which need more investigation. It is, however, presumed to be probably a product of the reaction of the Sangni thrusting.

The Kongsuweon thrust cuts the Sangni thrust. Likewise the Teokp'ori thrust cuts the imbrication on its east side. Thus there are disjunctions on the southwestern part of the Jeongseon zone, while in the vicinity of Jeongseon the zone extends without such a discrepancy. These disjunctions are considered to have taken place in the latter phase of formation of the Yeongweol anticlinorium or shortly thereafter, and immediately after the imbrication to the east of Bansong.

The Jeongseon imbricated zone narrows out at Weolgok west of T'aehwasan, but soon recurs and extends toward Tanyang. The Pyeolgongni and Kich'onni thrusts there correspond respectively to the Kongsuweon and Teokp'ori thrusts. In the Tanyang area the zone between them is bisected by the Kosuri thrust. The basal sliding seen to the north of Weolgok is common in this district.

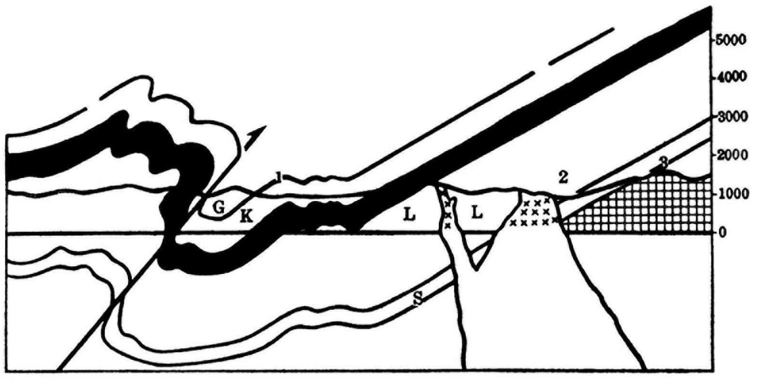
In the Mun'gyeong district farther to the southwest the middle or Mun'gyeong zone corresponds to the Jeongseon zone. In the northern part of the district the Sin'giri zone is protruded to the west and several thrusts run across the Mun'gyeong zone obliquely. Further tectonic complexity is revealed by the *Klippen* of the Okch'eon (?) system, and by some other *Klippen* and *Pseudoklippen* derived from the Sin'giri zone. Incidentally, a *Pseudoklippe* means here a block which looks like a *Klippe*, but in fact is an autochthonous block squeezed out by lateral compression. The structure there is so complicated that its clarification needs more study.

Returning to the northern terrain, the Paek'unsan syncline extends to the east of the Maehwadong thrust, which was originally brought into being in the Songnim phase between the elevating Taebaegsan block on the south and the subsiding Chungbongsan block on the north, probably by their differential movement. Because of such a difference the Pre-Cambrian basement is widely exposed to the south of the syncline, while the basement is mostly covered by the Korean system on its north side, except the dome of the Chungbongsan mountains and a gorge between Mungongni and Munŭngni. The Korean system on the Chungbongsan block is, however, not intensely folded.

The Paek'unsan syncline has a sigmoidal axis, convex to the north in the west but to the south in the east. To the west of Mt. Tuwibong (Tsuibon) where the axis is shifted to the north, the northern wing is steeply inclined or even upturned. The P'yeongan system there is in contact with the Korean system of the Chungbongsan block along a tectonic line called Chodongni which may have appeared in the Songnim phase, if not at the beginning of the Taebo disturbance, because it is cut by the Maehwadong thrust and the Surichi tectonic line. In the present distribution the P'yeongan system, which terminates once at the Maehwadong thrust, recurs at some distance beyond the thrust, where it forms isoclinal folds. On the south side of this folded zone the Oktong fault runs from east to west and its downthrow is on the north side. It is cut by the Maehwadong thrust. Therefore the faulting is thought to have been caused by the differential block movement in the interval between the isoclinal folding and thrusting. Adjacent to the east of the Maehwadong thrust line there are the granitic mass of Imongni and a fault running along the northwestern side of its outer circle. This fault is cut by the Surich'i tectonic line which in turn disappears in the granite mass. Because the tectonic line is subparallel to and as long as the Maehwadong thrust, they may be contemporaneous, while the Chodongni fault may be older. The granite is younger. Its intrusion must have taken place after the completion of the deformation.

The cross section through the middle part of the Paek'unsan syncline where the granitic mass of Op'yeong is intruded into is asymmetrical. The synclinal axis is much shifted to the north and the Greenstone in the northern wing is thrust onto by the Gobangsan series. Farther to the east beyond the Hambaeksan fault the Paek'unsan syncline becomes a large structural basin. The formations in its center are moderately undulated, but they are rather steeply inclined on its south side and abruptly overturned near its northern margin. Beyond this abrupt overturn there is the *Schuppenstruktur* on the border of the Ungbongsan structural basin.

It may not be accidental that such a remarkable *Schuppenstruktur* is found not only at the northeastern corner but also at the southwestern corner of the Chungbongsan block. Near Hwangjiri the structure is thought to have been introduced by the thrusting of the complicated anticlinorium and synclinorium on the border between the Chungbongsan block and the Paek'unsan syncline.



1 Cheongansa (Joanji)
2 Ch'eongori (Teikyori)
3 Taebaegsan (Taihakusan)

G. Greenstone series
J. Sadong-Hongjeom (Jido-Koten) series
K. Gobangsan (Kobosan) series
L. Great limestone formation
S. Myobong (Beiho) slate and Jangsan (Sohsan) quartzite

Fig. 17. Cross-Section of the Paek'unsan Syncline.

The Ungbongsan structural basin is composed of the Hongjeom and Sadong series on the great limestone formation. They form a large number of small *Schuppen* or small scale-shaped thrust sheets near the periphery of the basin, but the number of thrusts decreases and their interval becomes wider toward the north from the periphery. In the northwestern part of the basin the Hongjeom series is thrust by the great limestone formation, instead of the reverse relation prevalent in the south. In the southeastern corner of the basin the synclinorium with the axis along the Osipch'eon river suffered strong lateral compression, causing thrusts to form another series of *Schuppen*. Farther to the northeast the *Schuppenstruktur* is cut by a fault, confined to its northwest side. There the *Schuppen* dip to the north or west.

Another *Schuppenstruktur* is found at the southwestern corner of the Chungbongsan block near Uiimgil. It is not as large as that of the Ungbongsan basin. This is located in a triangular area between the Paek'unsan syncline on the south and the above-mentioned imbrication on the northwest side. The competent P'yeongan system of the syncline makes an upthrust on the Chungbongsan block along the Chodongni tectonic line. The anticline beyond the line developed into an anticlinorium and further into the *Schuppenstruktur* of Uiimgil. The Maehwadong thrust runs across the axis of this structure. Accordingly the *Schuppen* are found above and below this tectonic line. But if the lower *Schuppen* are excluded, the imbrication on the northwest side terminates with the Maehwadong thrust. The embroyonic anticline which developed this *Schuppenstruktur* must have been a branch of the Munŭngni anticline.

The deformation of the Korean system farther to the east of the Chungbongsan block is not strong. The Munŭngni anticline is very gentle. Its principal axis strikes to the northeast, but there are auxiliary axes with a NNW trend. The Pre-Cambrian basement is exposed in the gorge between Munŭngni and Mungonni where the axes in the two different directions intercross. The Jangsan quartzite which overlies this basement is exposed more extensively along the principal axis and forms domes where it intersects with auxiliary axes.

Bordering the Jangsan quartzite, the Myobong slate on it is exposed more extensively and cut by the long Surichi fault which runs through the west side along the axis. There are some faults also on its east side. Through these parallel faults the Mungongni anticline is broken into stepping blocks. These faults are mostly normal, but the western ones are partly upthrusts.

Farther east in the vicinity of Chomoksan the Upper Cambrian Chukryeon formation thrusts up on the Middle Cambrian Daegi limestone. This thrust cuts the upthrust of this limestone on the Chukryeon formation on its south side. In the interval between these tectonic lines there are some oblique faults. The dislocations of these three kinds are all products of warping behind the Chodongni thrust, which is related to the aforementioned southerly thrusting within the Paek'unsan syncline to the north of Cheongansa.

8. Kyeongsang group in the Tsushima basin

When KOTO (1907) gave the name of *Tsushima basin* to the area around the Tsushima Islands where the late Mesozoic Kyeongsang group was deposited, he called attention to the Inkstone series in Yamaguchi Prefecture (former Nagato Province) and northern Kyushu, which is a red tuffaceous formation similar to the Kyeongsang group. Earlier YABE (1905) had determined the late Jurassic age of the Naktong flora which was discovered in the basal part of the group. KATO (1925, 1932) on the other hand emphasized the parallelism of the late Mesozoic ingeous activity between the Japanese and Korean sides of the basin.

The Kyeongsang was precisely classified by TATEIWA (1929). Its lower part is the Naktong series which overlies the Yongnam land and is disconformably overlain by the upper part, *i.e.* his Silla (Shiragi) series in which thick andesitic flows are intercalated. In the Taegu-Kyeongju section the group is regularly inclined to the southeast and can be classified in descending order as follows:

Table 5. Stratigraphical Sequence of the Tsushima Basin.

Age	South Korea	Tsushima Islands	Chugoku N. Kyushu
Diluvium	Cheju volcs.		Volcanics
Pliocene	Seongwip'o		Iki
Miocene	Yeonil		
	Pyeolgongni		
	Changgi		Sasebo
Palaeogene		Ashiya	Ashiya
			Otsuji
			Shiranuhi
Cretaceous	Granite	Taishu	Chugoku granite
	Pulgoksa		Sensui
	Silla		Inkstone Wakino
	Naktong		Toyonishi
Jurassic			Toyora
Triassic			Mine
			Atsu
Palaeozoic			Yamaguchi Sangun
Pre-Cambrian	Kokulian granite Taebaegsan		

II. Silla (Shiragi) series

Chusasan (Shushazan) pyroxene porphyrite and red tuff, 1,000 m thick.

Keonch'eonni (Kansenri) dark gray marl, shale and sandstone, 800 m thick.

Ch'aeyaksan (Saiyakusan) pyroxene porphyrite, hornblende pyroxene porphyrite and red and variegate tuff, 200–250 m thick.

Taegu (Taikyu) red and variegate marl, shale and sandstone, 2,000 m thick.

Hakpong (Kakubo) pyroxene porphyrite, hornblende pyroxene porphyrite and red and variegate tuff, less than 250 m thick.

Silla (Shiragi) red and brown conglomerate, 200–600 m thick.

......disconformity......

I. Naktong series
   Ch'ilgok (Shikkoku) red and variegate marl, shale and sandstone, 500–950 m thick.
   Chinju (Shinshu) dark gray and variegate marl, shale, sandstone and brown conglomerate with intercalations of coal seams, 1,000 m thick.
   Hasandong (Kasando) red and variegate marl, shale and sandstone and brown conglomerate, 1,300 m thick.
   Naktong (Rakuto) dark gray marl, shale and sandstone and brown conglomerate with intercalations of coal seams, 700 m thick.

Covering the erosion surface of the Kyeongsang group there is the third group of rocks, TATEIWA's Pulgoksa (Bukkokuji) series; it is chiefly composed of acidic effusive and plutonic rocks, but some sediments are intercalated among them. Later he pointed out the presence of a Danian plant-bearing formation in the Tsushima Islands and named it the Taishu series (TATEIWA, 1934). It comprises much material derived from the Pulgoksa series.

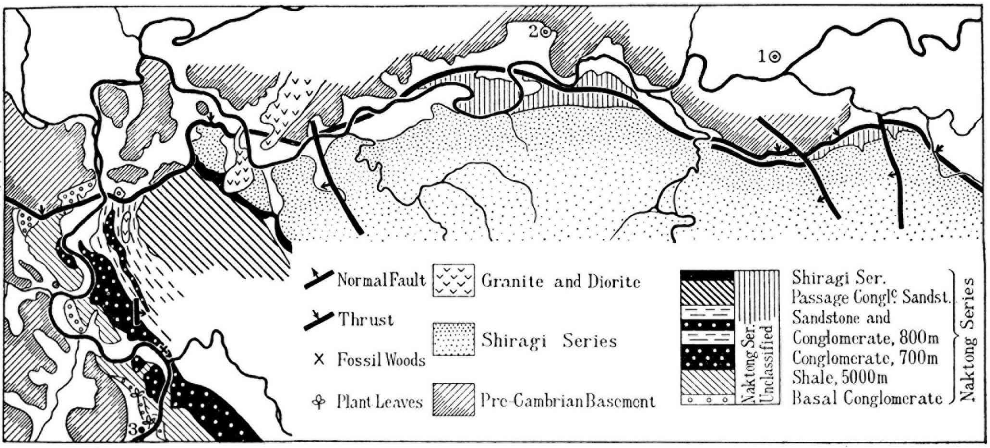
The group's correlation to the Mesozoic formations in Japan, has long been undetermined. I (1926) ascertained in Yamaguchi Prefecture that the Jurassic Toyora series is overlain by the Inkstone discordantly. Subsequently the Wakino series was discovered to lie beneath the Inkstone in northern Kyushu (KOBAYASHI and OTA, 1936). While the Wakino series and the upper part of the Naktong series contain limnic *Trigonioides-Plicatounio* fauna (KOBAYASHI and SUZUKI, 1936), the paralic *Glauconia* fauna of Yoshimo at the top of the Toyora series is intimately related to the Wealden Ryoseki fauna on the Pacific side of Japan (KOBAYASHI and SUZUKI, 1937). The top division was recently segregated from the series as an independent formation called Toyonishi (MATSUMOTO, 1949), because the division was found at some places to lie on the Toyora proper disconformably. The series comprises the Yoshimo shell bed in the upper and the Nanami plant bed in the lower part. It is my opinion that the series may be approximately contemporaneous with but heteropic from the lower Naktong series and ranges from late Malm to Wealden.

While the distribution of the Wakino series is restricted to a few places, the Inkstone series, overlapping the former, is widely spread in Yamaguchi Prefecture and northern Kyushu. They form the syncline of Kwanmon. To the northwest there is the anticline of Nagato where the Toyonishi and older formations are widely exposed. There are, in addition, some smaller basins of similar age in the Kibi, Tamba and Hida plateaus to the east and in central Kyushu in the south where red formations have deposited.

In Korea the Silla series covers Kyeongsangdo extensively and is generally underlain by the Naktong series. They are gently inclined to the southeast from the Teokyusan block, but in the north they extend to the northwest, forming the Ŭiseong wedge. According to SATO and YASUHARU the northern boundary of the wedge is marked by the Andong upthrust of the Taebaegsan block on the Kyeongsang group. Behind it there is the Yeongdong basin, the northern margin of which is also limited by a similar upthrust. Its western and southern borders are probably normal faults. Farther to the north there is the Silla series of Hwangjiri where the Naktong series is missing. To the west of the Teokyusan block there are also some Silla basins, but the Naktong series is not well developed. The block is directly covered by the Silla on its south side.

While the total thickness of the Inkstone and Wakino series is some 4,500 m at the maximum, the Silla series attains 12,000 m and the Naktong below it measures 4,000 m at the thickest. In other words the center of subsidence at the time must have been on the Korean side of the Tsushima basin. Assuming that the Toyonishi series is the correlative of the lower Naktong, the lake was restricted to the Korean side at the beginning of the Tsushima basin and there was still the Yoshimo embayment on its south side where *Ostrea*, *Corbicula* and other brackish molluscans were thriving.

As pointed out elsewhere (KOBAYASHI, 1941), the Oga orogeny attained its paroxysm in Yamaguchi and adjacent Kyushu at the transition from the Toyonishi to the Wakino epoch. Later investigation (MATSUMOTO, 1949) showed that this orogeny commenced in the interval between the Toyora and Toyonishi epochs, seeing that the upper Toyora and the lower Toyonishi series form the Takachi delta in the western Tabe basin in Yamaguchi Prefecture.



1. Antong 2. Pungsan 3. Naktong

Fig. 18. Uisong Wedge and Andong Upthrust.

The Toyonishi and Wakino series are orogenic sediments. During their sedimentation the Yoshimo bay emerged as land by the upheaval of the Nagato anticline and the Wakino lake was brought about reciprocally in a new depression. It is quite probable that the Wakino and Naktong lakes were separate basins at the time. Almost simultaneously the Tetori embayment in the Hida plateau became a lake. *Trigonioides*, *Plicatounio* and *Nakamuranaia* are characteristic pelecypods of these lakes.

At the close of the Wakino epoch the Wakino lake rather abruptly expanded very widely, seeing that the Inkstone series is distributed widely, overlapping the Wakino and covering the Toyonishi and older formations of the Nagato anticline. The small Inkstone lake of Inakura was also introduced on the south side of the Kibi plateau. The Kyeongsang basin of Yeongdong may have also been introduced behind the Teokyusan block.

The Inkstone series is divisible into three parts by two disconformities. The upper one is however, weak and local, while the lower one is more distinct and extensive, probably corresponding to the disconformity between the Naktong and Silla series in South Korea. In the Silla epoch the Tsushima basin may have been a single large depression. The Yeongdong, Chin'an and some other basins existed to the west of the Teokyusan block.

Because there is no Jurassic formation in the Kibi plateau, it is indeterminable when the Oga orogeny began there, but there is evidence suggesting that the Oga thrusting sheet had not reached its present site before the end of the early Inkstone epoch (IMAMURA and KUSUMI, 1951). Overlapping the lower Inkstone, the middle and upper parts of the series are more widely distributed in the plateau.

Variegate tuffs and tuffaceous sediments are contained both in the Wakino and Inkstone series, but the red compact tuff used for the Inkstone is mostly mined from the middle Inkstone series. The abrupt increase of volcanic and pyroclastic material in the series shows that the volcanic eruption became vigorous in the middle and late Inkstone epochs. Volcanic rocks of that time are mostly andesitic but liparitic after the Inkstone.

The Naktong flora suggests a warm and humid climate (KOBAYASHI, 1942). But it became more arid toward the Inkstone epoch. Estherians thrived in the inland depressions of the Wakino and Silla epochs (KOBAYASHI and KIDO, 1947) which were embraced by the Sakawa mountain range in Japan.

The Silla series must be middle Cretaceous because its flora containing dicotyledonous plants is cainophytic, while the Naktong flora is mesophytic.

By the invasion of the Chugoku batholithic granite the Tsushima and other basins became land, leaving a few small depressions containing thin sediments, called the Sensui series on the northern side of the Seto Inland Sea and the Yawata series in north Kyushu. Furthermore some sediments are known to be imbedded in the Pulgoksa volcanic rocks on the Korean side.

The Sensui series is gently inclined; the Yawata series forms a gentle syncline; the Inkstone series beneath the Yawata is somewhat more folded. In the Kibi plateau the upper Palaeozoic limestone appears to thrust itself upon the lower Inkstone at a great angle at Hina (NAKANO, 1952). The Inkstone in the still higher part is cut by small upthrusts.

Judging from these facts it is quite evident that crustal deformations were repeated in the inner zone of West Japan through the Cretaceous period, but at the same time it is certain that the deformation attained its paroxysm in the Oga phase, namely at the transition from the Yoshimo to the Wakino epoch. The structure of the Oga folded mountains is complicated. The leading trend of the Cretaceous folding and faulting on the other hand is nearly equatorial, *i.e.* subparallel to the axis of the Sakawa folded mountains.

Seeing that the Naktong lake appeared and expanded at the Ŭiseong wedge, the paroxysm of the Taebo disturbance in South Korea may be a little earlier than the Oga paroxysm. This is because the Naktong lake is a frontal depression reciprocal to the culmination of the Yeongnam land, because the Yeongnam land must have been broken in the process of culmination into the Taebaegsan and Teokyusan blocks at the Ŭiseong wedge before the Naktong epoch, and also because the fragmentation brought about by the culmination is presumably related to the differential movement between the metamorphosed and non-metamorphosed parts of the Okch'eon zone. More precisely, the former part thrust itself *en bloc* on the latter part along the Ch'ungju-Mun'gyeong line after the latter part had been imbricated. The thrusting was accompanied by a great culmination of the Teokyusan block and this in turn caused fragmentation of the Yeongnam massive along the southeastern extension of the tectonic line. It is my opinion that the area thus subsided is the progenitor of the Ŭiseong wedge.

The gentle dip of the Kyeongsang group toward the center of the Tsushima basin on the southeast side of the Teokyusan block is due to the culmination of the block because the group also dips distally on its south and northeast sides. In the Ŭiseong wedge the group is gently slanted toward the northeast and cut by the Andong upthrust with a subequatorial trend along which the Taebaegsan block thrusts itself upon the group. Within the eastern part of this block there is the Yeongdong basin of subsquare outline. Its geology has not yet been thoroughly investigated, but it is known that the group inclined to the south is thrust onto by the Pre-Cambrian rocks on its northern border and is faulted on the south and west sides. The Silla series in the Yeonghae area to the southeast of the basin is dislocated by a series of meridional faults.

The southerly upthrustings along the Andong tectonic line and also along the northern boundary of the Yeongdong basin probably took place in the transitional interval between the Silla and the Pulgoksa epoch. Such a compressive block movement took place when the Wakino-Inkstone series in the inner zone of West Japan was folded with equatorial axes. In the outer zone the Sakawa folded mountains were almost completed by the end of the Gyliakian (Turonio-Cenomanian) epoch. It is certainly interesting to see the change from the strong folding and thrusting in the outer zone to the gentle folding in the inner zone in West Japan. In South Korea there occurred upthrusts from the north because the basement of the Kyeongsang group was more rigid.

Subsequent to the Sakawa orogeny West Japan was bisected lengthwise by the Senonian Izumi subgeosyncline. Incidentally, the term, subgeosyncline means a zone of strong subsidence within the orogenic zone. The subsidence of this subgeosyncline is indicated by a thick inland sea deposit called the Izumi sandstone formation which attains a thickness of 6,800 m in its thickest part.

The blocking was strong in the inner zone and repeated more than twice. The repetition can be recognized by the fact that faults mostly crosswise to the Inkstone folding, cut the Palaeogene, though the Palaeogene is sometimes less displaced than its basement. The earlier phase of dislocation may have been sometime in the late Senonian or Palaeocene, because the Chugoku granite batholith which is exposed with lengthwise elongation is largely cut by the crosswise faults and overlain by the Oligo-Eocene. In other words the block movement is nearly contemporaneous with that of the Taebaegsan dislocation zone and they are intimately related to the grand invasion of the Chugoku batholith through which culmination, causing the faulting, the Izumi and other seas retreated over large areas. This emergence is what has been called the Akitsu epirogeny. If the Taishu series is really Danian, it is a relic of the Tsushima basin. But it is not improbable that the series is Oligocene, because it is probable that *Ostrea* known from the Tsushima Islands reveal the northern limit of ingression of the Oligocene Ashiya sea. Whatever the age of the Taishu series may be, Japan was then the maritime terrain of the Asiatic continent.

9. Metamorphosed Okch'eon (Yokusen) zone

In the Okch'eon orogenic zone the grade of metamorphism increases rather abruptly on the southwest side of the Ch'ungju-Mun'gyeong line. The northern part of this boundary has not yet been well investigated but, as mentioned already, its southern part in the Mun'gyeong district is indicated by the thrusting of the metamorphosed Okch'eon on the non-metamorphosed Okch'eon zone. In the former there are the Kyeongsang group and the Pulgoksa igneous group besides metamorphic rocks. The Kyeongsang group, which is distributed as patches along the lateral sides of the zone, consists mostly of the Silla series except the Cheonju and Hwasun districts where the Naktong appears to exist. In the Pulgoksa igneous group the batholithic granite and related porphyry are most extensive in the zone, especially along its axis.

The metamorphosed formation in question was classified by Inouye (1907) into the Kunsan formation and the Phyllite formation, both of which were considered Palaeozoic. Subsequently Koto (1909) referred them to his phyllite series in which he distinguished the Tongpok, Muan, Chyonjyu and Kunsan complexes and considered them to be Mesozoic. Nakamura (1924) on the other hand referred them to Pre-Cambrian and proposed the *Yokusen (Okch'eon) system* as their collective term. As its name suggests, its typical display is found in Okch'eongun, Ch'ungch'eong-bukto. It is composed there mainly of phyllitic rocks besides graphite phyllite, mica schist, quartzite and hornblende; and non-crystalline graphite deposits are occasionally imbedded among them. He classified the formation into three parts as follows:

(3) Lower Okch'eon formation chiefly made up of quartzite, sandstone and metamorphosed clayslate.
(2) Middle Okch'eon formation comprising hornblende schist, limestone, mica schist and phyllite besides some sandstone intercalations.
(1) Upper Okch'eon formation composed mostly of biotite schist and phyllite, though thin layers of conglomerate, sandstone, limestone, hornblendite and quartzite are intercalated in it.

The Okch'eon system in the Yeongdong and Ch'eongsan sheet-map areas which contain its lower formation and a part of the middle formation was later divided by SHIMAMURA (1927) into the following three:

3. Unmubong (Unmuho) formation: mica schist and phyllite.
2. Manweolli (Bangetsuri) formation: metamorphosed shale, phyllite, limestone, quartzite and thin graphite layers.
1. P'alunsan (Hachionzan) formation: metamorphosed shale, sandstone, quartzite, mica schist and graphite layers aside from rare occurrences of thin crystalline limestone beds.

The P'alunsan formation which forms an independent belt is clino-unconformably overlain by the Hoedongni bed of the Cretaceous Yeongdong series. In the western part of the sheet areas the Manweolli formation is overlain by the Sigŭmni bed, another member of the Yeongdong series, also clino-uncomformably. This formation near Manweolli looks similar to a certain part of the Cambrian formation in its lithic aspect, although its non-metamorphosed part is difficult to distinguish from the sandstone and shale beds of the Cretaceous Okch'eon formation below mentioned. There is a thick conglomerate bed in the Okch'eon formation at Kunseomyeon, Okch'eon-gun which bears boulders of granite, mica schist, granitic gneiss, black shale, quartzite and so forth. SHIMAMURA is of opinion that the Okch'eon in the area may be the metamorphosed facies of the Palaeozoic and Mesozoic formations.

Subsequently he (1925) surveyed the Cheonju series, *i.e.* KOTO's Chyönjyu complex near Cheonju, and made the following tripartition:

(3) Kirinbong (Kirinho) formation: biotite schist, phyllite and tremolite schist.
(2) Sindong (Shindo) formation: limestone, phyllite, biotite schist and quartz schist.
(1) Sadaeri (Shidairi) formation: sericite schist and quartzite.

In addition, there is a metamorphosed conglomerate containing quartzite, granite and clayslate. It may belong to this series, but at the same time it is noted that it is similar to the conglomerate in the Cretaceous Chin'an series. The Cheonju series is penetrated by numerous quartz veins. Because of the significant contact effect of granitic intrusion SHIMAMURA suggests that it may be the metamorphosed facies of the Cretaceous formation.

In the Hwasun district in Cheolla-namdo there is also a formation of dubious age called Kuam (Kigan). It was once considered Jurassic and at another time

Pre-Cambrian. According to ICHIMURA (1927) it is mostly composed of gray coarse quartzose sandstone, black sandstone, black shale, black clayslate and phyllite. In addition there are ottolerite slate, sandstone, white sandstone, quartzite, limestone, hornfels, mica schist and layers of anthracite and graphite. Incidentally ottolerite shale is very common in the P'yeongan system in the Kangweon-do limestone plateau, and can be found in shaly facies of the Bansong series in some rare instances. The Kuam is overlain by the Cretaceous Kubongsan formation and intruded by granite. With the find of *Cordites* (?) and *Pecopteris* (?) in its black clayslate member ICHIMURA suggested referring it to the P'yeongan system.

SHIRAKI (1934) classified the Okch'eon in the northwestern part of the Mun'gyeong district into the Paekhwari formation rich in limestone and the Sangnaeri formation poor in limestone. He is of opinion that the former may be Cambro-Ordovician and the latter Permian to Jurassic in age. He asserted further that they are overturned and imbricated. KOBAYASHI and AOTI (1942) agree with him on the imbrication and the age of the Okch'eon metamorphics in the Mun'gyeong district.

Through a survey of graphite deposit in the metamorphics KOBATAKE (1947) ascertained in Sangju district in Kyeongsang-bukdo that the lower Okch'eon merges with the P'yeongan system. Similar relations were found also in Hwasun-gun in Cheolla-namdo. Graphite biotite schist in the Yongdongni formation in the Haenam-gun (KINOSAKI, 1929) is also suggested by KOBATAKE as probably a metamorphosed member of the P'yeongan system. The middle and lower Okch'eon in Poŭn-gun, Ch'ungch'eong-bukto, on the contrary, are probably the metamorphosed facies of the Korean system or of the system in addition to the Greenstone series.

Up to the present no positive evidence has been obtained to show the Pre-Cambrian age of the Okch'eon system. On the other hand the gradual transition from the metamorphosed part to the non-metamorphosed part is known between Ch'ungju and Mun'gyeong. Where the P'yeongan system merges with the lower Okch'eon, the reference of the relatively thick limestone in the Okch'eon to the Korean system and of its rude conglomerate to the Bansong is highly probable. In the Mun'gyeong district it is known that they are imbricated by thrusting, the status making it difficult to decipher the sequence and structure of the metamorphosed Okch'eon. It is, however, a remarkable fact that the calcareous facies is not well developed in the Okch'eon system. KOBATAKE noted that the P'yeongan system directly overlies the Pre-Cambrian gneiss. Therefore the history of the part may be somewhat different from that of the other part of the Okch'eon zone. Either the Korean system in the former was extensively eroded out before the P'yeongan, or the P'yeongan system was transgressively spread on the Pre-Cambrian terrain beyond the bounds of the Korean system. Whichever alternative may be accepted, it is certain that, overlapping the Korean, the P'yeongan system covers the Pre-Cambrian basement transgressively. The inclusion of granite boulders in the conglomerates of the Okch'eon series of Yeongdong and also of the Cheonju series, however, distinguishes them from the conglomerates of the Bansong series and the P'yeongan system. The conglomerate suggests the inclusion of the Silla series which was metamorphosed by the intrusion of the Pulgoksa granite. Therefore it is still a question whether the Okch'eon metamorphics are exclusively older than the Taebo disturbance, although it is undeniable that the larger part of the Okch'eon system reveals a geosynclinal sediment which was later metamorphosed dynamically and still later thermally.

After this part of the Okch'eon zone had been metamorphosed by the Taebo orogeny, Cretaceous formations were accumulated on its lateral sides. One of them on the northwest side is found to the northeast of Kunsan. According to SHIMAMURA (1931), it consists of two parts as follows:

(2) Upper part; Aengbongsan (Ohosan) brown tuffaceous shale, 330 m thick.
(1) Lower part; Ch'eongso (Seisho) dark brown tuffaceous sandstone and conglomerate, 300 m thick.

This Cretaceous formation forms a syncline which is cut by faults on its two sides forming a graben. Another Cretaceous formation near Yongdong called Yongdong (Eido) series by SHIMAMURA (1927) is divisible into three parts in descending order as follows:

(3) Seonyudong (Senyudo) formation, about 350 m thick; marl, sandy shale and red shale.
(2) Hoedongni (Kwaidori) formation, about 1,200 m thick; conglomerate, green sandstone and red shale.
(1) Sigŭmni (Shikonri) formation, about 1,350 m thick; sandstone, shale, slate and conglomerate.

The conglomerate of the Sigŭmni formation contains granitic gneiss and that of the Hoedongni comprises granite, porphyry, porphyrite and mica schist besides granitic gneiss. The Sigŭmni formation which yields *Brachyphyllum* and *Frenelopsis hoheneggeri* may be a high Naktong member.

The Chin'an series near Chin'an is also divided into the following three parts by SHIMAMURA (1925):

(3) Sansudong (Sansuido) formation, over 600 m thick; sandstone and shale in alternation.
(2) Talkil (Tatsukichi) formation, 500 m thick; tuff, tuffaceous sandstone and shale.
(1) Mandeoksan (Bantokusan) formation, 800 m thick; tuff, tuffaceous sandstone, conglomerate, shale and marl.

The Talkil and Sansudong formations yield several land plants including broad leaves, insects and molluscan shells.

The above mentioned Kubongsan formation in the Hwasun district is about 1,200 m thick and consists of tuff, tuffaceous sandstone, dark reddish purple tuffaceous conglomerate, shale and sandstone of similar color and black or gray shale. Quartz-porphyry and quartzose sandstone and other rocks derived from the Kuam formation are contained in the conglomerate. Because *Zamiophyllum buchianum* and

Platanus beside some shells were collected by ICHIMURA (1927), the Kubongsan formation at least in part belongs to the Naktong series.

These are Cretaceous formations which overlie the Okch'eon metamorphic rocks, and are intruded by acidic rocks from quartz-porphyry to granite in many places. Not only this geological relation but also palaeontological evidence shows that they belong undoubtedly to the Kyeongsang group and mostly to the Silla series. It is certain that the group was deposited more widely than one can see now, but at the same time the material of the conglomerate tells that there were mountains on both sides and within the zone.

The Yeongdong series is gently inclined to the northwest or southeast, while the Chin'an series is monoclinal toward the northwest. Cut by faults the bases of the two series are unexposed. The Kubongsan which overlies the older rocks is gently undulated. Because the leading strike is parallel to the zone, it is seen that the zone was compressed crosswise after the deposition of the group. There are some strike faults and some others nearly rectangular to the preceding. It is certain that the dislocation took place after the intrusion because the Silla series is in fault contact with the Pulgoksa intrusives at many places, but judging from the outline of the intrusive body, it is not improbable that some of the faults existed before the intrusion.

In the southwestern part of the Okch'eon orogenic zone the Pulgoksa igneous activity was thus very strong. The granitic batholith is extensively exposed there. Most of the Okch'eon metamorphic patches are roof pendants of various size remaining on the batholithic body. The extensive exposure of the batholith in the axial part suggests the axis of culmination. By the block movement caused by the culmination the Kyeongsang group on the lateral sides was faulted down.

10. Taebaegsan (Taihakusan) dislocation zone

(See Geological Map II)

Peninsular Korea is cut by faults near the Japan Sea. They are, however, not simply parallel to the coast as suggested by KOTO's Taebaegsan dislocation lines. The complicated mosaic structure is precisely analyzed in the coastal region of the Kangweondo limestone plateau called here the Taebaegsan dislocation zone, although Mt. Taebaeg is located beyond the boundary fault of Hambaegsan. The mosaic structure of the zone is typically illustrated in Samch'eok-gun and its adjacent area.

The zone is divided by the Hwangjiri fault and its extension into two parts which are different in the mode of deformation. The northern part is again bisected by the Osipch'eon shattered zone. The Ungbongsan basin is located on its west side. On the east side of the belt there are the Korean system and the Pre-Cambrian basement farther east.

The Hambaegsan boundary fault is a great tectonic line in a north-south direction along which a zone over 100 m wide is strongly disturbed by a dislocation for a vertical distance of more than 1,500 m. Its downthrow is on the east side. Because the Hwangjiri fault draws the northern boundary of the Paek'unsan syncline, it is thought to have been brought into existence through the Taebo disturbance. It cuts the Silla series, however, and is traced to the southeast into the Maesanni faults. Beyond the end of this fault the Chikch'onggok and Sambang faults aligned *en échelon* belong to the same system. Along them the southern block must have slipped down or the northern block must have thrust itself upon the southern at a high angle. The secondary dislocation occurred after the deposition of the Silla series and igenous rocks intruded along the fault lines at some places. To the south of these faults there are the Mungdongni, Taehyeon and Kwangp'yeonni faults all with a northeast trend and with their downthrows on the southeast side, through which the blocks form descending steps. The vertical displacement attains over 1,000 m along the Kwangp'yeonni fault and over 500 m along the Taehyeon fault.

In the northern terrain to the east of the Osipch'eon shattered zone there are several long NNE faults most of which have the downthrows on their west side. Through them the blocks descend in steps toward the west. The westernmost one called Cheonni is, however, a hinge fault whose downthrow is on the west side in the south but on the east side in its middle and northern parts. In its latter part there are several auxiliary faults some of which are parallel to the principal one, but others run from north to south. The Magyori fault which defines the eastern margin of this fault zone has the downthrow on its east side. This shattered zone is called Osipch'eon because the Osipch'eon River meanders through it.

The downthrow of the Hwanjori fault is on the west side almost throughout its whole length except its northern terminal part where it is on the other side. The Sangdeongni fault which meridionally bisects the southern part of the terrain between the Cheonni and Magyori faults also has the downthrow on the west side. The fundamental structure between Magyori and Hwanjori faults is, broadly speaking, a large and gentle syncline and the Pre-Cambrian basement is exposed on its east and west sides. On the west side, however, the basement is restricted to a small strip near Kot'ori. A gentle anticlinal saddle extends therefrom to the east by which the above-mentioned large syncline is divided into a northern and a southern basin.

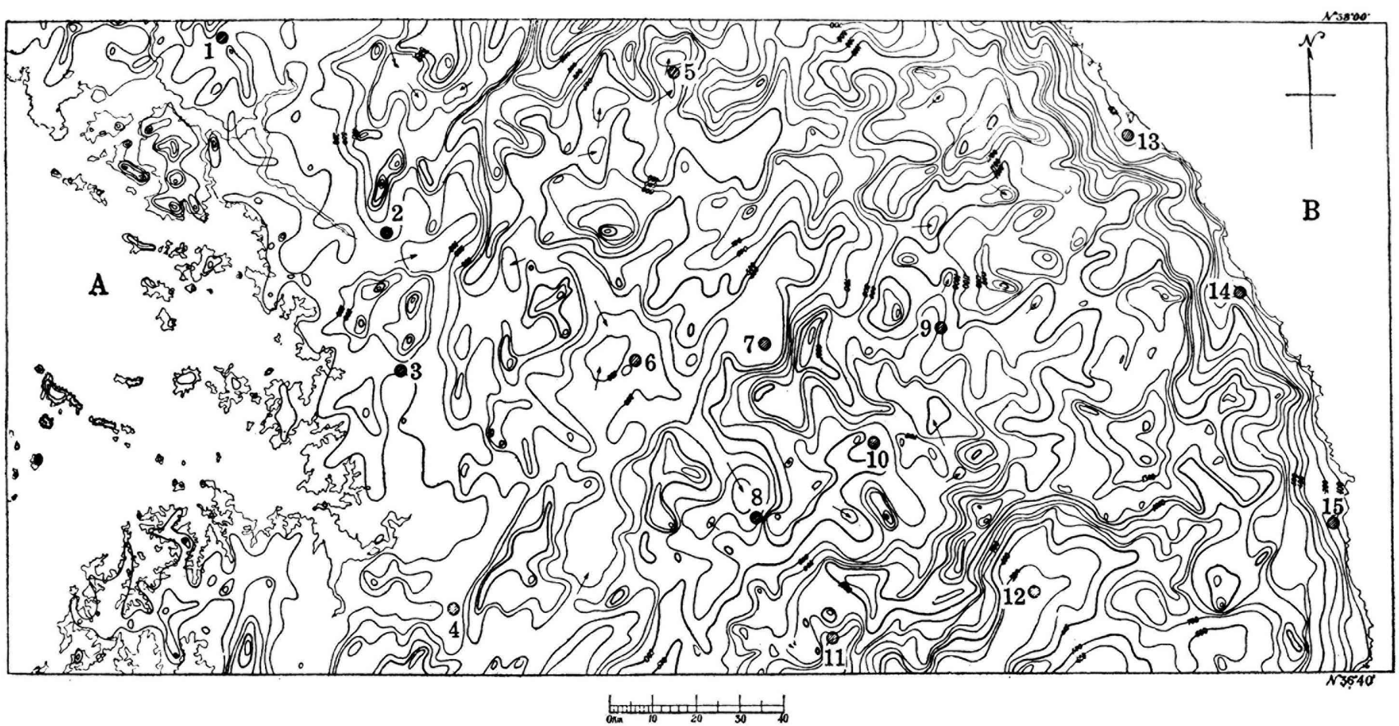
In the Ungbongsan structural basin to the west of the Sandgeongni fault the Korean system is overlain by the P'yeongan system. As mentioned already, the *Schuppenstruktur* of this basin is developed toward the Osipch'eon. Judging from this feature, the Wap'yeongni tectonic line must be one of the old tectonic lines. The undulation between the Magyori and Hwanjori faults is cut by a mesh of faults on various directions. As discussed already, the Hwanjori tectonic line and the Osipch'eon ditch were introduced by the Taebo disturbance. Thrust by the northern block, a basin was introduced in its front where the Silla series of Hwanjori was deposited. It rests mostly on the P'yeongan system. The series of Tomap'yeong is a filling in the ditch and the Hongjeom series is exposed on its east side. The deposition of the series was accompanied by the eruption of basalt and then of the liparite of Tomap'yeong.

While the quartz-porphyry mass of Poktoksan is cut by the Tonghwalli fault trending northwest, the granite-porphyry dyke of Cheongch'ari intrudes the Sang-deongni fault. This fault is, however, covered by the Seokpyeongsan porphyry and its distribution is somewhat different from that of the Silla series. Nevertheless it is presumed that the time interval between the two was not very long. Judging from the series of facts pointed out above, the block movement is related to igneous activity. They took place subsequent to the gentle folding of the Silla series. The depression in which the Silla series had deposited was, however, an outcome of the Taebo disturbance. Therefore the series of geological events from the Taebo disturbance to the Taebaegsan block movement must be inseparably related to the change of the terrain from the synorogenic compression to the postorogenic tension which in turn is causally related to the Pulgoksa igneous activity.

11. Geomorphological history of Central Korea

The summit level of Central Korea through Ch'ungju and Weonju represents the typical aspect of two-cycle mountains. As the result of a geomorphological analysis, I (1931) reached the conclusion that the two-cycle mountains were produced by asymmetrical geanticlinal upheaval after the previous peneplanation had not been completed. The upheavals repeated since then caused rejuvenation of erosion. I proposed the Yukpaiksan (Roppyakusan) plane for the older incomplete peneplane at the higher altitude and the Yeongtong and the Yeoju planes respectively for the narrow eastern and the wide western lower plane later introduced (see Pl. I). This conclusion was later vindicated by YOSHIKAWA (1947). The line between Weonju and Ch'ungju marks off the boundary between the western lowland and the mountainous regions on its east side. To the west of the line there is a hilly land up to 200 m above the sea on which there are monadnocks about 500 m high. To the east on the contrary the mountains are over 1,000 m and become higher toward the east. Taebaegsan is 1,549 m, Odaesan 1,563 m, and Kumgangsan 1,638 m above sea level; they are the highest summits in the Taebaegsan range along the coast of the Japan Sea. From this divide the mountains become lower gradually at first and then abruptly. Beyond this scarp there is a narrow lowland fringing the coast of the Japan Sea.

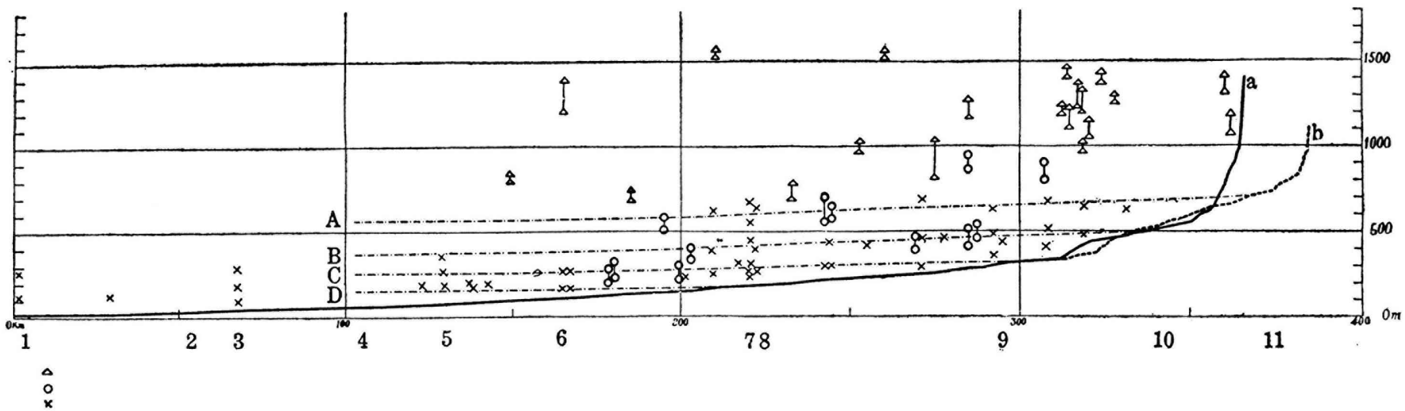
The terrain to the west of the Taebaegsan range belongs to the Hangang tributaries and the Yeoju plane extends over a wide area to the west of the topographic boundary through Weonju and Ch'ungju. The environs of Yeoju consist of granite, the land being even and flat. Hence the name *Yeoju* (*Rishu*) *plane*. The erosion scarp of the mountainous land is seen on the east side of the topographic boundary, but low planes extend into the interior of this mountainous land along the meandering Hangang River and its tributaries. The Yeoju group of planes is a collective term for several lower planes in and outside of the mountainous region. Those in the



1. Kaeseong (Kaijo)
2. Seoul
3. Suweon (Suigen)
4. Ch'eon'an (Tenan)
5. Ch'unch'eon (Shunsen)
6. Yeoju (Rishu)
7. Weonju (Genshu)
8. Ch'ungju (Chushu)
9. P'yeongch'ang (Heisho)
10. Chech'eon (Teisen)
11. Mun'gyeong (Bunkei)
12. Yeongch'un (Eishu)
13. Kangnŭng (Koryo)
14. Samch'eok (Sanchoku)
15. Ulchin (Uruchin)

A. Yellow sea
B. Sea of Japan

Fig. 19. Summit Level through Central Korea.



△ Upper erosion plane on the summit
○ Middle erosion plane on the slope
× The lower erosion plane

A. Taegwal-lyong (Taikwanrei) plane
B. Hachinbu (Kachinfu) plane
C. Chech'eon (Teisen) plane
D. Ch'ungju (Chushu) plane

a. Odaech'eon (River Godai)
d. Songch'eon (River Shosen)

1. Junction of the Hangang with the North Hangang (Kanko)
2. Yeoju (Rishu)
3. Junction of the Hangang with the Seomgang (Senko)
4. Ch'ungju (Chushu)
5. Junction of the Hangang with the Chech'eon (Teisen)
6. Tanyang (Tanyo)
7. Junction of the Hangang with the P'yeongch'ang (Heisho)
8. Yeongweol (Neietsu)
9. Jeongseon (Seizen)
10. Hachinburi (Kanchinfuri)
11. Hoenggyeri (Okeiri)

Fig. 20. Yeoju Group of Planes Along the Hangang River.

mountains are classified into the Ch'ungju, Chech'eon, Hachinbu and Taegwallyong planes by YOSHIKAWA (1947) in ascending order.

(1) The Ch'ungju (Chushu) plane is indicated by the river floor near Yeongweol, 180 m above the sea at the changing point of the river floor 10 km below Yeongweol, and 160 m near Ch'ungju.

(2) The Chech'eon (Teisen) plane is indicated by the river floor near Odaech'eon, Songch'eon and Yuda, and also by the river floor near Taehwamyeon. It is 320 m at the changing point near P'yeongch'ang and forms rock terraces with dolines on the top near Yeongweol and Yeongch'un but dissected piedmont slopes near Chech'eon, and is 260 m high near Ch'ungju.

(3) The Hachinbu (Kachinfu) plane is revealed by the river floor near Hachinbu and Ch'angdongni and the piedmont slope near Tunnaemyeon. Its height above the sea is 490 m at the changing point above Odaech'eon and 10 km below Hachinbu.

(4) The Taegwallyong (Taikwanrei) plane is shown by the river floor and piedmont slopes near Hoengsyeri. It is 700 m above the sea at the changing point of the river floor above Sangch'eon 5 km below Hoengsyeri and 570 m near Ch'ungju.

Among these four planes the higher ones are more extensive along the upper course of the river, while the lower ones are well developed along the lower course. All of them can be traced down till one reaches Ch'ungju whence the hilly land of the Yeoju plane extends to the west. This plane itself is the western extension of the Ch'ungju plane in the mountainous region, but for descriptive purposes the four planes together with the Yeoju plane are combined in the Yeoju group of planes so as to distinguish the lower planes from the higher Yukpaiksan plane.

The Yukpaiksan plane is, as represented by its summit level, always higher than 900 m and undulated with a range of variation in relief about 600 m at the maximum. Because a high and a low plane in the undulation are found to be separated by a relatively steep scarp at some places, the Yukpaiksan plane must be an aggregate of two or more planes in different altitudes. But they are difficult to analyze because, unlike the Yeoju group of planes, they are relics of the old peneplanation which remain as patches of undulation.

The Yukpaiksan plane is as a rule detached from the rivers and valleys of today by a steep slope below the height of 900 m or so above sea-level. The contrast between the higher and lower planes is generally more significant in the western part of the mountainous land where the topography is in a mature stage. It becomes less significant toward the backbone range which is in a younger stage of the erosion cycle. Nevertheless the geologic structure of the mountains is highly complicated, and due to differential erosion the grade of dissection varies greatly. Accordingly a great variation in the topographic relief is introduced. It is rather seldom that the river flows for any long distance along any tectonic line. The main course of the Hangang River which meanders among the mountains must be antecedent.

In marked contrast to this hydrographic habit the Osipch'eon which flows into the Sea of Japan is a fault line valley. It runs along faults which form a shattered zone, taking a meandering course down to the vicinity of Samch'eok where it turns to the east abruptly and flows into the sea. Because the divide is located much closer to the Japan Sea than to the coast of the Yellow Sea rapid erosion took place on the east side. Near Hwangjiri where the Naktonggang is captured by the Osip-ch'eon, an excellent wind gap is seen. Because the erosion was rapid along the Osipch'eon its lateral erosion destroyed the older low planes to a larger extent. In consequence it is difficult to classify the low planes of Yeongtong as was done for the Yeoju group of planes. But it is noted that there are also several rock terraces near Hwangjiri along the Osipch'eon which are remnants of older erosion planes. Near Samch'eok and Kangnŭng there are hills of about 100 m in height, and coastal terraces of similar height are seen near Kangnŭng, Hugho and Samch'eok.

The summits of Yukpaeksan, Sakŭmsan and their environs to the east of the upper Osipch'eon are particularly flat and about 1,000 to 1,250 m above the sea. Because this flat plane is not dislocated by faults in the Taebaegsan dislocation zone, it is evident that the Yukpaeksan plane was a product of peneplanation after the block movement. Because the Yukpaeksan plane was elevated before the completion of the peneplanation, it is represented by an undulated plane the relief of which ranges up to 600 m at the maximum.

As mentioned already, the block movement subsequent to the Silla deposition was accompanied by the late Mesozoic Pulgoksa igneous activity. The fault mesh in this region was thus introduced. The fault system is not much related to the present relief of topography because, leveling the faulted relief, the Yukpaeksan plane was originally brought about by erosion during the tranquil Palaeogene period.

The Samch'eok Neogene formation consists of deltaic facies in the southwestern part and of lacustrine facies in the northeastern part. This deltaic sediment is mostly composed of the detritus of the Cretaceous Tomap'yeong liparite and covers the linear scarp on its west side. It is difficult to say whether it is a fault line scarp produced by differential erosion after the Yukpaeksan peneplanation or a fault scarp produced by a renewed dislocation along the pre-Yukpaeksan fault.

The upper Miocene of Samch'eok is only gently undulated, not suffering from any faulting. It is one of the oldest among the basin fillings or blankets on the Yeoju and Yeongtong groups of planes.

As discussed later a strong faulting occurred in other places in Korea in the middle Tertiary period. The linear scarp bounding this Neogene might be a scarp of the faulting, although there is no supporting evidence. Because there is no other Tertiary in the area, it is difficult to distinguish the middle Tertiary dislocation from the older one. Nevertheless it is evident that there is no considerable disloca-tion of the Yukpaeksan plane.

In summarizing these facts it can be concluded that the Yukpaeksan plane was originally the product of the Palaeogene erosion, but its peneplanation is still going on very slowly in the part not reached by the rejuvenation of the Neogene erosion. Nevertheless there is still a difference of 600 m between the top and bottom of its relief. It is therefore an unfinished or incomplete peneplane. Since the Middle Tertiary the subdued Palaeogene land was elevated in the form of an asymmetrical geanticline with its axis close to the coast of the Japan Sea. The gradual and minor upheavals were repeated intermittently. As a result the present group of lower planes was introduced on each side of the divide. The marginal plane of Yeoju is very wide, while that of Yeongtong is incomparably narrower because the geanticline is quite asymmetrical. The east side of the divide, which faced more powerful forces of erosion than the other side, is rugged.

12. Destruction of the Tsushima basin

Although it is not the present object here to discuss the geology of Japan, the description must be extended to Kyushu and its vicinity, because the tectonic development of South Korea is intimately related to that of West Japan. In northern Kyushu and western Chugoku there are the principal zone of the Sangun metamorphic group on the north side and its auxiliary zone of Motoyama on the south side (KOBAYASHI, 1950). On each side of the latter there is a non-metamorphosed zone of the Yamaguchi group. All of them belong to the Akiyoshi orogenic zone.

Metamorphic rocks of the Sonoki peninsula in western Kyushu have previously been referred to the Nagatoro metamorphic group of the Sakawa orogenic zone because they were thought similar to the Mikabu metamorphics in the Nagatoro zone (KOBAYASHI, 1941). Therefore I was led to the assumption that this zone should reveal a sharp bending of the Nagatoro zone to the NNW. But now I consider it more reasonable that the Motoyama zone is abruptly bent to the SSE in the peninsula, because the metamorphics of the peninsula are no less similar to the Sangun metamorphics than to the Mikabu metamorphics. Furthermore it is a general tendency of the Sakawa folded mountains to be bent to the south in western Kyushu.

The so-called Itoshima granite west of Fukuoka intrudes into the Sangun metamorphic group concordantly. Therefore the granite behind the Sangun zone must be a member of the Hida gneiss group in the pliomagmatic zone of the Akiyoshi orogenic zone. Accordingly it is certain that the axis of the Akiyoshi folded mountains passes through Fukuoka and is presumably bent to the south as in the Motoyama zone.

The major tectonic lineament of the Akiyoshi zone above mentioned remained after the Oga deformation. The Kyeongsang group comprising the Wakino and Inkstone series on the mountains is folded with the main axis of folding running ENE and forming the Kwanmon syncline and the Nagato anticline. The group in northeastern Kyushu forms the southern wing of the syncline. To the northeast of this syncline there is the Nagato anticline; and the Toyonishi, Toyora, Mine and

Atsu series and the Yamaguchi group are widely exposed in its saddle, in addition to a strip of the Sangun metamorphics of Toyogatake between the Toyora and Mine series. These four Mesozoic series indicate the great strength of the Oga deformation. The Inkstone and even the Yawata series on it are folded, though not very strongly. On the Korean side of the Tsushima basin, the Kyeongsang group is tilted but scarcely folded, although it is thrust onto from the north side on the northern border of the basin. Such a significant difference in the mode of the post-Inkstone deformation tells the difference in the basement of the Kyeongsang group which was rigid on the Korean side but still somewhat flexible on the Japanese side.

Subsequent to the post-Inkstone folding the intrusion of the Chugoku granite took place. In West Japan it is exposed with the same elongation to the axis of the post-Inkstone folding, but such parallelism between the granite and the Kyeongsang group is insignificant on the Korean side of the Tsushima basin. The vast terrain of Eastern Asia was culminating because of the Chugoku batholithic invasion. In the course of the culmination there took place block movements. The fault mesh in the Taebaegsan dislocation zone is an example. It is certain that the Tsushima basin was deformed by this block movement.

The modification of the Tsushima basin can be recognized from the Palaeogene palaeogeography. The Palaeogene of northern and western Kyushu first schematized by NAGAO (1928) was later revised by H. MATSUSHITA (1950). The coal-bearing formation of Ube in southern Yamaguchi was previously thought to be Miocene (TOKUNAGA and IIZUKA, 1930), but late Eocene mammalian remains and other fossils were recently discovered in it (YABE, 1944 and TAKAI, 1944). Furthermore the Oligocene Ashiya series was found in northwestern Nagato (IMAMURA, 1951). Therefore it is certain that the sea ingressed from the Palaeo-Shiranuhi sea and the flat land was flooded very extensively in the Ashiya inundation phase. The red or purple regolith at the base of the Palaeogene is a product of lateritization. It is probable that the paralic Palaeogene in the Tsushima Islands indicates the northern coast of the Ashiya embayment. Subsequent to the inundation the Palaeogene depression was somewhat modified and shifted toward northwest Kyushu.

In the southeastern corner of the Korean peninsula there is the Changgii series which overlies the erosion surface of the Pulgoksa and other Cretaceous rocks. It yields the Changgii flora of Oligo-Miocene aspect, but no marine fossil has so far been discovered in it. It is overlain disconformably by the P'ongongni series which consists in the main of andesitic flows and tuffs.

The mode of deformation which the Palaeogene suffered is quite different from that of the Inkstone. The Palaeogene is principally deformed by faults with NNW or NW trend in addition to those with NNE or NS trend. It is remarkable that the displacement along these tectonic lines appears greater in the basement than in the Palaeogene, because it suggests that the displacement had already taken place before the deposition of the Palaeogene. It is also a remarkable fact that the western block is displaced to the south along some of these tectonic lines.

On the Korean side of the Tsushima basin the distribution of the Tertiary formation is restricted to the Ulsan zone to the east of the Yeonghae-Pusan line. The Palaeogene there is cut by step faults with NNE trend which are parallel to the above-mentioned line. This fault system is called Hansan by KOTO and the eroded plane of the faulted terrain is overlain by the upper Miocene called Yeonil series which is distributed along the coast of the Yongil bay toward the north as far as Yeonghae. Its basal plane is uneven and it begins with boulder conglomerate. Therefore it must be a sediment deposited immediately after the middle Miocene block movement. The upper Miocene is slightly slanted toward the bay.

The coastal line of this bay and that from the Changgii cape to Ulsan, as well as the outline of the Tsushima Islands and the submarine trenches on both sides of the islands, are all subparallel to the Hansan system.

The above-mentioned series of facts shows how crucially important the Hansan fault system was in the formation of the Tsushima strait. But palaeogeography suggests that the depression of the same trend existed already in the Palaeogene period. In Yamaguchi and northern Kyushu, however, the NW or NNW faults are more prevalent than the NNE ones. Along some of them the eastern block is elevated above the western, while the western block is shifted to the south along some others. This shifting, together with the sharp bending of the Akiyoshi folded mountains, and also of the Sakawa folded mountains at their western ends, must be due to the pull of that part toward the south by the advance of the Ryukyu arc. On the Korean side behind such shifting the block movement took place by tension. The Tsushima strait is thus the sunken part of the Tsushima basin and a horst at the middle is represented by the Tsushima islands. *Thyasira bisecta* and other fossils dredged from the sea bottom around the islands (NIINO, 1934) provide the proof of the extensive distribution of the Miocene formation in the strait.

III
THE GEOLOGICAL HISTORY OF SOUTH KOREA FROM A COMPARATIVE TECTONIC STANDPOINT

1. Cycle of oronization

One of the most important findings of historical geology has been that parts of the crust were capable of folding while others were incapable of it. The latter is called a *geosyncline* and the former a *Kraton.* On the earth there are rigid masses of various dimensions. The largest of the circum-arctic Kratons is Laurentia which is widely covered by blankets on the south and west sides. The northeastern part of this Kraton which is bare is called the Canadian *shield.* Laurentia is one of the megakratons, while the Aar and Gotthard *massifs* in the Alps are microkratons.

The term *block* appears to be used frequently for the still smaller unit, as in block movement.

The geosyncline is a narrow sinking zone where thick sediments are accumulated. Orogeny is a phenomenon which deforms a geosynclinal material. The result is an orogenic zone of arcuate mountains. How geosynclines have been formed is not yet well understood, but it is known that the presence or absence of strong intrageosynclinal volcanism provides differential characteristics by which the geosynclines are distinguished into ortho- and para-geosynclines respectively. Orthogeosynclines tend to become orogenic zones, as revealed by anticlinoria with metamorphosed axes. The Alps, the Caledonian mountains and the Japanese Islands are such examples. The parageosynclines on the other hand are apt to become polyaxial foldings with or without metamorphosed parts as exemplified by the Okch'eon and P'yeongan zones. An orogenic cycle is a series of crustal movements through which a geosyncline turns into an orogenic zone.

Japan provides a typical example of the migration of a geosyncline through orogenic cycles. More precisely, when the inner side of the primary Chichibu geosyncline was made into an orogenic zone by the Akiyoshi cycle, its outer side developed into the Shimanto geosycline. Later the inner side of the secondary geosyncline became another orogenic zone in the Sakawa cycle and its outer side turned into the Nakamura geosyncline. The inner side of the third geosyncline has already been folded, but the third mountains may probably be still in the making. These three cycles of orogeny have been analyzed into many phases, a phase denoting a stage of development.

In my "Sakawa cycle" (1941) I classified the phases of the cycle into pre-orogenic epirogeny, orogeny and post-orogenic epirogeny, but neither the pre-orogenic nor the post-orogenic epirogeny agrees with the typical epirogeny that occurs on a Kraton. Because pre- and post-orogenic epirogenies are thus unsuitable terms, I now prefer to call them *prorogeny* and *metaorogeny* respectively. Prorogeny is a geosynclinal subsidence as indicated by the Flysch type of intrageosynclinal sediments of tremendous thickness which are monotonous and fine-grained. Metaorogeny is the crustal movement after an orogenic paroxysm. An orogenic zone is still labile in the interval from the mobile paroxysm to the stable post-orogenic period. The Molasse type of sediment accumulated in intraorogenic basins or peri-orogenic zones is thick, coarse and ill-sorted, because much material was transported from high mountains in a short time; and facies and thickness vary greatly because orogenic zones are mobile or labile.

A cycle of sedimentation is generally classified into transgressive and regressive and sometimes in addition, inundation phases. But this is an epirogenic cycle of sedimentation. An orogenic sedimentation also goes through cycles when a migration of geosyncline takes place. The latter cycle consists of the *Flysch* and *Molasse* in the broad sense of the terms. The Molasse in an orogenic zone merges laterally with the Flysch in the new geosyncline.

When such a migration takes place, the crustal movement occurring in the already existing orogenic zone, simultaneously with the prorogeny of the new geosyncline, is quite different from epirogeny or any of the three kinds of orogenic cycle. The movement is called here *interorogeny*. As the orogenic zone is the hinterland of the new geosyncline, it is not stable. Basins in the hinterland may be separated from the geosyncline by an embryonic anticline growing in the inner side of the geosyncline. Accordingly, if sea floods into the basins, it is not a simple and extensive transgression but an ingression through the embryonic anticline along any channel. The Triassic history of the Variscan mountains is an example of interorogeny, but it is not quite typical because it was too far from the Alpine paroxysm. Jurassic Japan is a typical example, although its precise description will be deferred to another occasion.

Intrageosynclinal volcanism, the spilitic suite in the Alpine or Caledonian geosyncline for example, is the igneous activity in a prorogeny which, however, varies in intensity among different geosynclines. Ortho- and para-geosynclines are distinguished by prorogenic magmatism. Before orogeny there takes place frequently some embryonic folding through which the geosyncline differentiates and becomes undulations.

In an orthogeosyncline an embryonic anticline develops into an anticlinorium. As pointed out in my "*Sakawa cycle*," it is quite probable that the Nagatoro metamorphism was going on in the inferior part of an embryonic anticline under a heavy load of its thick superior part. The embryonic anticline was gentle but large. It was later folded and thrust into an anticlinorium. Therefore the kinetic deformation of the superior part followed the static alteration of the inferior part of the crust. Such a crustal disturbance is accompanied by igneous activity which may be broadly classified into basic intrusion, acidic injection and batholithic invasion in the inferior part and andesitic and liparitic volcanisms in the superior part. An orogenic cycle is closed with the batholithic invasion of granite which is, however, mostly not granite, though it is generally so called. It is better to use the term grano-diorite or quartz-monzonite, because it is derived from mixed magma in the orogenic period. The Sakawa cycle of Japan presents a typical example of these sequences which are not essentially different from those of the so-called Caledonian or Alpine cycle in Europe. The history of South Korea, however, is quite different from any of the histories of these orthogeosynclines, because it consists of a parageosyncline and two massifs on its two sides.

Generally speaking, orogeny and epirogeny, Kraton and geosyncline, or ortho- and para-geosyncline, are pairs of concepts in *real opposition* to each other and therefore there is every gradation of change between the paired concepts. STILLE's labile quasikraton is an intermedium between the mobile geosyncline and stable Kraton. The parageosyncline is another intermedium which is between a quasikraton and an orthogeosyncline.

Tectonic elements vary greatly in dimension. The microparageosyncline and the two microkratons which constituted South Korea reveal a part of the Chinese Heterogen. Therefore the development of the Heterogen is the history of South

Korea. Because the Heterogen was embraced by megageosynclines from its east side, it is characteristic of the South Korean tectogeny that its development is intimately related to that of the neighbouring geosyncline.

The Hwangho and Yangtze provinces which occupied the northern and southern parts of the Heterogen are quite different in their Palaeozoic history. The Hwangho province gradually became undulated after the Taoke igneous activity with the result that it was divided into elevating lands and subsiding depressions. These latter are collectively called the Hwangho basin. If local ingressions in the Silurian and possibly the Devonian period are ignored, the Hwangho province including Korea, South Manchuria and North China was land during the prolonged middle Palaeozoic era, but nevertheless the Korean and P'yeongan systems are para-unconformable except in the northern periphery of the basin affected by the disturbances of the Mongolian geosyncline. Therefore it is certain that the northern Heterogen elevated or subsided *en bloc*, but differential movements among various parts of the province took place in the latter part of the P'yeongan period.

The Songnim and Taebo disturbances, which correspond respectively to the Akiyoshi and Oga orogenies in Japan, have greatly disturbed the Hwangho basin. Where Jurassic history is recorded, it can be recognized that there were some disturbances. There is, however, a remarkable difference between the basin and Japan. In the former there was almost continuous volcanic activity throughout the Mesozoic since the late Triassic while in Japan the Triassic and Jurassic formations are almost free from pyroclastic material. In Korea the Songnim disturbance deformed the P'yeongan geosyncline strongly, but the Okch'eon was not much folded. The Songnim disturbance was not accompanied by any plutonism, while the whole Heterogen was granitized by the batholithic invasion after the Taebo disturbance. Therefore the crustal revolution from late Jurassic to Cretaceous was much greater than that before the Taebo disturbance corresponding to the Oga in Japan. The Nevadian disturbance in North America was almost contemporaneous with the paroxysmal phase of the Chinese Heterogen.

It is certain that no migration of geosyncline took place in South Korea. Through the Songnim disturbance the Okch'eon geosyncline was differentiated into some embryonic folds, and a basin brought about far behind in the Kyeonggi land. No hinter basin was brought into being by the Taebo disturbance, but a spatulate basin came out on each side of the metamorphosed Okch'eon zone where it was larger on the frontal side than on the rear side. The Tsushima basin beyond the Yeongnam land can best be taken as a hinter basin of the Oga mountains rather than as a frontal basin of the Okch'eon orogenic zone.

After the Taebo disturbance the batholithic granite invaded into the massives as well as into the orogenic zones with the result that they were completely fused. The post-Taebo granitization took place not only in the Hwangho but also in the Yangtze province. As a result the whole Heterogen became a rigid mass. The later tectonic development was its fragmentation discordantly to the previous tectonic lineament, because the basement of the Heterogen was made almost homogenous by the granitization.

In my *"Sakawa Cycle"* I proposed *"oronization"* as a term for the consolidation of the crust. The degree of oronization becomes greater by folding and regional metamorphism, but the effect of granitization is the greatest. The Chinese Heterogen which had been a complicated heterogeneous aggregate became a large homogeneous rigid mass by granitization, but then it began soon to break into pieces. Such a crustal fragmentation is called *anoronization*. The Liao tectonic line, the Weonsan-Seoul rift valley and the Korean arc are all products of the post-Taebo anoronization. Anoronization follows oronization and the cycle formed by the two is a geological phenomenon of a higher order than the cycle of orogeny.

2. Differentiation of geosyncline

Although the concept of the geosyncline was introduced by HALL and DANA from their observations in the Appalachian mountains, the progenitor of the mountains to the southwest of New York was, like the Okch'eon, a parageosyncline. The intrageosynclinal volcanism, which took place in the Ordovician period, was very weak. The Taconic and Acadian disturbances in the northern part of the geosyncline caused some deformation in its middle part. The Queenstone and Catskill deltas were both produced by a plentiful supply of terrigenous material from the rising mountains. Likewise the change in the subsiding axis after the Sadong epoch and the appearance of the Bansong lake must have had something to do with the Akiyoshi cycle of the Chichibu geosyncline which was presumably located north of the present site of Japan.

As the result of the Appalachian revolution there was produced a series of parallel or subparallel folds and thrusts, their aspect being similar to that of the western Kangweondo limestone plateau where the imbricated structure was introduced from an embryonic anticline on the inner side and an embryonic syncline on the outer side. The synclinal zone is indicated by the Bansong series. Likewise the upper and lower Palaeozoic formations are extensive respectively on the outer and inner sides in the central and southern Appalachian mountains.[1] The mountains correspond to Central Korea also in their geomorphological history in that the present mountains were introduced by upheaval after the folded mountains had become a peneplane.

Compared to the Appalachians, the Okch'eon geosyncline which was first denominated by YAMANARI (1926) is much smaller, but it is quite probable that it extended to the west through the Yellow Sea, although it remains to be seen where the Okch'eon orogenic zone recurs in Central China. On this question I would like

1) It is now well ascertained that the Appalachian mountains to the west of the Blue Ridge thrust which used to be considered the main part of the Appalachian orogenic zone are no more than its frontal non-metamorphosed part, and the piedmont plateau on the Atlantic side of the mountains belongs to the metamorphosed zone of the Orogen.

to point out the fact that the deformation of the Weiyang phase is strong in the Nanking hills in the lower Yangtze (LEE, 1939).

In South Korea the zone is divided into metamorphosed and non-metamorphosed parts by the Ch'ungju-Mun'gyeong line. Although the northern part of the boundary has not been closely investigated, the southern part is indicated by a thrust line, along which the metamorphosed Okch'eon thrusts itself upon the non-metamorphosed Okch'eon, similar to that seen at Rhaeticum where the Eastern Alps rest on the Western Alps. Such a long tangential displacement as seen in the Alps, however, cannot be recognized in the Okch'eon zone where the known thrusts are mostly high-angled. Therefore it cannot be expected that the non-metamorphosed Okch'eon lies concealed beneath the metamorphosed Okch'eon extensively. The Ch'ungju-Mun'gyeong line is quite different from LOGAN's line along which the northern Appalachians have thrust themselves on the Laurentian front.

It is a kind of intraorogenic tectonic boundary which lies between parts different in their metamorphism. On this account it corresponds to the Mikabu line in the Sakawa orogenic zone, but there is an essential difference in that the Mikabu line is parallel but this line is oblique to the orogenic zone. On the basis of my observation in the Mun'gyeong district, I contended that the boundary thrust was introduced by the thrusting of the metamorphosed part *en bloc* on the non-metamorphosed part, after imbrication within the parts, just as the Weongweol anticlinorium thrusts itself *en bloc* on the Chodongni basin along the Sangni thrust. The tectonic bearing of this thrust, however, must be more profound than that of the Sangni thrust.

Because stratigraphic sequence is not yet established in the metamorphosed part, we are far from knowing its structure. In the non-metamorposed part on the other hand stratigraphy is quite advanced. There the Korean system, 2,000 m in thickness, is overlain by the Hongjeom, Sadong and Gobangsan series, all together over 1,000 m in thickness with para-unconformity in between, which indicates middle Palaeozoic hiatus. Because it is certain that the geosyncline was scarcely deformed by the middle Palaeozoic epirogeny, it is readily presumed that these formations of over 3,000 meters thickness were accumulated almost throughout the geosyncline. The Greenstone series on the Gobangsan attains at the thickness far in excess of 2,500 m at its maximum. In other words the basement attained a maximum subsidence of over 6,000 m, but the Greenstone may not be deposited all over the geosyncline.

Because the base of the Korean system is unexposed in the geosynclinal part of the Kangweondo limestone plateau, nothing definite can be told of the origin of the geosyncline. But the Pre-Cambrian basement is exposed on its lateral sides. On the southeast side where more exact observations can be made, the Jangsan quartzite lies on the flat basement. It is certain that the Yeongnam massive was a flat land at the time. The quartzite is a deltaic sediment containing well-rounded slates and others.

As the stratigraphy of the Korean system will be described in detail, only a few facts of tectonic importance are noted here. The thickness of the great limestone formation is fairly constant, but the thickness varies from 40 to 300 m in the Jangsan quartzite and from 80 to 250 m in the Myobong slate. Accordingly the total thickness of the Korean system varies to some extent. But it is thinner in the eastern than in the western plateau, being about 1,300 m thick on an average. This part of the system may be sediment from the shallow shelf sea, because terrigenous beds wedge in and intraformational limestone conglomerates are developed in the system.

In the western plateau, and in the axial part of the geosyncline in particular, carbonaceous muddy limestone and slate are developed in the late Middle and early Upper Cambrian. The black slates appear similar to pure graptolite shales in their lithic aspect. This kind of black mud facies may indicate an off-shore sediment in the Sargasso Sea, as emphasized by RUEDEMANN in his discussion published in 1934 of the origin of the pure graptolite shales. The *Olenoides* zone of Yeongweol belongs to this part whence later *Olenus* and several other trilobites were discovered in different horizons—trilobites known from remote places but quite new to Eastern Asia. ULRICH and SCHUCHERT in 1902 claimed the appearance of an axial elevation in the Appalachian geosyncline in the Ordovician period, but in the Okch'eon geosyncline there is no evidence which suggests such a swelling ridge; the axial part subsided most, at least till the Sadong epoch.

It is certainly a remarkable fact that the Hwangho basin was neither deformed nor eroded during the land period from late Ordovician to early Carboniferous. At that time the Hwangho basin must have been simply kratonic. Subsequently the Moscovian and Sakmarian subsidences invited marine transgressions.

After the retreat of the Sakmarian sea, the warm humid land surrounding the basin became covered by thick vegetation and the main coal measures were deposited in the basin. Later the climate became more arid in the Gobangsan epoch when the *Gigantopteris* flora flourished. Still later in the Greenstone epoch it became so arid that no vegetation could flourish inland. As discussed elsewhere (KOBAYASHI, 1950), the increasing aridity depends on the appearance of the Mongolian orogenic zone and the upheaval of the embryonic Akiyoshi anticline by which the Chinese Heterogen was embraced.

The sequence of Japan shows that the Chichibu geosyncline was modified by the prorogenic warpings in the Usuginu phase between the Permian and Triassic and the Misaki phase between the Skytic and Anisic epochs. The geosynclinal subsidence was great after the Usuginu phase and still greater after the Misaki phase. From the great geosynclinal subsidence indicated by the thickness of the strata, the reciprocal upheaval of the embryonic anticline can be presumed to have been great, if the source of the terrigenous material is surmised.

The change of the subsiding axis after the Sadong epoch must have been sympathetic with the Usuginu movement. The great subsidence of the Pongdugonni basin in the Greenstone epoch is comparable with the Aniso-Skytic subsidence in the Chichibu geosyncline.

It is probable that the Chungbongsan dome and the Yeongweol anticline were reciprocally elevated at the same time as the subsidence. These undulations were unquestionably very gentle, but the geosynclines were gradually differentiating into positive and negative elements which were to become embryonic anticlines and synclines in the Songnim phase.

3. Embryonic folding and imbrication

A geosynclinal material deforms strongly in a relatively short time, but deformation is not restricted to the time of disturbance but goes on slowly before and after it. The Okch'eon geosyncline differentiated into undulations in the Usuginu phase and the differential movement was greatly accelerated in the Greenstone epoch as indicated by the tremendous thickness of the Greenstone series. The undulations thus emphasized developed into embryonic folding by the Songnim disturbance. The contemporaneous deformation was much stronger in the Chichibu and P'yeongan geosynclines but sharp folds were quite local in the Okch'eon geosynclines. These gentle folds were, however, the progenitors which developed into the complicated imbrication in the Taebo phase.

When the same formation occurs repeatedly in belts by folding or thrusting, the crustal movement recorded in it can be figured out spatio-temporally by its lattice analysis. In the southern part of central Shikoku the early Cretaceous crustal movements and the palaeogeographic changes caused by them were deciphered by this method and the result reported in detail (Kobayashi, Kimura and Huzita, 1945). Prior to this study a lattice analysis was attempted on the Bansong series and in accordance with its revelations the Songnim disturbance should be distinguished into three phases as follows:

1) Early Songnim phase in which the incipient undulation became embryonic up and down warpings.
2) Middle Songnim phase in which the broad warpings were somewhat reciprocal to the preceding and the Bansong lake was introduced in the depression.
3) Late Songnim phase in which the whole Okch'eon zone was heaved up and the lake disappeared.

The Paek'unsan syncline virgated to the east from the syncline on the outer side of the Okch'eon zone and the lake expanded in the Jeongseon-Uiimgil-Weongweol triangle. The deltas of the lake and the surrounding mountains can be restored in detail by lattice analysis. Furthermore the movements in the zone can be correlated with those in the hinter basin of Namp'o with some accuracy.

Most of Korea was land during the Jurassic period, and therefore there is no direct evidence which can specify the age of the Taebo disturbance, but it is presumed to be in the late Jurassic or Jurasso-Cretaceous transition, because Eastern Asia as a whole was more tranquil in the Jurassic than in the period before and after.

The imbrication of the Okch'eon zone was brought about by this disturbance. Although there is no synorogenic sediment, the tectonic development can be analyzed into the following subphases by the relation between the active and the passive, or more precisely by the relation between two faults, one cut by the other. The former must be older than the latter.

1) Early Taebo subphase in which the embryonic folds developed into the Pongdugonni synclinorium, the Yeongweol anticlinorium and other major tectonic elements.
2) Middle Taebo subphase in which the Yeongweol anticlinorium thrust itself *en bloc* upon the Pongdugonni synclinorium.
3) Late Taebo subphase in which the northwestern side thrust itself on the other side with the result that the structure of the Jeongseon zone was completed.

As to the Yeongweol anticlinorium the three steps of development can be distinguished in its early subphase as follows:

a) The differential folding between its eastern and centrowestern parts.
b) The development of a series of folds in the centrowestern part into a series of thrusting sheets.
c) The thrusting of the centrowestern part *en bloc* on the eastern part along the Machari thrust.

The thrusting of the metamorphosed part on the non-metamorphosed part along the Ch'ungju-Mun'gyeong line may have taken place after the completion of imbrication in the latter part. It is certainly noteworthy that thrusting *en bloc* or *Schollenüberschiebung* took place after the folding and thrusting within the block had been well advanced.

There are several tectonic lines running parallel to the Jeongseon zone which attains a maximum length of 100 km or more. Its aspect is similar to that seen in the central and southern Appalachians. It is a general tendency in the western plateau that the rocks are more metamorphosed on the northwest side than on the other. The structure of the P'yeongch'ang zone is unknown because it is barren of fossil. Because most of the thrusts dip 45 to 60 degrees to the west and many of the thrusting sheets are 5 to 10 km in breadth in the Yeongweol anticlinorium, the anticlines and synclines in the anticlinorium before the thrusting are presumed to have been regularly isoclinal and similar in magnitude. The deformation of the synclinorium on its southeast side does not differ much from it.

The imbrication of the Okch'eon zone is different from the Scottish one which consists of a few principal thrusts and many auxiliary ones. The outer zone of West Japan is more or less similar to but different from the Okch'eon zone in the more arcuate course of the thrust lines.

As noted already in my "*Sakawa cycle*," it is more similar to that of the Appalachians in its long parallelism, but still different in that the thrusting becomes weaker toward the Allegheny-Cumberland border in the latter. This was probably because the foreland was the low mid-continent, but on the contrary there was the high Yeongnam land in front of the Okch'eon zone.

It is especially noteworthy in this zone that (1) the Korean system is mostly composed of limestone, but (2) the P'yeongan system of terrigenous sediment and (3) conglomerate is extensive in the basal part of the Bansong series. Furthermore (4) the Paek'unsan syncline virgates from the Okch'eon zone in a direction diagonal to the folding of the zone. These phenomena provide excellent examples of differential deformation caused by the same disturbance. They give clear views of (1) the isoclinal folding of the P'yeongan system in the syncline, which develops into the thrustings of the Korean system in the north, (2) the basal conglomerate of the Bansong series which resisted the waves of folding, (3) the remarkable intraformational folding within the limestone of the Korean system and (4) the same kind of folding of the shale between the sandstones in the P'yeongan or Bansong formation. (5) The difference in resistances resulted in basal sliding between the competent and incompetent rocks.

Through these observations it is found that competency decreases generally in the order of conglomerate, sandstone, shale and limestone, or in other words, in the order of grain size because *the finer the grain, the easier it is to change their relative positions by compression.* In the Yeongweol and Samch'eok coal fields the coal measures greatly vary in thickness. Where the coal-bearing Sadong series is strongly disturbed, there are swellings forming pockets of powder coal at some places.

In this region chert is rare but in Japan it is seen that chert is folded or even fluted intraformationally more easily than limestone. In a study on Radiolarian rocks (Kobayashi and Kimura, 1944) it was noted that when chert is folded, (1) radiolarians lose their spines by rotation, (2) spines are aligned parallel to the direction of shifting of particles because that is the line of least resistance, (3) spines dissolve easily because their surface area is great relative to volume and (4) radiolarians lose their structure and are elongated by compression till they become simple ellipsoids of silica. In Kangweondo trilobites and other fossils are sometimes deformed in two dimensions and sometimes in three dimensions. At some clear-cut exposures of the Chikunsan shale, trilobites twisted in three dimensions were found, but the Chikunsan shale formation itself is apparently monoclinal. Therefore the twisting must be due to intraformational deformation.

4. Granitization and fragmentation

The primary fragmentation of the Pre-Cambrian Kraton, and the secondary one after massives and orogenic zones were fused by granitization, can both be seen in South Korea. The fragmentation of the Yeongnam massive is an example of the former and that of Korea after the Taebo disturbance is an example of the latter.

While the Korean system and the Hongjeom and Sadong series are not much different in facies and thickness between the Paek'unsan syncline and the Chungbongsan block, it is known that the subsiding axis changed somewhat after the Sadong epoch, probably influenced by the Akiyoshi prorogeny, and that the subsiding zone was transformed into the embryonic Paek'unsan syncline inclusive of the Ungbongsan basin by the Songnim disturbance.

The Okch'eon geosyncline was compressed from northwest to southeast by the Taebo disturbance. Because the embryonic syncline of Paek'unsan ran from west to east, the compression introduced diagonal folds in the western wing of the syncline. Seeing that the Maehwadong, Surich'i and a few other long tectonic lines are subparallel to the diagonal fold, it is certain that the Chungbongsan block was broken into pieces.

It is a remarkable fact that the terrain to the north of the Paek'unsan syncline is imbricated by thrusts parallel to the above mentioned diagonal folds. The Maehwadong tectonic line is especially important because the folding and thrusting are mostly restricted to the west of this line; the syncline is not much disturbed and the Korean system on the Chungbongsan block warps gently.

Between the block and the syncline, however, there took place a remarkable differential movement to form the Chodongni upthrust of the former upon the latter. The vicinity of Uiimgil, where the Maehwadong tectonic line crosses this tectonic line, reveals a very complicated structure. The waves of folding dashed against the Chungbongsan block and the frontal anticline and syncline in front of it became ripples. Ripples or minor folds thus produced became thrusts. The Maehwadong thrust is therefore a boundary thrust running through this *Schuppenstruktur* between the anticlinal and the synclinal elements.

The Paek'unsan syncline is arcuate with convexity on the north side because it was introduced incipiently by the differential movement between the negative Chungbongsan and the positive Taepaiksan block probably in the Songnim phase. In the Taebo phase the syncline was compressed from the north till it became an asymmetrical syncline with axis on its north side and the Chungbongsan block thrust itself upon the syncline at a high angle. How the low-angled thrusting within the P'yeongan system of the Paek'unsan syncline to the north of Cheongansa and those within the Korean system of the Chungbongsan block near Chomoksan were introduced, is not thoroughly understood. They may be due to the differential movement within these formations which might not have caused any great dislocation on the Pre-Cambrian basement. The P'yeongan system is more widely disturbed on the east than on the west side of the Hambaeksan fault. The peripheral anticline of the Ungbongsan basin and the Paek'unsan syncline are both inclined to the north at their junction where the upper Korean system and the lower P'yeongan system of the anticline are wrinkled into minor folds each of which has developed into a small thrusting sheet. The strongly arcuate thrusts are no more than 3 km in breadth. They alternate one with another to form a *Schuppenstruktur*.

Similar structure is found not only along this boundary but also on the two sides of the Osipch'eon river which, cutting the Chungbongsan block, flows NNE.

1) The Ungbongsan basin was primarily the northern expansion of the Paek'unsan syncline.
2) A narrow ditch, however, was formed along the Osipch'eon river.
3) The foldings on the upper Korean and lower P'yeongan formations wrinkled into minor folds toward the ditch.
4) The folds developed at length into arcuate thrusting sheets.

The terms, *Schuppenstruktur* and imbrication, have long been thought to be synonymous and very obscurely defined. In the Kangweonsan limestone plateau there are two distinct types of thrusting structures as follows:

1) The structure is composed of a series of long parallel or subparallel thrust-sheets for which it is better to use the term *imbrication*. It is found in the deformation of the geosynclinal part.

2) The structure is composed of a number of small arcuate thrusting sheets which are aligned more or less alternately. Because its aspect is quite similar to that of fish-scales, it is appropriate to apply the term *Schuppenstruktur* to this type of structure. It is found on the block at its corners.

The Paek'unsan syncline is limited by the Hwanjiri fault on its north side. The Chungbongsan block beyond it is bisected by the Magyori fault. A narrow belt between this fault and the Cheonni fault through which the Osipch'eon meanders is the Osipch'eon shattered zone. As described in the preceding chapter, the mode of faulting is different among these tectonic divisions.

Because such a blocking of the Yeongnam massif was finished by the end of the Pulgoksa igneous activity, it is quite reasonable to consider that the Ŭiseong wedge sank before the deposition of the Kyongasang group, owing to the fragmentation of the Yeongnam massif into the Taebaegsan and Teokyusan blocks. Because thrusting between the metamorphosed and non-metamorphosed parts of the Okch'eon zone is found in the northwest part of the wedge, the movement of the block sympathetic with the thrusting of the metamorphosed Okch'eon may have produced down-warping in front of the block, which became the depression of the Ŭiseong wedge.

It is indeterminable how far the Yeongnam land extended toward the southeast before the deposition of the Naktong series, but at any rate the Tsushima basin is a hinter basin of the Oga mountains. The Naktong lake at the beginning was larger than and detached from the Wakino lake, but it became a large single depression in the Inkstone-Silla epoch. The Kyeongsang group in the basin is much thicker on the Korean side than on the Japanese side. It measures 4,000–4,500 m in the Naktong, and 4,500–5,000 m in the Silla series in the Taegu-Kyeongju section, roughly 10,000 m in total. The Wakino and Inkstone series are 900 m and 2,300 m respectively and about 3,200 m, when taken together.

The Namp'o basin was produced behind the Okch'eon zone after the Songnim disturbance, but none after the Taebo disturbance. In the Akiyoshi and Sakawa orogenic zones post-orogenic narrow basins were introduced along the Akiyoshi and the Sakawa median lines, as well as along the Mikabu line and the like. But there is no intraorogenic basin in the Okch'eon zone.

There are narrow spatulate grabens along its borders, where the Silla series was deposited. The basin on the frontal side is large and the series measures 2,500 m at Yeongdong, 1,900 m at Chin'an and 1,200 m at Hwasun. The basin on the rear side is small and the series is only 600 to 700 m at Kongju.

The Silla series is only about 500 m thick at Hwangjiri in the eastern limestone plateau, where it spreads over a fair-sized area on the Taebaegsan dislocation zone, but the series at Tomap'yeong is a tiny strip within the Osipch'eon shattered zone.

The series in these basins are all produced in the depressions at intervals between the primary and secondary fragmentations.

The eruption of andesitic rocks in the Silla epoch was followed by liparitic ones in the Pulgoksa epoch. At the same time there took place a great batholithic invasion. If the Yokokura igneous rocks are excluded, the Cretaceous granitic rocks in Western Japan are exclusively on the inner side of the median tectonic line. Batholithic granite intruded into the ancient blocks as well as into the orogenic zones in Korea.

The vast terrain of Eastern Asia was granitized by the invasion of the Chugoku batholith with the result that the orogenic zone was fused with the blocks. Therefore the secondary fragmentation took place without any relation to previous tectonic lineament. In other words there is a great discordance between the tectonic developments before and after oronization. Cutting the P'yeongnam and Okch'eon orogenic zones, the Korean arc began to appear. While the earlier fragmentation of the ancient massives into blocks was an accessory phenomenon caused by the orogeny which deformed the geosyncline, the later fragmentation is an independent phenomenon in itself. Furthermore it is a remarkable fact that the earlier fragmentation is not much related to igneous activity. The later fragmentation began with batholithic invasion which occurred in the later orogenic phase of the former disturbance. The Akitsu culmination caused by the invasion at the transitional time from late Cretaceous to early Tertiary introduced faults along which lipalitic dykes have intruded.

Still later in the middle Tertiary there took place a *Grossfaltung* and also faultings at certain places through which basalts and alkaline rocks were repeatedly effused. Between the two crustal movements there was a tranquil period when peneplanation took place and the Yukpaeksan plane was introduced.

In the Kangweondo limestone plateau the earlier disturbance was severe in the Taebaegsan dislocation zone where the mosaic faults were made. The faulting was, however, different on the two sides of the Hwangjiri fault. On its south side step faults were formed with the downthrow on the west side, and they reach the Hambaeksan fault of which, however, the downthrow is on the other side.

On the north side of the Hwangjiri fault the Osipch'eon shattered zone is a kind of graben between the Cheonni and Magyori faults. The rectangular disposition of this graben relative to the Paek'unsan syncline apparently resembles that of the Rhine valley to the Jura mountains. On its east side there is a complicated fault mesh which cuts the Korean system, but the Pre-Cambrian basement is extensively exposed farther east beyond the Hwangjiri fault.

The upper Miocene of Samch'eok is in part a fossil delta or an alluvial fan which existed at the northern end of the Osipch'eon graben, but the facies of the fan somewhat abruptly merges with the fine lacustrine sediment farther north where it laps over to the east, covering the Magyori fault. Furthermore it can readily be seen near Yukpaiksan that the faulted blocks are beheaded by the Yukpaiksan plane. Therefore it is certain that the middle Tertiary upheaval of the plane was not accompanied by faulting in this part of Korea.

In North Korea faulting at the time was strong. As a result the Kilchu-Myeonch'eon graben and the Chilbosan horst were produced. The Hamg'yeong fault system which is responsible for their appearance, however, has the downthrow generally on the northwest side, *i.e.* on the side of the Kaema plateau. Therefore the southern scarp of the plateau must be an erosion product. The Palaeogene of the Fushun and Pongsan coal fields are also cut by faults. Where the Palaeogene is absent, it is difficult to decide the age of the block movement. But the Weonsan-Seoul rift valley, the belts of the Daedong series of the Namp'o area, the spatulate grabens of the Silla series in the Okch'eon zone and elsewhere indicate block movements. The Taebaegsan block thrusts upon the Ŭiseong wedge along its north border.

5. Oronization and anoronization

The Chinese Heterogen is so intimately related to the Mongolian and Chichibu geosynclines that tectonic developments of one of them cannot be explained without reference to those of the others. In the history of the Japanese islands it is recognized as a general tendency that waves of folding diagonal to the Japanese arc were aligned *en échelon* in the prorogeny, while the folding in the orogenic period is parallel to the arc. The *échelon* structure in the northeastern part of the Kangweondo limestone plateau must be genetically related to the folding in Japan *en échelon*.

Nevertheless Japan is related in the Cretaceous period and before more closely to the Touman-Suifun area than to Korea proper. The area may be said to be a part of Japan which was left after the appearance of the Japan Sea. It is much easier to explain the history of Eastern Asia when Japan is on the east side of Korea, although their relative positions have changed from time to time.

West Japan can now be seen as the part to the south of the Akiyoshi axis except the Hida plateau and a few spots which belong to the pliomagmatic zone of the Akiyoshi mountains. The Mesozoic and later formations overlying this granitized gneiss basement escaped any sharp folding.

On the southern side of the Hida gneiss zone there is the Sangun metamorphic zone and then the Yamaguchi folded zone. In the western part, however, the last zone is bisected by the insertion of the Motoyama metamorphic zone.

Because these zones were not well oronized before the Chugoku batholithic invasion, they suffered *Bruchfaltung* in the Oga phase. It has been fairly well ascertained since recently that the Itoshima granite adjacently to the west of Fukuoka intruded into the Sangun metamorphics concordantly. Because it must be a member of the Hida gneiss group, the axis of the Akiyoshi mountains runs from the Hida plateau to Fukuoka in northern Kyushu.

Because the Tsushima basin lies on the Yeongnam land on one side and the Akiyoshi mountains on the other, the boundary in these basements is unknown, but there is a great difference in the deformation of the Kyeongsang group. It is folded in Yamaguchi and northern Kyushu whereas it is generally monoclinal on the Korean side of the Tsushima basin.

Aside from local foldings, the blanket after the invasion of the Chugoku batholith is, however, unfolded even on the Japanese side. On the Korean side the Ulsan zone to the east of the Yeonghae-Pusan line is cut by step faults of the Hansan system. The Tsushima horst and submarine ditches on its lateral sides are all parallel to the fault system. They reveal as a whole a block movement by tension.

In western Chugoku and northern Kyushu there are faults in similar direction but the NW to NNW faults are more predominant and control the distribution and deformation of the Palaeogene. Some of them show a southerly shifting of the western block.

Central Kyushu lies between the faulted northern and folded southern terrain. The Kuma land in southern Kyushu which is a part of the Sakawa mountains is an obstacle wedged in between the Oyashima folded zones of the Cretaceous and Palaeogene formations or more precisely, between the Nakamura zone on the south and the Amakusa islands and other places in central Kyushu on the north side.

The Sakawa and Oyashima mountains are sharply bent to the southwest in southern Kyushu and so probably are the Akiyoshi mountains in northwestern Kyushu, because the Motoyama zone forms the Sonoki bending. The sharp bending of these mountains must have been due to the southern advance of the Ryukyu arc. The southerly shifting of the western block relative to the eastern one as seen in northern Kyushu and its vicinity is also an indication of the same pull. The southern bending of the Hakusan volcanic zone must be related to the shifting.

The movement was strong before the Palaeogene as well as after it. Shifting or sliding caused the fragmentation of the Tsushima basin and the sunken part became the strait. The Hansan fault system indicates tension on the rear side.

The Korean arc is a product of anoronization from the late Cretaceous period revealed by an asymmetrical warping and associated faulting.

In the middle Tertiary period there was a marked faulting of the Hamgyeong system in North Korea and of the Hansan system in South Korea. In Central Korea on the other hand the typical two-cycle mountains were introduced by the upwarping of the asymmetrical geanticline which was repeated without faulting.

The Taebaegsan range is a product of such *Grossfaltung*, which is traceable as far as the central Manchurian plain where it is shown by the divide between the Liao and Sungari rivers.

There is a peri-Korean chain of volcanoes comprising Mt. Paektu and Ullung and Cheju islands. In the mountainous land of Kaema-East Manchuria the upwarping was made with axis subrectangular to the preceding, which was asymmetrical, and the Kaema plateau terminates at the southern scarp. This land is extensively capped by plateau basalt at some places.

Summarizing all of the known facts, it can be said with certainty that Korea entered into a period of anoronization through the batholithic invasion during which the Korean arc was began to be produced. This arc and the Ryukyu arc are aligned *en échelon* forming a still larger arc known by the name of Peri-Tunghai. As discussed in my *"Sakawa Cycle,"* the Ryukyu arc is a growing orogenic zone. In other words the southern wing of the Peri-Tunghai arc is oronizing, while its northern wing is anoronizing. Kyushu between the two wings is intermediate, or perhaps it is more accurate to say that the well oronized northern part or the basement was anoronized, while the anoronized part in the south or the non-oronized blanket on the basement was oronized. Because oronization and anoronization take place in the two wings of an arc, they may be *different stages of the same tectonic development caused by the same agency in different places having different conditions.*

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Plate I

Yukpaeksan plane near Mt. Yukpaek, 1,220 m above the sea, in the left-lower part of the map.
Scale 1:100,000

Explanation of Plate II

Figure 1. Isoclinal foldings of the upper part of the Korean system and the Hongjeom series in the east of Sanyanggae, north of Oktong, Hadong-myoen, Yeongweolgun.

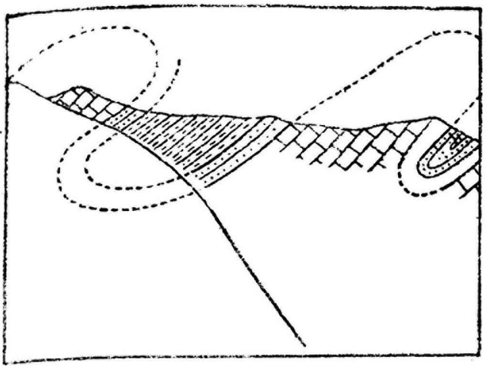
Figure 2. The Kongsuweon tectonic line along which the great limestone formation of the Korean system thrusts itself onto the Daedong series. 1. Cheosa-dong and Cheoam on the Hangang river in the NNE of Yeongweol.

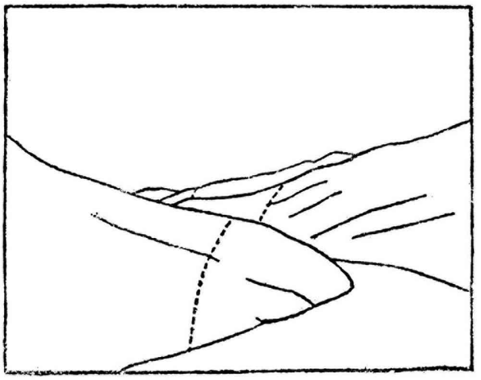
Figure 3. Strong intraformational folding of the great limestone formation, in fluidal aspect below the simply monoclinal basal conglomerate of the Bansong series on the large cliff at Ch'ori, about 3km. to the east of Yeongweol.

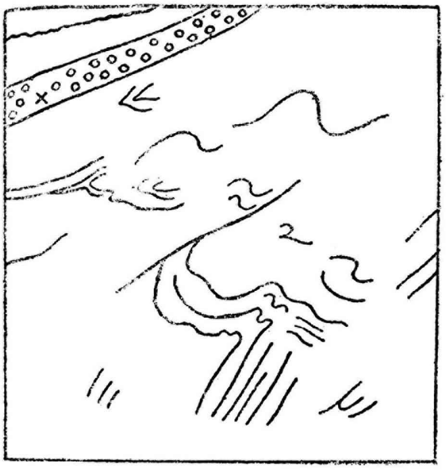
Figure 4. Para-unconformity between the Hongjeom series above and the Tsuibon limestone below, exposed on the bank of the Naktong-gang, at a point adjacently north of Dongjeom-ni, Sangchang-myeon, Samch'eok-gun, Kangweondo.

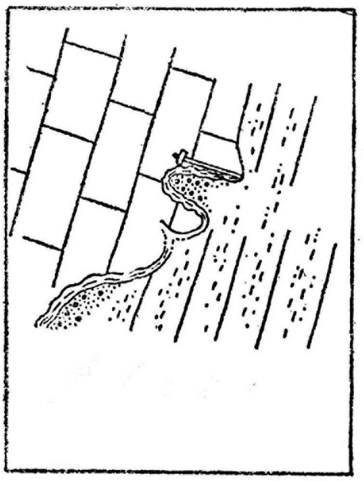
Figure 5. Another exposure of the same para-unconformable relation as the preceding seen at Kyesanmal, Sangchang-myeon, Samch'eok-gun, Kangweondo.

Figure 6. Conglomerate and conglomeratic sandstone of the Hongjeom series at Ungbong, 10km. due north of Yeongweol.









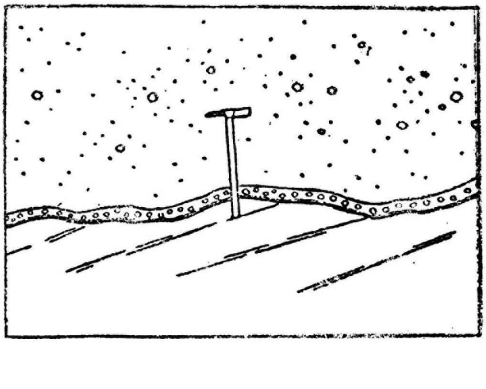
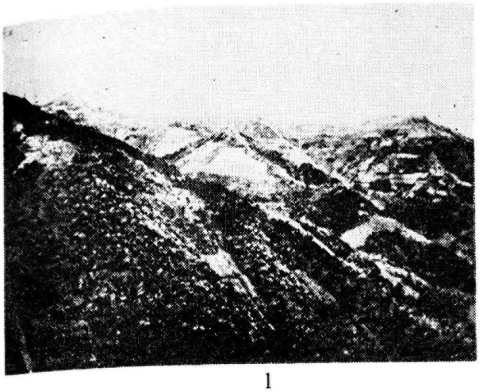


Plate II



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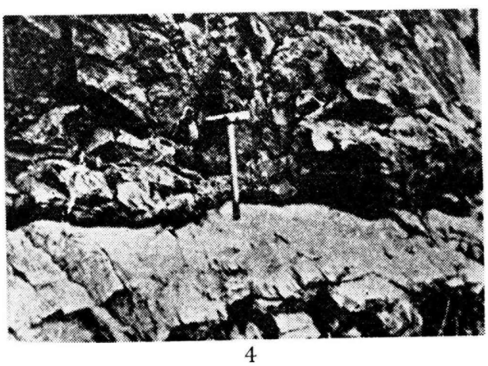

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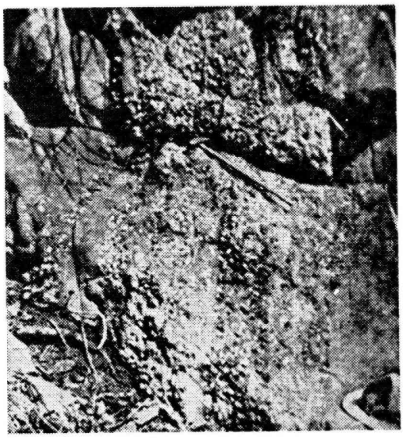
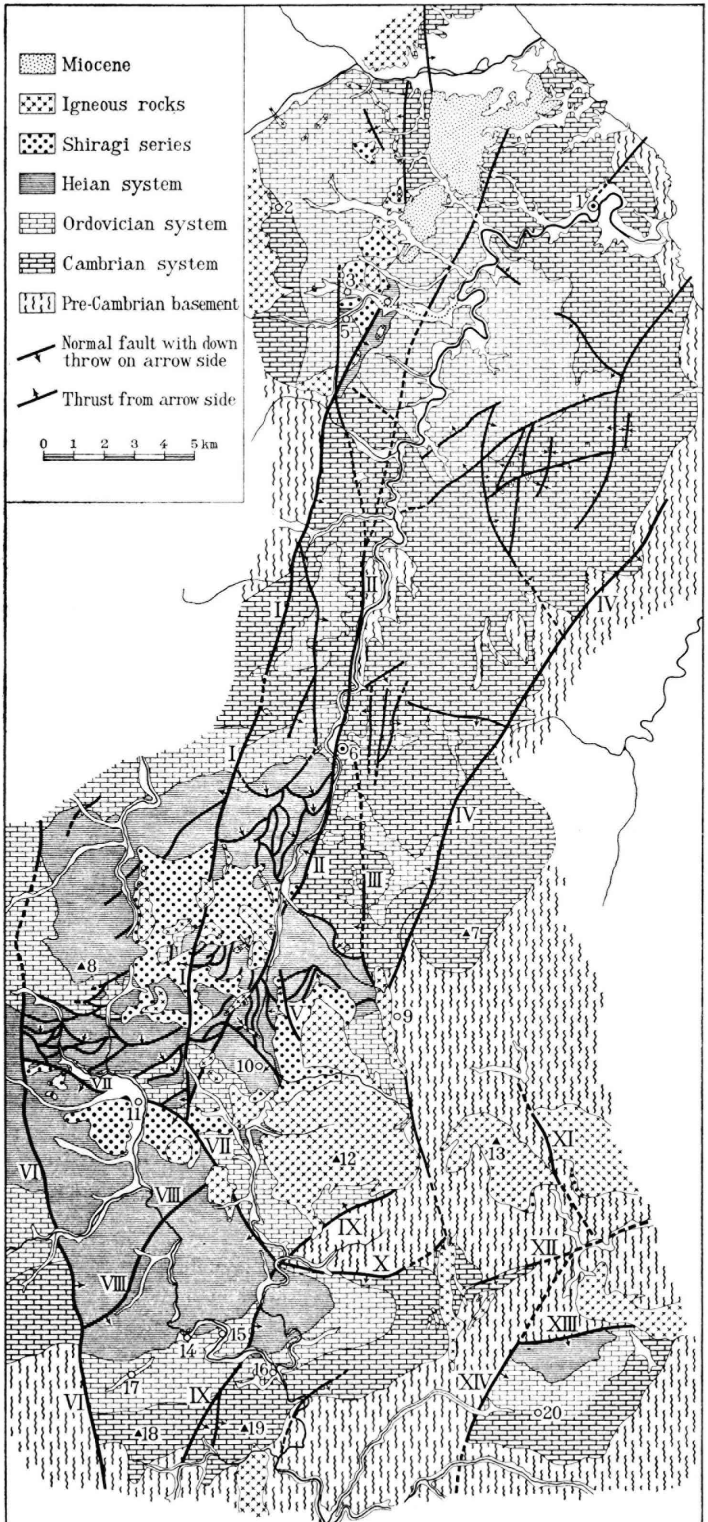


6

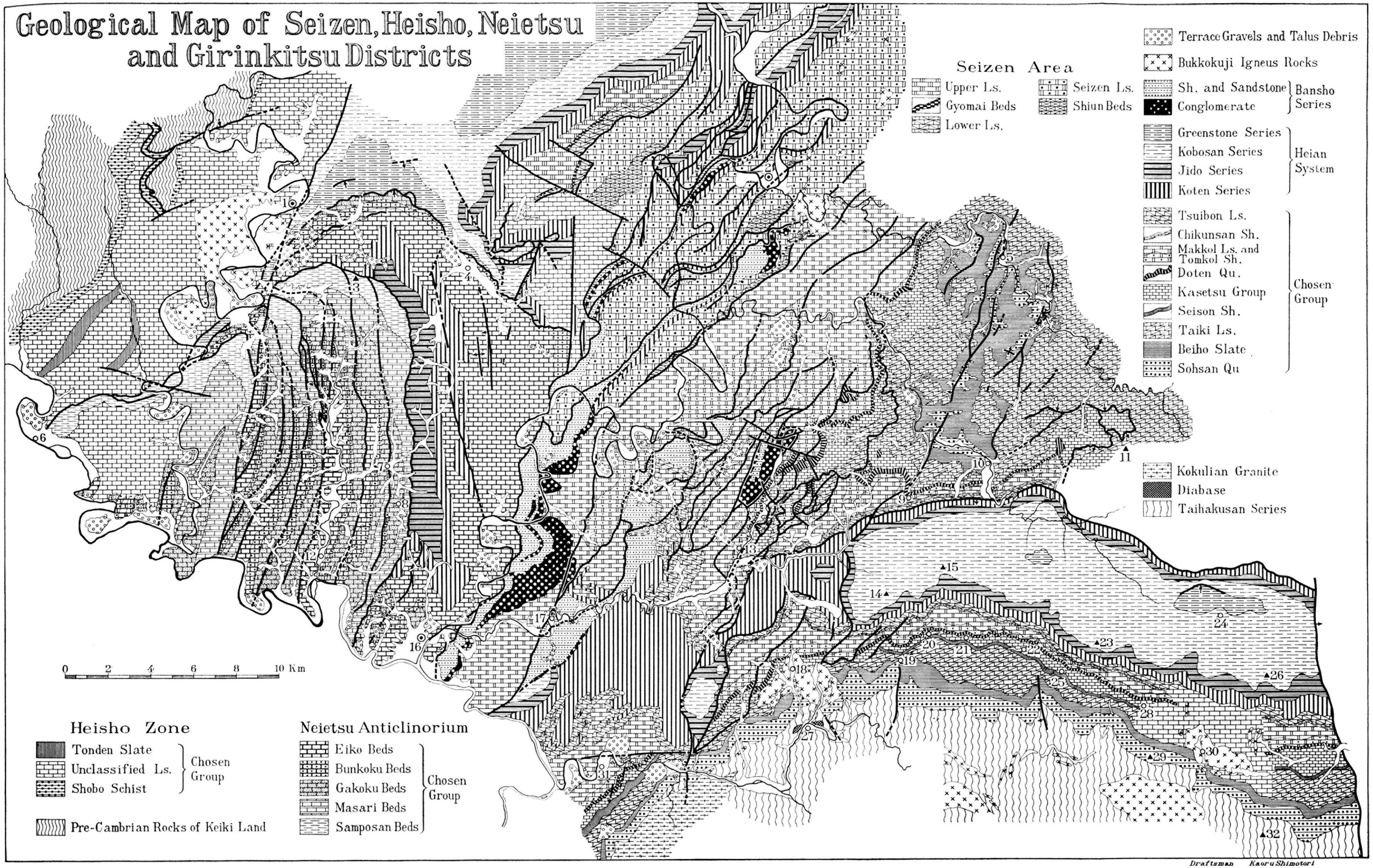
Geological Map (II) of the Taebaegsan Dislocation Zone.



1. Samch'eok
2. Ch'eonŭnsa
3. Koch'eonni
4. Tomap'yeong
5. Samseori
6. Kot'ori
7. Yukpaeksan
8. Ungbongsan
9. Cheongch'ari
10. Simp'eori
11. Hwangjiri
12. Paekpyeongsan
13. Poktusan
14. Kyesanmal
15. Chodongni
16. Tongjeomni
17. Kŭmch'eonni
18. Choneoganibong
19. Yeonhwasan
20. Seokp'och'i

I. Cheonni fault
II. Magyori fault
III. Sangdeongni fault
IV. Hwangjori fault
V. Naesamcheon fault
VI. Hambaeksan fault
VII. Hwangjiri fault
VIII. Mundongni fault
IX. Taehyeonni fault
X. Maesanni fault
XI. Tonghwali fault
XII. Chilksch'onggok fault
XIII. Sambang fault
XIV. Kwangp'yeonni fault

Geological Map (1) of Jeongseon, P'yeongch'ang, Yeongweol and Uiimgil Districts.



1. P'yeongch'ang
2. Jeongseon
3. Sambangsan
4. Ch'angni
5. Hwaamni
6. Chuch'eonni
7. Mach'ari
8. Wagok
9. Chamiweon
10. Munŭngni
11. Chomoksan
12. Mohari
13. Uiimgil
14. Chikunsan
15. Tsuibon
16. Yeongweol
17. Bansong
18. Imongni
19. Daegi
20. Makkol
21. Tomkol
22. Hwajeolch'i
23. Paek'unsan
24. Cheongansa
25. Kuraeri
26. Hambaeksan
27. Nokch'emni
28. Sesongni
29. Jangsan
30. Op'yeong
31. Oktong
32. Taebaegsan

Volcanic Geology of the Cenozoic Alkaline Petrographic Province of Eastern Asia

Tōru TOMITA

Introduction

The writer published the following two views concerning basaltic magma in 1932. (1) There are two types of basaltic magma: basaltic parental magma of the alkaline rock series and a basaltic parental magma of calcalkaline rock series. (2) Of these two types, the first is considered primordial or original magma. This is juvenile magma, while the second is a secondary magma produced under the effect of sialic substances which constitute xenoliths of sedimentary origin and the walls of reservoirs in the circum-Pacific tectonic zone (TOMITA, 1932).

After having advocated the above hypothesis, the writer has been striving for years to verify and express it distinctly. Meanwhile, foreign geologists who entertain the same view have increased in number (RITTMANN, 1936; BARTH, 1939; WALKER and POLDERVAART, 1949; MACDONALD, 1949). However, this view is still hypothetical and is not conclusive enough to be supported by many geologists, and there are a number of geologists who oppose the hypothesis. Nevertheless, in the writer's opinion, this is an important petrographic and geologic problem which must be solved. The importance of the problem should not be denied on the ground that it cannot be solved at present. We should make a concerted effort toward its satisfactory solution.

At present, the writer is at a disadvantage, because he lost in the war specimens collected in Eastern Asia, their sections, field-books, unclassified materials, unpublished geologic maps, field photographs, and sketches. It has been absolutely impossible for the writer to carry out the research he had planned.

The writer is very dissatisfied, feeling that he is obliged to write the present paper under such circumstances. Nevertheless, it may not be useless to prepare a paper on the basis of knowledge which he still retains in his mind. It is hoped that this paper may be of help to future investigators.

The present paper consists of the following three parts: (I) volcanic geology, (II) rock-forming minerals, and (III) petrogenesis. In Part I, Cenozoic volcanic activities in North China, Manchuria, the circum-Japan Sea region, and the inner zone of southwestern Japan are correlated, and their volcanological characteristics are discussed. In Part II, the natural history of rock-forming minerals of the Cenozoic alkaline petrographic province of Eastern Asia is described. In Part III, the classification of the evolution types of olivine-basaltic magma is attempted, and the mode of magmatic differentiation is made clear. In addition, a mechanism of formation of special rocks is discussed.

The writer's thanks are due to Prof. Tateiwa for his assistance on the detailed geology of Korea.

1. History of Research and Problems

According to Dr. Kotō, the petrographic province of Eastern Asia (1915), or the Eastern Asiatic petrographic province (1916) is the region where Cenozoic basalts are distributed in Eastern Asia. Basalt distribution centers around Korea, Manchuria and Mongolia, and extends to Siberia and the coastal districts of Southeastern China. Kotō thinks that the southern margin of this petrogaphic province reaches the inner zone of Japan and he plotted the southern boundary on a map.

On the other hand, since 1905, with the progress of geologic surveys in Cheju-do and Ullŭng-do in Korea and in Matsushima, Kakarajima and the Oki Islands in Japan, it has been discovered that alkaline volcanic rocks are distributed on these islands. All these rocks belong to the Cenozoic. Hereupon, a doubt arose as to whether the region bordering on the Sea of Japan including southwestern Japan and the Korean peninsula was to be included in the alkaline petrographic province. This was around 1910.

In those days A. Harker's (1896, 1909) view of the Atlantic suite and the Pacific suite was dominant. Immediately after his publication of a map showing the distribution of the suites the alkaline petrographic province came to be questioned in Japan. Therefore, it was extremely important to describe in detail and publish the lithologic character of the alkaline rocks discovered in the petrographic province in question. The achievements of Dr. Kōzū (1911, 1912, 1913; Kōzu and Seto, 1926) who singlehandedly carried out the research on these rocks are really meritorious. A report on the feldspathoid volcanic rocks from Ullûng-do presented by Dr. Tsuboi (1920), further confirmed the peculiarities of the petrographic province in question. The localities which had been known up to that time were mostly insignificant volcanic islands, and the quantity of alkaline volcanic rocks was very small. As to their origin, most geologists seemed to believe that Daly's theory (1910, 1918) was applicable, that is, alkaline rocks are produced in small quantities as a heteropic facies of differentiation of basaltic magma.

However, the discovery of an enormous amount of alkaline rocks (trachyte or rhyolite) in the Kilchu—Myŏngch'ŏn district, Hamgyŏngpukto, Korea, (Yamanari, 1925) not only confirmed the circum-Japan Sea alkaline petrographic province but also furnished us with important problems on petrogenesis: (1) Alkaline effusive rocks from the circum-Japan Sea alkaline petrographic province may possibly have been derived from basaltic magma as a result of crystallization differentiation, that is, as a result of crystallization differentiation of basaltic magma. Alkali-trachytes and alkali-rhyolites may have been produced, and on the other hand, feldspathoid effusive rocks such as nepheline-bearing and leucite-bearing rocks and limburgite may have also been produced. (2) The above mentioned basaltic magma may be essentially different from basaltic magma (represented by miharaite) which is considered the parental magma of andesites of the Japanese type. Though both are called basaltic magma, when examined in detail there may be at least two kinds of basaltic magma, one of the alkaline rock series and the other calc-alkaline rock series. (3) The difference in the period of activity between the basaltic magma of the alkaline rock series and the basaltic magma of the calc-alkaline rock series may have been caused by different geologic environments (geotectonics and crustal movements) or other factors.

In order to try to solve these problems, it was necessary (1) to confirm whether the explanation of genesis based on crystallization differentiation of the alkaline effusive rocks from the circum-Japan Sea alkaline petrographic province is proper or not; and (2) to clarify whether the basalts from Kotō's Eastern Asiatic petrographic province are different from those of the Japanese type, and to attempt geologic comparison between the petrographic province in question and the petrographic province of Japan.

Intending to solve these problems, the writer began to study Dōgo in the Oki Islands. In his first report (1922–1932) he disclosed the following points: (1) through the evolution of feldspar, olivine, alkali-augite, and alkali-hornblende, volcanic rocks such as alkali-trachyte and alkali-rhyolite were doubtless derived from olivine-basaltic magma through crystallization differentiation; (2) two-pyroxene andesites found in the same place as alkaline rocks differ from alkaline rocks in age of effusion—effused prior to alkaline rocks—and in their parental magma; (3) the parental magma of andesites of the Japanese type is siliceous basaltic magma, as the parental magma of the alkaline volcanic rock series is olivine-basaltic magma and the parental magma of the calc-alkaline volcanic rock series is siliceous basaltic magma; (4) the parental magma of all volcanic rocks has the nature of basalt belonging to the alkaline rock series. The parental magma of the calc-alkaline series was produced as a result of parental magma being contaminated by xenoliths of sedimentary origin (alumina and quartz); (5) opportunities of capturing xenolith are given by crustal movements; zones of orogenic folding are subject to disturbance of the earth's crust; therefore, the parental magma of the calc-alkaline rock series is likely to form; (6) basalts which represents Kotō's petrographic province of Eastern Asia belong to the same series as basalts of the circum-Japan Sea alkaline petrographic province. Consequently, the petrographic province of Eastern Asia may be called the Cenozoic alkaline petrographic province of Eastern Asia. In other words, the circum-Japan Sea alkaline petrographic province is included in the Cenozoic alkaline petrographic province of Eastern Asia and is a region where centers of magmatic differentiation are densely concentrated.

In spite of these conclusions, many problems remain unsolved. Further geologic and chemical studies will be required to explain the genesis of geologic phenomena such as (4) and (5) mentioned above. The problem of the true nature of magma cannot be clarified unless it is pursued not only from the viewpoint of mineral constitution but also chemically and quantitatively. The results of the writer's systematic study in these lines were published in a series (1935, 1936A; Tomita and Sakai, 1938). Alkaline rocks from various places in the circum-Japan Sea alkaline petrographic province have been reported, though fragmentally, by other geologists.

Now, let us turn to the eastern Asiatic continent. Alkaline rocks from the continent reported up to about 1933 were as follows: Nepheline basalt (Kotō, 1912) from Ying-e-men, Ch'ing-yüan-hsien, Feng-t'ien Province; olivine gray pseudo-basalt and limburgite (Lacroix, 1928, 1919) from Manchuria, Jeho, Mongolia, and Shantung; and barkevikite and monchiquite (Ogura, 1933) from Feng-t'ien and Kuantung Provinces. However, the writer predicted that still more alkaline rock localities would be discovered (1935, p. 298). A new locality at that time was where a leucitic rock had been found in Wu-ta-lien-ch'ih volcano. After that, surveys were made of the volcanoes in Manchuria, and it was found that the basalts in Manchuria belong to the alkaline rock series. In addition, leucite basalt was reported from Erh-k'o-shan in Lung-chiang Province (Ogura and Matsumoto, 1939) and Ch'i-hsing-shan (Ogura, Sawatari and Murayama, 1939) extending from Feng-t'ien Province to South Hsing-an Province. Quite recently Harumoto (1949A) disclosed that the basalts in Hsi-hsia-hsien, Shan-tung Province, are all nepheline basalt.

Moreover, in southwestern Japan, Harumoto (1949B) discovered that melilite basalt occurs in the vicinity of Nagahama, Shimane Prefecture (famous as a locality of nepheline basalt).

With the progress of the studies described above many rock types were discovered. At present, in the Cenozoic alkaline petrographic province, a variety of petrographic types ranging from acidic dike rocks such as paisanite and grorudite to the so-called typical alkaline volcanic rocks such as leucite basalt, nepheline basalt and melilite occurs. But it must be emphasized that the problems of the petrographic province do not differ at all from those which the writer considered at the time he set about to study the province. (1) Many rock types were produced by differentiation of the olivine-basaltic parental magma. What is the process of differentiation? (2) What is the geologic age of magmatic activity in the Cenozoic alkaline petrographic province of Eastern Asia and how has the activity changed? (3) Of what type was the magmatic activity in the Cenozoic calc-alkaline petrographic province of Japan which occurred at the same time as the activity in Eastern Asia? (4) What is the genetic relation between olivine-basaltic magma, which the writer assumes to be one of the parental magmas of igneous rocks, and siliceous basaltic magma of the Japanese type (the writer's Mihara magma), which the writer provisionally considers to have been produced secondarily from olivine-basaltic magma (mostly by assimilating "sial" substance)?

2. Outline of Volcanic Geology

The Cenozoic alkaline petrographic province of Eastern Asia is very extensive. In order to comprehend its extent, its geographic distribution will be described, without regard to geologic age. The eastern margin of the province is the marginal part (or the continental shelf) of the eastern Asiatic continent. In northeastern and central Japan, the margin of the province seems to barely touch the coastal districts of the Japan Sea (in Hokkaidō and Sakhalin). In the Chūgoku district (Okayama, Hiroshima, Yamaguchi, Tottori and Shimane Prefectures) and northern Kyūshū, the margin penetrates deep into the Japanese islands and reaches the so-called Median Tectonic Line. Islands on the continental shelf include the following: the Oki Islands, Takeshima, Ullŭng-do, and small islands belonging to the San'in district in the Japan Sea; Ikishima, Kakarajima, Matsushima, and Madarashima on both sides of the Iki Strait; Gotō and Cheju-do west of the above islands; the southern islands, in the region extending from the northern end of Taiwan to P'eng-hu-Tao; farther south, the region including the northern part of Hainan Island and the Lei-chou Peninsula; and Wei-chou Island (YAGI, 1949)[1] situated west of the above region. The northern half of the Korean peninsula exhibits the characteristics of the alkaline petrographic province. The Soviet Maritime Province is also considered to belong to the alkaline petrographic province. It is beyond question that North and South Manchuria, the Mongolian plateau, and Jeho belong to the same province. This petrographic province extends probably as far as Siberia and is contiguous with the area of the arctic basalt described by WOLFF (1914).

In the Japanese Islands, there is a volcanic zone lying along the island arc (a) and another volcanic zone crossing the island arc (b). Arc a is divided into the outer volcanic zone and the inner volcanic zone. Petrographically, the outer volcanic zone generally belongs to the pyroxene andesite series and the inner volcanic zone to the hornblende andesite series (sometimes accompanied by biotite). Arc b is represented by the Fuji and Norikura volcanic zones. In these volcanic zones, the pyroxene andesite series occurs near the Pacific and the hornblende andesite series near the Japan Sea —the side relatively near the continent. The volcanic zones, which parallel each other and extend north and south, constitute a volcanic zone on the west Pacific side in the circum-Pacific andesite zone.[2]

However, an olivine-basaltic region—in other words, the Cenozoic alkaline petrographic province encompasses a great area closer to the continent than the

[1] In Tung-ching Bay; 21°N, 109°E.

[2] The relation between an active volcanic zone and a deep-focus earthquake plane (thrust plane) is very important, but is not discussed in this paper.

inner volcanic zone, which is represented by the above-mentioned hornblende andesite series.

In southeastern Asia also, this distribution is remarkable. There is an outer pyroxene andesite zone and an inner hornblende andesite zone in the andesite zone in Java and Sumatra. Indochina and Borneo, which correspond to a more continental part as compared with the Java—Sumatra arc, belong to a region where olivine basalt—alkaline volcanic rocks—occur. LACROIX (1933) compared the Cenozoic basalts from Indochina with those from Manchuria, Jeho, Mongolia, and Shantung.

As mentioned in the beginning of this chapter, the above description was made without regard to geologic changes. The present condition, however, is the result of innumerable changes which occurred from the beginning of the Tertiary to the present. The changes of the petrographic province which took place in the inner zone of southwestern Japan are particularly noteworthy. It is no exaggeration to say that it is impossible to discuss the problem of parental magma without knowing of such changes.

As mentioned above, the Cenozoic alkaline petrographic province of Eastern Asia occupies a very extensive region, the greater part of which has been a continent since the Mesozoic; the Tertiary formation is lacking in many cases. It was found that the circum-Japan Sea alkaline petrographic province (one of the sub-petrographic provinces of the Cenozoic alkaline petrographic province of Eastern Asia) is the most suitable region for the study of geologic disturbances. However, the changes throughout the Cenozoic cannot be revealed just on the basis of the data of this sub-petrographic province. In order to fully clarify the mode of changes, comparative study is necessary, and the significance of each region must be clarified.

Table 1 shows a tentative correlation of each typical region. This table is not conclusive but is published for reference and also as a foundation on which studies in this line can be made easier in the future.

Any one who examines this table will notice many interesting facts about volcanic geology and petrogenesis in the petrographic province in question. For convenience' sake, the volcanological history is divided into seven periods, and the principal characteristics of each period will be described, in the sequence of older to younger.

(1) The first period of volcanic activity (Paleogene to earliest Miocene)

Volcanic activity in the Paleogene has not been clarified at all except in the vicinity of Fu-shun in South Manchuria, the Mongolian plateau, and the vicinity of Fan-chih in Shan-hsi Province. These three areas are characterized by basaltic activity.

In Fu-shun and Fan-chih the basaltic lava flows are intercalated by black shale beds, which yield fossil plants. The fossils had been considered (particularly by Chinese geologists) Oligocene, but, according to ENDŌ (1931), they belong to Upper Eocene. The basalt from Fu-shun is called *kokuhangan* (black porphyry) by some Japanese geologists, but it is unnecessary to use such a special name. From this basalt, Dr. SUGI (1940) discovered a plagioclase, the optic axis of which is abnormally small, and he explained that the optical abnormality is caused by twinning. Plagioclase-like feldspar with a similar optical abnormality is frequently found in the groundmass of basalts effused after the last period of Miocene in the Cenozoic alkaline petrographic province of Eastern Asia. The writer (1931A) has called it "potash andesine." As is evident from the name, the writer attributed the optical abnormality to molecules of potash feldspar which are more abundant than in common plagioclase (neutral feldspar). Potash andesine is a metastable feldspar, and it was thought that such a metastable type was produced because a homogeneous crystal could not be formed as it was too rich in potash feldspar to crystallize as plagioclase. Even now the writer has not given up this idea. MACDONALD (1942) discovered in basalt from Hawaii a feldspar which closely resembles the writer's potash andesine in optical property and mode of occurrence (it seems to be the anemousite inferred by BARTH, 1930); thus supporting the writer's view concerning the cause of optical abnormality, MACDONALD named it "potash-oligoclase." In short, potash andesine and potash-oligoclase are quite different from the abnormal feldspar which was described by Dr. SUGI. Basalt that contains these minerals in its ground mass is rich in potassium (sometimes it is associated with anorthoclase, but not always) and belongs to a very basaltic type. This is a characteristic of basalts of the Cenozoic alkaline petrographic province. This is noteworthy not only for researchers of these rocks but also, taking into consideration that it is present in basalt of the Inner Pacific Ocean, for those studying the evolution of feldspar.

Basalt of the Mongolian plateau is one of the so-called plateau basalts. The basalt forms lava flows several hundred meters thick, consisting of many lava sheets. These thickly accumulated lava flows may not have been effused in the same age. Actually, north of Ta-t'ung, there are volcanic cones similar to the Ta-t'ung volcano group (Late Pleistocene). It is beyond doubt that the basaltic lava flows effused from the volcanoes of this age overlie the Paleogene lava flows. However, the Pleistocene lavas are not very abundant, so it is not a great mistake to consider most of the basaltic lava flows in the Mongolian plateau Paleogene.

The basaltic lava flow found in the vicinity of Fan-chih in Shanhsi Province is composed of many sheets and is intercalated by black shale, which yields fossil plants. The genera and species of the fossil plants are the same as those from Fushun. Therefore, Chinese geologists consider them the same age.

The chemical composition of the basalt from the Mongolian plateau is quoted from LACROIX's report (1928, p. 48) and is shown in Table 2. In this table's notes the petrographic name adopted by Lacroix is shown. However, it is more reasonable to call it analcite olivine-basalt than 'basanitoid.'[3] Mongolian basalt is

[3] A basalt which is chemically basanite but does not contain nepheline (i.e. a basalt in which *ne* is calculated in the norm but is not contained in mode) is called basanitoid by Lacroix. His

generally rich not only in analcite but also in other zeolites. In parts of the lava flows, the lava is highly porous or amygdaloidal. In such a rock type abundant zeolite is macroscopically noticeable and sometimes well-formed crystals of natrolite are found. Some rock types have fine veins of zeolite. Even in a rock type in which zeolite cannot be easily detected with the naked eye, zeolite filling the interstices is usually discernable under a microscope.[4] If we re-examine Table 2 with this knowledge, we shall notice that in the rock type which contains more than the norm amount of *ne*, the amount of H_2O associated with Na_2O increases. By this fact it is understood that norm *ne* is attributable to analcite and natrolite. The presence of a fair amount of analcite basalt in the basalts of the first period of volcanic activity described in this chapter is not limited to the Mongolian plateau basalt but is found universally throughout the entire petrographic province. Since this fact is significant volcanologically, it is especially noteworthy. Examples will be cited below.

The Yongdong alkaline basalts in the Kilchu—Myŏngch'ŏn district, Hamgyŏng-pukto, Korea—These basalts form a thick layer of lava flows. Though their relation to the overlying P'yŏngnyuk-tong beds is an erosional unconformity, the longer lava flow, 1,000 m thick, extends over 50 km and disappears where cut by a fault. The other flow is also cut by a fault or sinks into the ground. Its extent is therefore unknown, but judging from the above figures, it may be thought a huge lava sheet. Several places in this lava flow are agglomeratic; hence it is known that there were many effusion centers. It was probably a large volcano of the Hawaiian type in the earliest stage of the Miocene. A rock type (effusive rock type in the relatively early period) in this basaltic lava flow is analcite basalt (TOMITA, 1933B), and samples containing macroscopic well-formed crystals of analcite can be collected in some localities. However, as a matter of course, the Yongdong alkaline basalt is not entirely composed of analcite basalt. Generally speaking, it is olivine-trachybasalt having many olivine phenocrysts; chemically speaking, one of its characteristics is that it is rich in potassium. Its chemical composition is shown in Table 3.

The Ŏil basalts associated with the Ŏil beds in the Yongil area are also olivine basalt, but their lithologic character has not been ascertained. Though both are altered, the original Shimonagu basalt developed on the west coast of Dōgo in the Oki Islands and the Higashiyama basalt on the south side of Lake Shinji are inferred to be undoubtedly olivine-basalt from the presence of pseudomorphs. In the

calculation of *ne* is based on the fact that the ground mass is rich in *ne* or that the Carnegie molecule is contained in plagioclase (that is, anemousite). The writer does not agree with his opinion on anemousite. (TOMITA, 1933A, P. 26).

[4] Besides zeolite, chalcedony is found in the pores of these rocks. With respect to zeolite, there is the following literature: MATSUZAWA, I., 1940, On the natrolite from the vicinity of Shen-wei-t'ai, Inner Mongolia: *Bull. Orient. Archaeol.*, Ser. B, v. 2, 'Mongolian Plateau', P. 29–31.

It is said that the basalts in this region are accompanied by trachyandesite and trachyte. (MATSUZAWA, I., and IWAO, S., A geological study of several rocks developed in the Mongolian Plateau, *ibid.*, p. 1–28.)

Shimonagu basalt there are large and small pores, which are filled with zeolites and green earth; the zeolites, analcite, natrolite, and chabazite are distinguishable (TOMITA, 1926, 1931B).

The basalt which has suffered thermal metamorphism by the Takayama gabbro in Yamaguchi Prefecture is considered to be of the same age, that is, of the first period of volcanic activity. A geologist who studied this thermal-metamorphosed basalt supposed that this basalt was the same age as the Takayama gabbro (NOJIMA, 1941). However, as a problem on an extensive geologic phenomenon such as volcanic activity, it may be reasonable to choose a correlation common to an extensive region.

It is thought that there was a time lag between the active period of the Mongolian plateau and that of the regions east of it. That is, Mongolian basalt was effused in the early Oligocene (or in the beginning of Eocene), but the effusion occurred in the end of the earliest period of Miocene in the Yongil area in South Korea and in the San'in district, Japan. In the Kilchu—Myŏngch'ŏn area, the active period was between the above two activities, that is, in the beginning of the earliest Miocene (or beginning in the end of the Oligocene).

It is very interesting that in Japan the activity in the earliest Miocene is represented by the calc-alkaline rocks (pyroxene andesites and rhyolites), while there was no activity of those rocks in the region extending from the Kilchu—Myŏngch'ŏn district to the continent. The only exception is the Yongil area which belongs to the petrographic province of the Japanese type. This remarkable contrast did not appear in the Tertiary but had existed from the Cretaceous (though the extent of the petrographic province was somewhat different).

The next problem which is worthy of notice is that of the Miocene alkaline rocks in the Fossa Magna zone in the central part of Japan. In the writer's opinion, the age of the famous teschenites in Takagusayama was the end of the first period of volcanic activity; the volcanic activity represented by the Misaka beds is older than the age of the above teschenites (during the earliest Miocene). If this correlation is correct, the following petrographic province can be recognized: the basaltic province that surrounds Japan and, through the present San'in district and the Hokuriku district, extends to the Pacific via the Fossa Magna. In this petrographic province alkaline trachyte was produced under favorable conditions. An example may be seen in Ryūsōzan north of Shizuoka City (MAKIYAMA, 1950). The differentiation tendency observable in this example is not only the same as that of the above-mentioned Mongolian basalt but also as that of the alkaline volcanics formed in the end of the Tertiary. Thus, part of the features of the Cenozoic alkaline petrographic province of Eastern Asia had already appeared in the earliest Miocene.

(2) The second period of volcanic activity (Early and Middle Miocene)

This is actually a period of no alkaline volcanic activity. On the Chinese continent it was a long erosion period and in the last stage the Shanwang series (probably a lacustrine deposit, famous for abundant yield of fossil plants) was deposited.

In Hamgyŏng-pukto, Korea, it was the period of deposition of the P'yŏngnyuktong, the Hamjindong, and the Manhodong beds. Though there was some basaltic activity in Hamgyŏng-pukto, it was inconsequential compared with the scale of other magmatic activities apparent when the Cenozoic alkaline petrographic province of Eastern Asia is viewed in the light of ages and regions.

In spite of such tranquil conditions on the continent, the petrographic province of Japan experienced a period of prominent igneous activity; volcanic rocks were formed and plutonic rocks were intruded.

The first activity in the petrographic province of Japan in this period is represented by rhyolites, and the effusion of the rhyolite was followed by the eruption of two-pyroxene andesites. Prominent volcanic activities that occurred in this sequence were accompanied unquestionably by tuff and agglomerates, and tuffite was formed in the areas of deposition; the rocks are distributed almost throughout Japan (though their petrographic characters differ in different areas).

The first activity in this period was a disturbance which occurred in the Early Miocene. From the end of the Early Miocene to the beginning of the Middle Miocene there was a calm period of erosion and deposition which continued for some time, and then volcanic activity again became prominent (about the middle of the Middle Miocene). No rhyolite was erupted in this period, but in the Inland Sea zone, peculiar biotite andesite and amphibole andesite was formed. Similar rocks are found in the San'in district. Andesite of the same period is found in Dōgo, but it is only two-pyroxene andesite. Exceptionally, in the south shore area of Lake Shinji, no volcanic activity occurred. The Kimachi and the Fujina beds were deposited. (It seems that a strait which may be called the Shinji Strait, was formed during this period.)

A great episode in this period was the intrusion of the Tertiary plutonic rock mass, examples of which are observable in various places in Japan. The Takayama gabbro mass which has been well-known for a long time belongs to this period. Aplite occurs on the northwestern side, cutting the mass. This fact suggests the formation of acidic rocks during the same period. Actually, concerning the examples in the San'in district only, in Tamasakimura, northeast of Susa, dikes of granite porphyry traverse the Miocene series and in Dōzen, the Oki Islands, nordmarkite cuts the Miocene series. This Miocene series is thought to belong to the Early or Middle Miocene.

The Tertiary plutonic rocks in the Fossa Magna zone and those in Tanzawayama are probably of the same period. Moreover, in the granites of the outer zone, granite, apparently of the same period, occurs.[5)] The granite mass in the Chūgoku district is more questionable. This mass seems to be a fairly involved complex of rock masses, and it is supposed that granites of this period may be contained in the complex. It is expected that future study will solve the problem.

[5)] T. Kobayashi infers that the granite mass traversing the Cretaceous formation in Uwajima, Shikoku (Takatsuki granite mass) intruded in the Miocene: Kobayashi, T., 1950, Regional geology of Japan (Shikoku district): Asakura Shōten, Tōkyō, p. 59.

In short, in Japan this period indicates a pure calc-alkaline petrographic province, extending as far as the Yongil area, South Korea, while on the continent it was a period of dormant volcanic activity.

The Yongil area, Korea, is particularly worthy of notice. This area kept in step with the petrographic province of Japan in the second period as it did in the first period. That is, the area was calm in the second period and was in a geologic environment quite different from that of the alkaline petrographic province. The area, however, was calm in the Pliocene when the alkaline petrographic province became active. Thus, the Yongil area, though geographically located at one end of the Korean Peninsula, geologically belongs to the Japanese islands, which seems to suggest that the Korean peninsula was connected with the Japanese islands in the Pliocene and had similar geotectonics.

When the second volcanic activity gradually subsided, a period of erosion and deposition continued for some time in Japan also, and from the end of the early stage of the Late Miocene a great diastrophism occurred in Eastern Asia.

(3) Third period of volcanic activity (Late Miocene)

The period's great diastrophism was the activity of olivine-basaltic magma in the beginning of the period, which extended at least over the northern half of Eastern Asia. In Taiwan Miocene olivine basalt occurs in the vicinity of Ma-wu-tu in Hsin-chu Prefecture (the present Hsin-chu district, Hsin-chu Prefecture) (YEN, 1949). This basalt may be an effusive rock of the same period.

The activity of basaltic magma in and after this period modified the features of the Cenozoic alkaline petrographic province of Eastern Asia and complicated the relation between the Cenozoic alkaline petrographic province of Eastern Asia and the andesitic province of Japan. Therefore, in a study of the Cenozoic alkaline petrographic province of Eastern Asia, special attention should be paid to the activity of basaltic magma. For convenience' sake, the basalts of this period are named B_1.[6)]

The chemical composition of B_1 basalt is shown in Table 4. As is evident in the table, the basalt from Wei-ch'ang in Jeho Province (Nos. 11–13) is poor in *an* and rich in *or* in the norm. Basalt of a similar type occurs in Dōgo. These belong to basalts in which differentiation has progressed. Nos. 14, 15, and 17 from Japan contrast sharply with the above basalt. These are rich in *an* and relatively poor in *or*. Nos. 14, 15, and 17 closely resemble one another in chemical composition (particularly remarkable in the feldspar constituent in the norm). In spite of that, it is interesting that their localities— Dōgo, Kaho in Fukuoka Prefecture, and Shōdoshima in the Inland Sea,— are relatively far apart.

In many petrographic provinces and comagmatic regions in the world, basalts of very similar character were effused in various places throughout extensive regions and during a relatively short period. The writer calls such basalts "areal

6) For the same reason, the basalts after this period are abbreviated as follows: Early Pliocene basalts: B_2; Older Pleistocene basalts: B_3; Younger Pleistocene basalts: B_4; and alluvial basalts: B_5. This nomenclature of B_1–B_5 is used for geologic units and not for types.

basalts" (1951). The above-mentioned nos. 14, 15, and 17 are good examples of areal basalts. The "areal" does not imply a mode of occurrence like the so-called 'plateau basalts.' Rather, the basalts form sometimes a lava flow covering an extensive area (the Deccan basalts), sometimes a group of dikes (the Scottish basalts), and sometimes they occur sporadically (Hawaiian basalt). In general, extensive lava flows are apt to attract attention, but if, in sporadic occurrences, the rocks closely resemble one another in lithologic character, that resemblance must be an important characteristic.

Nos. 14, 15, and 17 lack macroscopic phenocrysts, and it is understood that the chemical composition shows the constituents of original magma. Therefore, not only petrogenetically but also geologically the rocks are very significant. The writer, as a result of various petrogenetical studies, regards no. 15 as representative of the parental magma of various alkaline volcanic rocks. It is thought that the parental magma of alkaline volcanic rock series in the Cenozoic alkaline petrographic province of Eastern Asia is also the magma of olivine-basalt of a similar character.

That alkaline volcanic rocks were formed through differentiation from such olivine-basaltic magma is known by the presence of rocks of a type intermediate between trachybasalt and alkaline trachyte in various types, summarized by the geological term basalts. In Dōgo, the Oki Islands, the first alkaline trachyte (AT_1) was effused. This AT_1 is mainly plagioclase-bearing anorthoclase-trachyte, and, when the evolution system of feldspar is traced, shows evidence of magmatic evolution from trachybasalt to alkaline trachyte. There was a period of erosion and deposition after the effusion of B_1, and the Hotokedani beds were deposited in Dōgo. The eruption of AT_1 seems to have begun with violent explosions in the course of the deposition of the Hotokedani beds, and a thick pumice bed of AT_1 directly covers the upper part of the Hotokedani beds. In some places the basal part of the AT_1 lava flow forms an obsidian cliff, indicating that it was a lava flow which flowed into the water.

Table 5 gives a chemical analysis of AT_1 from Dōgo. As is evident in the table, though the amount of silica varies considerably, the constituents of norm feldspar fall within fairly definite limits. Moreover, the minimum value of the constituent *an* is within the limits of 6–8. This minimum limit may be regarded as almost fixed. This datum is highly serviceable when the evolution of feldspar is discussed, but further discussion is omitted from this paper.[7] In short, it is fortunate that rocks which are significant petrogenetically occur in our petrographic province.

Volcanic rocks correlated with AT_1 of this nature have not been discovered in other areas in this petrographic province. An important discovery, however, was a pumice bed found intercalated in the Matsue beds, in the vicinity of Matsue, on the mainland across from Dōgo. The discovery that the white pumice constituting

[7] The writer considers it appropriate to determine the boundary between the "plagioclase" province and the "orthoclase" province in the feldspar composition diagram by the rocks containing plagioclase and anorthoclase or the rocks containing the crystals of zonal plagioclase and anorthoclase.

this pumice bed is of the same composition as the pumice which is the early ejecta of AT_1 in Dōgo played a more important part in the correlation of the two areas than did fossils (TOMITA and SAKAI, 1938). The writer believes that it is necessary to apply this correlation method in stratigraphical studies.

In the third period of volcanic activity, the first eruption of sanukitic andesites occurred in the Inland Sea zone (at least in Shōdoshima). The geologic age of the eruption was probably the end of the Miocene and the age has been correlated with the age of AT_1. The following phenomenon is interesting: in the early part of the third period olivine-basalt (areal basalt) of a similar lithologic character was effused both in Dōgo and Shōdoshima. However, in Dōgo, which is the inner area of the petrographic province where the evolution of olivine-basaltic magma progresses, alkaline trachyte was formed, and in the Inland Sea zone, which is the marginal part of the petrographic province, a peculiar rock of sanukitic andesites was produced.

Whether the difference in formation is related to the difference of geologic environments becomes a problem. Study of this problem is interesting and very important volcanologically, and I would like to suggest the following conclusions.

(1) The crust of the Inland Sea zone is a fractured zone and its geologic structure is very complicated. (This can be partially inferred from the features in the vicinity of the Nagatoro metamorphic rock zone in the Chūbu district). (2) Into such a crust olivine-basaltic magma intruded from a deep subterranean area. During intrusion and in a magma reservoir after intrusion, the nature of the magma changed as crustal substances were supplied to the magma from the magma conduit and the wall of the magma reservoir. (3) From such secondary magma sanukitic andesites differentiated and were formed by crystallization.[8] (4) In the inner part of a petrographic province like Dōgo, the subterranean geologic structure is relatively simple, and magma which may rightly be called secondary magma was not formed or was formed only slightly. Hence, crystal differentiation may be regarded as having occurred directly from juvenile magma.

In short, by the third volcanic activity, the features of volcanic rock formation exhibited by the second volcanic activity had changed completely. In particular Dōgo in the Oki Islands, which had belonged to the calc-alkaline petrographic province, changed to the alkaline petrographic province. There are in the world several instances of an area which belonging to a certain petrographic province in some period changing into an area belonged to an entirely different petrographic province in another period. The writer has called this phenomenon "petrographic revolution" (1936). This is an extreme magmatic cycle. I should point out that genetical studies of igneous rocks without any conception of magmatic cycle or petrographic revolution frequently breed careless error.

[8] In my opinion, xenoliths which we can collect as samples were captured in the period when the assimilation of magma declined. The nature of the magma had been considerably changed in this period. The mode of change in xenoliths due to magma has been studied and reported, but the research must be accumulated. Current knowledge indicates only a part of the changes in the nature of magma and may not deal thoroughly with the formation of secondary magma.

A prominent geologic phenomenon in the final stage of the third period of volcanic activity was peneplanation. A good example of this phenomenon is found in Hamgyŏng-pukto, Korea. In this region, gneisses which are the bedrock border on the Miocene series by a remarkable fault, and after the region was peneplained the lava flow of the Chaedŏksan basalt was effused. This remarkable fault (Yamanari's great Kilchu—Myŏngch'ŏn fault) was formed after the deposition of the Middle Miocene series and before the peneplanation. No fault which can be assigned to this period has been discovered in other regions. The level plane underlying the Laohotingtzu basalt in the P'aektu-san region is thought to be the same age as the peneplain in question. It is said that a similar level plane is found also in Manchuria. The eastern part of the Shan-tung Peninsula is famous for the development of old topography, and a level plane is found at the bottom of the basaltic lava flow in this district. In Japan, a level plane in the Kitamatsuura Peninsula, northern Kyūshū, recently pointed out by the writer, is a good example. In this peninsula also the level plane has been preserved by a covering basaltic lava flow. The lava plateau topography exhibited by the basaltic lava flow can be attributed to the underlying peneplain. Furthermore, the low-level peneplain in the Chūgoku districts is also of this age. The conclusion is that this peneplanation occurred extensively in at least the northern half of the Cenozoic alkaline petrographic province of Eastern Asia. On the other hand, there were also areas of deposition. In short, the third volcanic activity completely subsided with the end of Miocene.

(4) The fourth period of volcanic activity (Pliocene)

The volcanic activity of this period also began with the eruption of basalts. Generally speaking, the basalts (B_2) formed a typical lava plateau; the eruption is typed as a fissure eruption.[9] Of course the lava plateau has been cut into buttes by later fluvial erosion. The great lava plateaus in the western part of North China, Manchuria, North Korea, and Shan-tung belong to this age. In these regions, the lava plateaus lie on the peneplanes, and their flat surface is partly attributable to the fact that they flowed onto the peneplanes.

In Japan, B_2 has preserved plateau topography in the southwestern part of northern Kyūshū. The remarkable level plane of the Higashimatsuura Peninsula is attributable to a basaltic lava flow, and the level plane has been preserved under the lava flow. B_2 in the Chūgoku district is exceedingly eroded and dissected. In some areas basaltic blocks lie scattered on the summits or lie sporadically in the cultivated farmlands. Therefore, the original mode of occurrence is not known at all.

B_2 is composed of various basalts. Compared with B_1, the variation in the basalts is remarkable. In certain lava flows (actually several lava sheets in layers), the type of variation is macroscopically distinguishable from the lower part upward. Since there is type variation in different areas, it is difficult to summarize the character-

[9] B_3 which will be described below exhibits a similar topography. In the field, B_2 cannot be distinguished easily from B_3. In the northern part of Korea and South Manchuria, there are several examples where B_3 flowed down the valleys and developed in the B_2 lava plateaus.

istics of B_2. However, a general characteristic is that the porphyritic type is predominant, and phenocrysts of pyroxene and plagioclase are conspicuous. As a geologic unit, these are customarily described simply as basalt, but strictly speaking, they belong to olivine trachybasalts. There are very few chemical data for the rocks (Table 6).

We should note that special alkaline rocks, that is, limburgite, nepheline basalt, and melilite basalt, are contained in the basalts belonging to B_2.

Limburgite has been reported from Ch'i-hsing Shan (part of T'ai Shan), T'ai-an Hsien, Shan-tung Province, Ōgusoyama, Shimane Prefecture, and Sukumozuka in the vicinity of Tsuyama, Okayama Prefecture, but the mode of occurrence is not known for any locality. It probably occurs in small rock bodies like volcanic necks. Limburgite was also described from Chi-lin Province (Mu-tan-chiang Province) Manchuria, Mu-ling-ho, the area southwest of Lin-hsi-hsien, Jeho Province, and Ta-li-po, Chin-p'eng-hsien, Jeho Province (Hsing-an Province). The geologic age of these examples is unknown. For convenience' sake, limburgite is described in this paper together with the above-mentioned rocks. Their chemical composition is shown in Table 7.

Nepheline basalts occur in Ts'ao-shih-erh, Ying-e-men, Ch'ing-yüan Hsien, Feng-t'ien Province; in the vicinity of T'ang Shan, Hsi-hsia Hsien, Shan-tung Province; and in Nagahama, Shimane Prefecture. The nepheline basalts in Ying-e-men and Shan-tung form lava plateaus. The manner of occurrence of the nepheline basalts in Nagahama is not known. Melilite basalt occurs as a type of lava in the vicinity of Takano. A chemical analysis of nepheline basalts from Eastern Asia is shown in Table 8. The basalt in which the magmatic water is contained was nepheline basalt from Nagahama. The same problem arose in the basalt from the Kitamatsuura coal field in Kyūshū, which in the writer's opinion is also a B_2 basalt.

These peculiar alkaline rocks are distributed in areas where neutral or acidic alkaline volcanic rocks (alkaline trachyte, pantellerite, comendite, etc.) are not found. Furthermore, they have not been discovered in areas where neutral or acidic volcanic rocks do occur. Hence, one may conclude that at least in the Cenozoic alkaline petrographic province of Eastern Asia, limburgite and nepheline basalts (including melilite basalt) do not occur associated with neutral or acidic alkaline volcanic rocks. It is thought, therefore, that those peculiar alkaline rocks were formed through an entirely different process—though the original magma of both was the same.

The climax of the fourth period of volcanic activity is represented by the eruption of neutral or acidic alkaline volcanic rocks. This was an astounding event throughout this petrographic province. It was a remarkable contrast to the very slight volcanic activity in the Japanese Islands at this time. It is noticeable that sanukitic andesites (the second eruption of the rocks) were formed in the Inland Sea zone and the Kyūshū district which are on the margin of this petrographic province.

There were only a few centers of activity of neutral or acidic alkaline volcanic rocks:

P'aektu-san: The description of this volcanic body has been omitted as it is not within the province of this paper. The eruption of alkaline volcanic rocks began with alkaline trachytes, gradually progressing through lava of high acidity, and at last ending in comenditic lava. This sequence is the same as that in the Kilchu—Myŏngch'ŏn district in Hamgyŏng-pukto, Korea, and Dōgo in the Oki Islands. The chemical composition of those lavas is shown in Table 9.[10]

P'aektu volcanic zone: Sobaek-san, Pukp'ot'ae-san, Changgun-bong, Hwang-bong, Kwandu-bong, P'aeksa-bong, Namsŏl-lyŏng, and Turyu-san which rise in a row toward the SSE or SE from P'aektu-san are composed of alkaline trachyte or alkaline rhyolite. That is, according to YAMANARI (1928), Hwang-bong and Kwandu-bong are composed of alkaline rhyolite and the others are of alkaline trachyte. According to KINOZAKI (1932), Turyu-san is composed of alkaline trachyte (chemical composition: Table 10, no. 3). These mountains, consisting of alkaline volcanic rocks, were named by KAWASAKI (1927) the P'aektu volcanic zone. He considered that this volcanic zone extends farther towards the southeast; that is, he thought that Ch'ilbo-san in Kilchu-myŏn, Ŭngdŏk, Kapsan (in Hamgyŏng-namdo; chemical composition: Table 10, nos. 79 and 83), and even Ullŭng-do in the sea belong to the P'aektu volcanic zone. Developing this view, HOMMA (1930) established an arcuate alkaline rock volcanic zone including the Oki Islands and trachyte forming the hills between Tsuiyama and Kinosaki in Hyōgo Prefecture.

If such a volcanic chain or zone is recognized, a volcanic zone including the Oki Islands, Matsushima and Kakarajima in northern Kyūshū, and Cheju-do must be recognized. However, it is highly questionable whether the distribution of alkaline volcanic rocks may be treated within the concept of a so-called volcanic zone.

Kilchu—Myŏngch'ŏn district, Hamgyŏng-pukto, Korea (see Table 1): The eruption sequence of alkaline volcanic rocks (TATEIWA's Ch'ilbosan group) in this district has not been thoroughly disclosed in spite of the detailed survey by YAMANARI and TATEIWA and the writer's supplementary survey. The reason is that the alkaline volcanic rocks are widely distributed and some groups are isolated. Most of the rocks, however, are correlated with those of Dōgo. The varieties which do not occur in Dōgo are the Chaedŏksan basalt, the Namyangdong beds, and AT_1 (Kal-san, Mokchin, and Sangam-san alkaline trachytes), which belong to a series of groups having the genesis of the above order. Since the Chaedŏksan basalt belongs to B_2, these varieties are older than the alkaline volcanic rocks in Dōgo; in other words, they correspond to the lowest part of the Ch'ilbosan group.

If this correlation is correct, the eruption cycle in this district proceeded from neutral rocks to acidic rocks and was repeated twice. It occurred only in the Pliocene, but in Dōgo it was a long-range event extending from the Late Miocene to the Pliocene, and there are some differences in lithologic character (the difference of AT_1 in the above two areas is particularly remarkable). Generally speaking, however, not only the geologic disturbances but also the lithologic characteristics

[10] For comparison purposes Table 9 includes the chemical composition of Pleistocene ejecta.

in the two areas closely resemble each other. Sometimes it is very difficult to determine from which of the two areas a sample was collected.

The chemical composition of alkaline trachyte and alkaline rhyolite in this district is shown in Table 10. For purpose of comparison with the above rocks, the chemical composition of the Turyusan alkaline trachyte (no. 73) and comendite (nos. 79 and 83) from Kapsan in Hamgyōng-namdo is also shown in the table.

Data already published are shown in Table 11. Generally speaking, these rocks are richer in alumina than silica. It cannot be readily concluded whether this fact is due to a peculiar rock type different from the general chemical characteristics of the rocks in this district shown in Table 10 or whether it is an error in analysis. (For various reasons the writer supposes it to be the latter. At any rate it is shown as an appended table for future reference but is not used as a datum for genetical discussion).

Dōgo, Oki Islands: Dōgo is a match for the above-mentioned Kilchu—Myŏngch'ŏn district in the occurrence of many rock types. As described above, B_2 has not been discovered in Dōgo and rock formations corresponding to the Namyangdong beds and Kalsan, Mokchin, and Sangamsan trachytes developed in the Kilchu—Myŏngch'ŏn district are also lacking on the island. Hence, the oldest Pliocene series there is the Nakajima beds, which are correlated with the Naesandong beds in the Ch'ilbosan group. Later formations are essentially the same as those developed in the Kilchu—Myŏngch'ŏn district, and the types of alkaline volcanic rocks in the two areas strikingly resemble each other. One outstanding example which the writer observed during his survey will be described immediately below. Lava corresponding to the Puhyang alkaline rhyolite (Table 10, no. 78) in the Kilchu—Myŏngch'ŏn district is not found on the surface in Dōgo, but an ejected block was discovered in the Washigamine beds in Dōgo. Their similarity is unquestionable from a comparison of the chemical compositions of the two rocks. The chemical composition of the ejected block in Dōgo is listed in Table 12, no. 95.

Worthy of special mention concerning the volcanic geology of Dōgo is the fact that peculiar alkaline dike rocks were intruded after the eruption of comendites. The dike rocks are partly paisanite and grorudite, which may be called alkaline quartz porphyry, and partly tinguaite porphyry, which may be called a phonolitic trachyporphyry. The time sequence of these rocks is not known. My view is that these dike rocks represent the final stages of the cycle of alkaline magma activity in Dōgo, that is, there was no eruption of Pleistocene alkaline neutral and acidic rocks in Dōgo.

Table 12 lists the chemical composition of the alkaline trachyte and later differentiated types of Dōgo. Many analyses of alkaline rhyolites are contained in the table, because various types of rocks were analyzed in order to ascertain that there are two types in the evolutional system of the rocks there.

Dōzen, Oki Islands: The oldest rock formation in Dōzen is the Tertiary formation (probably Early or Middle Miocene) and quartz syenite body[11] which traversed the Tertiary and contact-metamorphosed it. This plutonic rock body may be correlated with the Takayama gabbro and the Tamasaki granite porphyry in the San'in district. It may be a body that intruded in the end of the Middle Miocene.

The volcanic rocks of Dōzen were described by Kōzu (1913) and Shimoma (1928). According to Kōzu, there are (K_1) trachybasalts, (K_2) olivine-bearing glassy trachyte (chemical composition shown in Table 12, no. 109), (K_3) hornblende trachyte, (K_4) biotite trachyte, (K_5) hornblende-bearing plagioclase trachyte (chemical composition shown in Table 12, no. 109), and (K_6) aegirine augite trachyte. According to Shimoma, (S_1) trachybasalts and basalts, (S_2) andesite, (S_3) trachyandesite, (S_4) plagioclase-bearing biotite-augite trachyte, (S_5) biotite-augite trachyte, (S_6) hornblende trachyte, (S_7) olivine-bearing biotite trachyte, and (S_8) comendite occur in Dōzen.

When the Dōzen types are compared with those from Dōgo, some types are seen to resemble each other and others are quite different. Andesite does not belong to the eruption cycle of alkaline volcanic rocks, but probably to the pre-alkaline volcanic rocks. Trachybasalts and basalts are roughly divided into two groups on the basis of the period of eruption, pre-alkaline trachytes and post-alkaline trachytes. Alkaline trachytes which traverse the former are developed in a radial dike group with Takuhiyama at the center. This development is a remarkable example of radial dike groups in Eastern Asia. From their geological relation, the trachybasalt and basalt of the pre-alkaline trachytes unquestionably belong to B_1, and those of the post-alkaline trachytes to B_3. The presence of those belonging to B_5 has not been established.

Many of the trachytes from Dōzen contain plagioclase (andesine or oligoclase) and also hornblende and biotite. These probably correlate with AT_1 in Dōgo. However, a type (K_6) described as aegirine-augite trachyte belongs to AT_2, and comendite (S_8) is comenditic. Therefore, though few in number, they distinctly show that they passed through a cycle of formation of alkaline volcanic rocks.

In short, it is hoped that geologists will study in detail the volcanic geology and volcanic rocks of Dōzen just as they have studied the adjoining island of Dōgo. The rock types from Dōzen are very interesting petrogenetically.

Matsushima, Kakarajima, and Madarashima, Nagasaki Prefecture: The three islands, Kakarajima, Matsushima, and Madarashima, between Iki Island and the Higashimatsuura Peninsula, that is, in the Iki Strait, are composed of basalts and alkaline trachyte. In Matsushima alkaline trachyte is predominant (chemical composition: Table 13, nos. 111 and 112) and is well-known since olden days (Ōtsuki, 1910, Kōzu, 1911). The time sequence of the alkaline trachyte and the basalt has not been confirmed. According to Ōtsuki, dike-like basalt is found on the northeast coast of Matsushima, so the eruption of the alkaline trachyte may be

[11] Kōzu calls the quartz syenite "kurokigan" (Kōzu, S., 1914, Igneous rocks in the Oki Islands; *Bull. Geol. Surv. Japan*, no. 1, p. 83)

prior to the eruption of the basalt. If this observation is correct, this dike-like basalt was effused after the Pliocene and may belong to B_3 of the Pleistocene.

The alkaline trachyte of Madarashima is more acidic than that of Matsushima and is a variety close to alkaline rhyolitic rock. In this island the time sequence of this rock and basalt is unknown (personal communication from N. Aoyama).

Iki Island: This island has not been considered an alkaline volcanic rock area. However, quite recently, the writer, judging from reported related findings, thinks it highly possible that volcanic rocks belonging to the alkaline rock series may be present on the island.

It is said that in some localities the liparite reported by Ōtsuki (1910) occurs as dikes in the basalt and in other localities as xenoliths captured by the basalt. If the basalt is correlated with B_2 and B_3 respectively, the eruption period of the liparite will be the same as that in Dōgo. In addition, from Ōtsuki's description, the liparite closely resembles platy alkaline rhyolite from Dōgo. Next, the rock described as hornblende andesite closely resembles in lithologic character a variety of trachyte from Dōzen, and it was effused before the basalt. This basalt may reasonably be regarded as B_3. On the other hand, as the basalt erupted before and after "the younger Tertiary," it is clear that it erupted at least twice. Though one may question whether the so-called younger Tertiary is the younger Tertiary or Pleistocene, generally speaking, the geologic history of Iki Island coincides with that of the Oki Islands, and the lithologic character of these rocks shows a remarkable similarity.

Cheju-do: Alkaline trachyte (chemical composition: Table 13, nos. 113 and 114) on the summit of Halla-san in Cheju-do contains fayalite and closely resembles a rock of a similar type (Table 9, nos. 51, 52, and 53) found on the summit of P'aektu-san. According to Haraguchi (1931) the alkaline trachytes from Cheju-do are the oldest effusive rocks among the volcanic rocks of the island and are older than the sedimentation of the Sŏgwip'o beds (oldest Pleistocene). Consequently, it would be no great error to think that the eruption of the alkaline trachytes occurred at the end of the Pliocene. That is, one may presume that the alkaline trachytes erupted in the same period as those of P'aektu-san, the Kilchu—Myŏngch'ŏn district, and Dōgo.

It is said that the trachyandesites and basalts of this island are younger than the Sŏgwip'o beds. For convenience, the chemical composition of the trachyandesites is included in Table 13.

As described for the eight sites considered above, volcanic activity occurred in the Cenozoic alkaline petrographic province of Eastern Asia in the Pliocene. The volcanic activity of this period was the most remarkable event in this petrographic province and the rocks produced were generally neutral and acidic alkaline volcanic rocks. Only in Dōgo, residual-magmatic dike rocks such as alkaline quartz porphyry and tinguaite have been found. In short, the center of eruption was the center of magmatic differentiation.

(5) The fifth period of volcanic activity (Early Pleistocene)

After the end of the fourth period of volcanic activity this petrographic province entered a period of calm sedimentation. It is very interesting that a remarkable gravel bed was formed in each region. The gravel beds in the continental region are particularly noticeable. There was a period of gravel bed formation after the Paleogene, and gravel beds correlated with the Sanmen gravel bed are extensively distributed in the drainage basin of the Huang Ho. In Japan, thick gravel beds containing shingles are found in the mountainland of the Chūgoku district. These gravel beds may be of the same period. The sand and gravel bed (intercalated in the basaltic lava flow) in the Sasebo coal field district, northern Kyūshū, may be no exception. The sedimentation of such great gravel beds calls to mind the so-called Pleistocene heavy rainfall period, but it is difficult to prove positively that there was actually a period of heavy rainfall. Regardless of the existence of such a climatic factor, we may reasonably suppose that epeirogenetic movements occurred in the extensive region.

The volcanic activity of this period also began with the eruption of basalts (B_3). The rocks are rich in a type which lacks phenocrysts and resembles a similar B_1 type. However, when compared in detail, it is found that the B_3 of this period does not have as greasy a luster or as scintillating a feldspar ground mass. Generally, plagioclase basalt is abundant. Phenocrysts other than plagioclase include pyroxene and olivine (the latter is generally small in quantity). Some types contain kaersut-hornblende and biotite.

The chemical compositions of basalts from P'aektu-san, Dōgo, the San'in district, and northern Kyūshū are listed in Table 14. In Cheju-do, the activity of this period was that of hornblende trachyandesites, and its chemical composition is shown in Table 13. In Ullŭng-do, basalts occur in the lowest part of the peculiar alkaline volcanic rocks. According to HARUMOTO (1948), the basalts form lava flows, agglomerate and frequently occurring dikes, and include many types. Though there is not enough field evidence to determine their geologic age, from a consideration of their volcanologic characteristics and lithologic character, the basalts of this island are considered a product of this period. The chemical composition of the basalts is indicated in Table 15 together with that of peculiar alkaline volcanic rocks.

There are many cases in which the basalts appear in the form of plateau lava flows. The form of eruption gives an impression of fissure eruption, but the basalts were not always effused in that form. The eruption in Ullŭng-do was a central eruption, and, in P'aektu-san, the basalts were effused like parasitic cones on the great volcanic body of alkaline trachytes. The lavas were highly fluid, however, and flowed copiously down along the former river beds. The lava flow meandering along the Namdae-ch'ŏn in Hamgyŏng-pukto, Korea, is a good example. The Changdŏk basalt may have reached the lowland.

Because of the long-distance flowing, there is no lava plateau in the San'in district and northern Kyūshū. Lava plateaus due to fissure eruptions are commonly found on a small scale. However, in such an eruption, it seems that there were conduits of the central eruption at the points of eruption, or it may be reasonable to assume that the final stage of fissure eruption took the form of a central eruption.

Most lava plateaus do not consist of a sheet flow of lava. Generally speaking, basalt which was effused in the early period is black and that which was effused in a later period is gray or white. Basalt from the later period has remarkable platy joints (columnar joints are also well developed) and horizontal interstices are in which biotite (actually phlogopitic brown mica) or sometimes brown hornblende is found frequently developed.

Tholeiitic basalt is frequently present among the basalts of this period. Quartz-basalt (quartz captured as xenocrysts) is also found occasionally, and in the Yongil-man district in Korea and in the southern part of northern Kyūshū (the southern part of the Shimabara Peninsula), a type suggesting the development of two-pyroxene andesite occurs. These examples indicate that two-pyroxene andesite is formed from olivine-basaltic magma by a certain action, a very important fact petrogenetically.

The period of volcanic eruption was followed by a period of subsidence, which continued for some time. In the latter period, erosion was active, and in some areas sand and gravel beds (the Kŭmsan beds in the Kilchu—Myŏngch'ŏn district and the Obama beds in the Shimabara Peninsula) were deposited. Then volcanic activity revived. In P'aektu-san, pumice (Table 9, nos. 71 and 72) was ejected with a great explosion, and at the same time blocks of trachybasalt (Table 9, no. 69) and nordmarkite (Table 9, no. 70) were hurled out. In the Kilchu—Myŏngch'ŏn district, there was some feeble activity of alkaline trachyte. The activity on Ullŭng-do is particularly interesting. Though various alkaline trachytes were erupted, it is noteworthy that a peculiar alkaline volcanic rock having nepheline (phonolite) was formed at that time.

Of further note was the formation of hornblende andesite in Japan. The type locality is Unzen volcano, and both Kinugasa lava and Kusembu lava belong to it. Numerous blocks were captured by these lavas.[12] Hornblende andesites of the same period occur in the following localities: Taradake, Sannotake, and Ninotake of Kimpōsan; Kuradake and Tawarayama on the western shoulder of Aso volcano; Kurodake, Hanamureyama, Ryōshidake, Kuroiwayama, and Sensuisan in the Kujū area; and Fukumayama, Okoshiyama, Bunsekiyama, Tobidake, Minakuchi-yama, and Takasakiyama in the Yufu—Tsurumi area. The area where these volcanoes are distributed is a zone about 25 km wide extending from the Shimabara Peninsula through Aso volcano to Beppu Bay. It was hitherto believed that the area belongs to the inner volcanic zone in southwestern Japan. But in the writer's opinion, based on considerations of the petrographic province, the area corresponds to the marginal zone of the region of B_3 activity in the Cenozoic alkaline petrographic province of Eastern Asia. Considered with the fact that sanukites were formed in the marginal zone of the region of B_1 and B_2 activity, it is very inter-

[12] The captured blocks are so numerous it is no exaggeration to say that they appear at every blow of the hammer in field surveys.

esting that hornblende andesite is present (hornblende andesite containing abundant captured rock fragments as described above). The area where the activity of olivine trachybasalt had taken place was reduced to the coastal zones of the San'in district and northern Kyūshū in the Holocene epoch. This will be discussed later.

At the end of the fifth period of volcanic activity, older alluvial fans, sand and gravel beds, and terraces were formed.

(6) The sixth period of volcanic activity (Late Pleistocene)

The first event in this period was a great faulting, which was followed by the activity of B_4.

North China: The formation of the Tat'ung volcano group was remarkable. About eleven small volcanic cones lie scattered in the area more than 10 km east of the capital of Ta-t'ung Prefecture, Shanhsi Province. Craters still remain in several cones. Large and small bombs can be collected from some cones. The volcanic activity began with an outflow of black compact olivine-basaltic lava[13] during the deposition of loess near the end of the Middle Pleistocene. The final stage of this activity is represented by the formation of small cones consisting of scoriaceous lava, and the eruption was accompanied by many explosions. After the formation of the volcanic bodies, these were covered partially or entirely by loessic loam due to aeolian migration. The fact that the original form of the volcanic bodies has not been remarkably eroded and dissected is attributed to the porosity of the lava constituting the cones, the resulting prominent permeability of the lava, and the arid climate.

Similar small conical volcanoes rise sporadically NNW from Ta-t'ung. Aerial photography revealed these cones on the Mongolian plateau. The regular arrangement of the cones suggests that they consist of lava which erupted along a geotectonic line such as a fissure, but there is no confirmative evidence for this view. There is a possibility, however, of interpreting them as the results of volcanic activity promoted by faulting movements that accompanied the epeirogenetic movements in Eastern Asia.

The above-mentioned epeirogenetic uplifting movements (which caused the formation of older alluvial fans, sand and gravel beds, and terraces described in the foregoing paragraph), and the faulting movements that accompanied them were a large-scale phenomenon throughout all of Eastern Asia. That is, until that time, the Japanese arc and the islands in the West Pacific had been connected with the continent, but as the peripheral sea (continental shelf sea) came into being as a result of the large-scale faulting movements of this period, the islands were separated entirely from the continent, and broke off into an arrangement which has barely changed up to the present. Consequently, faults of this period have important geologic significance and are found even in the parts which are still land.

[13] This lava is highly fluid and reaches as far as the Sang-ch'ien Ho. Several parts have the appearance of ropy lava. A thorough petrographic study of this lava has not been attempted by the writer or other scientists. The lava which occurs as dikes in the adjoining gneiss is olivine trachydolerite that contains purple pyroxene.

(In Japan, the Chijiwa fault in the Shimabara Peninsula and faults traversing the so-called Pleistocene gravel beds in various areas are examples.) Depressions and collapse on a large scale in volcanic bodies (for example, P'aektusan, Ullŭng-do, etc.), are not just local volcanic events, the writer believes, but are local manifestations of the areal geologic phenomena mentioned in this paragraph.

Paektu Volcano: Ch'ŏn-ji, crater lake of Paektu-san, is 3–4 km in diameter and 375 m in maximum depth. (The distance between the highest peak and the lake bottom is 863 m.) This lake is a gigantic caldera. It seems not unreasonable to think that the formation of this caldera is associated with the great explosion of pumice, which we have discussed above. It is questionable, however, whether the gigantic caldera was formed at the time of the great explosion. The writer doubts that it was formed at that time. Probably the crater formed in association with the pumice ejection is, so to speak, the embryo of the present caldera, and may have been enlarged by later collapses. The writer is inclined to consider collapse as an effect of crustal movement (particularly the crustal movements that affected the whole region of Eastern Asia).

In the sixth period of volcanic activity in the end of the Pleistocene, Paektu volcano also became active. Alkaline trachytic mud lava was discharged and poured down on all sides. This outpouring of mud lava was subsequent to the development of the present scale caldera. It is confirmed by mud lava attached to the crater wall.

It is not known whether lava or ejecta were discharged in the later eruptions (recorded in historic times).

Kilchu—Myŏngch'ŏn district: The two basalts of Ŭngdŏk and Kuktong and the later alkaline trachyte are the representatives of the volcanic activity of this period in this district. Though the center of eruption of the lavas is not known, it is inferred from their lithologic character (particularly the glass basis) that the lavas were not a lava flow which ran down from a distant place but a local product. The lavas include many varieties,[14] and it is interesting that there is a hypersthene-bearing variety. In the Ŭngdŏk basalt, sporadic large crystals of feldspar are frequently found as phenocrysts, and captured assemblages of pyroxene and plagioclase are also enclosed.

The large crystals of feldspar are potash andesine, and it is noticeable that they exhibit a reverse zonal structure (Itō, 1935). On the other hand, xenoliths consisting of assemblages of pyroxene and plagioclase are considered cognate xenoliths. Generally speaking, olivine spherulite is not rare, regardless of its age of eruption, in the basalts of the Cenozoic alkaline petrographic province of Eastern Asia. It is frequently present, particularly in the Pleistocene basalts (B_3 and B_4), and there is no example of the above-mentioned cognate xenoliths except in the Pleistocene basalts. The writer believes that this is a noteworthy fact from a petrogenetical point of view.

[14] This is also one of the general characteristics of local basalts.

The chemical composition of Ŭngdŏk basalt is shown in Table 6 (no. 146). This is the only reliable analysis of the basalt. It is noteworthy that the basalt has quartz in the norm.

Central Korea: Of the vast amount of Pleistocene basalt in North Korea, the one which is regarded as Late Pleistocene (B_4) is the Ŭngdŏk basalt. The lava flows (KINOZAKI, 1937) in Central Korea which are described next are considered Late Pleistocene lava.

The basaltic flow distributed along the graben running NNE between Wŏnsan and Kyŏngsŏng was effused after the development of the normal fault associated with the formation of this graben. The direction of this graben is parallel to the coast line at the southeast end of the Korean Peninsula and the extended trend of Tsushima Island. In Japan, the direction determines the extended trends of southern Kyūshū and the direction of the zone connecting the two volcanoes, Aso and Kirishima. In the writer's opinion, the direction was determined by the great crustal movements at the end of the Middle Pleistocene.

There are at least two localities regarded as the eruption center of the Ch'uga-ryŏng graben basalt: one is 680 m upland and the other is Ap-san (452.5 m). Both retain the original form of a volcano of the *aspite* type. The lava which flowed out of the former crossed over Ch'uga-ryŏng, reached as far as Anbyŏn, and stopped in the vicinity of Pokkye in the south. The total length of the lava flow was about 60 km. The lava which issued from the latter, though it was stopped in the vicinity of Pokkye in the north, reached as far as Ch'ŏlwŏn in the south, and its total length is about 30 km. These two lava flows meet in the vicinity of Pokkye, so the Ch'uga-ryŏng basalt forms a narrow lava flow extending as far as 90 km. In Ap-san, there is not only a crater (about 200 m in diameter and about 20 m deep) but are there also more than twenty small protuberances which resemble parasitic cones, and volcanic topography still remains fresh.

It is interesting that basaltic activity in the early period of Pleistocene took the form of fissure eruptions, and that the activity of the later period was a central eruption.

The writer is inclined to believe that the basalts found on the east side of the Ch'uga-ryŏng, namely, the basalt in the vicinity of T'ongch'ŏn (which closely resembles the Ŭngdŏk basalt), that in Hoeryŏng County, and that in the vicinity of Kŭmhwa east of Ch'ŏlwŏn (Table 16, no. 145) erupted in the same age.

There is a great basaltic flow west of the Ch'uga-ryŏng graben and distributed along the geotectonic line running parallel to this graben. This is the basalt of the Koksan—Singye district. The lava flow is about 45 km N-S and a maximum of about 20 km E-W. Though it is small compared with the basalt flow in the Ch'uga-ryŏng graben, this is one of the largest lava flows (including the andesitic lavas in Japan) in Eastern Asia. The original form of volcanic topography (*aspite*) has not been considerably eroded. I regret to say that I have no knowledge of the lithologic character of these basalts.

Ullŭng-do: As described above, a central eruption occurred in Ullŭng-do in the fifth period of volcanic activity, and the eruption was followed by the outflow of alkaline trachytes (including phonolite). The volcanic body thus produced was shattered by faulting movements in the end of the Middle Pleistocene. Then the sixth volcanic activity began, and Nan-bong was formed on the summit which had sunk and collapsed. This Nan-bong is noted for being composed of leucite trachyandesite (Table 15, nos. 137 and 139). At the same time alkaline syenitic ejecta were thrown out. The island remained entirely calm after that.

Cheju-do: All the trachyandesites in Cheju-do were thought to be of the fifth period of volcanic activity. The writer, however, doubts that all may have been effused in this period.

The foregoing paragraphs are an outline of the condition of the continental region and Korea. It is very interesting, by way of comparison, to consider the volcanic activity in the Japanese Islands during this period.[15]

As described above, the volcanic activity of this period commenced after the great crustal movements (the crustal movements by which the Japanese Islands were entirely separated from the continent). The Chijiwa fault in the Shimabara Peninsula and the graben in the Yufu-Tsurumi area were formed in these crustal movements. The San'in type hornblende andesites were the effusive rocks in this period of activity. Of these, the principal ones are: the Fugendake lava in Unzen volcano, the lavas of Ichinodake in Kimpōsan volcano, Kujūsan, Kujūdake, Ōfunayama, Yufudake, and Tsurumidake, the hornblende andesite on the summit of Futago volcano, and the lavas of Aonoyama, Sambesan, and Daisen in the Chūgoku district. These lavas frequently contain oxidized biotite as well as oxidized hornblende, and quartz and feldspar are mixed as captured crystals (Sugi, Taneda and Yamaguchi, 1948).

There is considerable evidence that the activity of olivine basaltic magma helped form these San'in type hornblende andesites. According to Homma (1936), peculiar rocks in which olivine and quartz coexist are found in the volcanic rocks of Unzen volcano. The peculiar rocks are found not only in the lavas of the Fuken period in question but also the above-mentioned lavas of the Kinugasa—Kusembu period (belonging to the fifth period of volcanic activity) and the Holocene lavas (Furuyake and Shin'yake), which will be described later. Homma published an interesting genetic opinion on the Furuyake lava (erupted in 1657), stating that the Furuyake lava originated from a mixed magma which was formed by intermixing olivine basaltic magma with quartz-bearing biotite hornblende andesitic magma. Although Homma's opinion needs to be explained in some detail, the writer agrees with its main points.

In addition, a lava flow of olivine basalt was recently discovered in the Yufu—Tsurumi area (T. Kasama, personal communication). This is called Bateisan lava and is probably an effusive rock of this period of activity.

[15] In this paper the only volcanic activity in the inner zone of southwestern Japan which is in a close geologic relation with the Cenozoic alkaline petrographic province of Eastern Asia is sketched.

The final display of this period was the great eruption of the Aso lava and the formation of the Aso caldera. The lithologic character of the Aso lava has not been thoroughly studied. The embryo of the Aso caldera probably formed before the eruption of the Aso lava and probably was later enlarged to its present size. The formation of this embryo is thought to have been in the above-described period of great crustal movements. In short, in the same period, a caldera was formed in P'aektu-san in the north and then alkaline trachytic mud lava was effused, and a caldera was formed in Aso volcano in the south. A great eruption of the Aso lava also occurred. This contrast is very interesting and significant. It cannot be overlooked that, though the lavas of Aso volcano are pyroxene andesite, the alkali content is too high to be classed as a Japanese-type pyroxene andesite.

(7) The seventh period of volcanic activity (Holocene)

The beginning of the Holocene was a calm sedimentation period. In the continental region, loessic sand beds were formed by the erosion and resedimentation of the loess bed, and the weathering of the loess bed itself progressed considerably. In particular, as the Japanese Islands were completely separated from the continent, the coast line advanced inland to its present position, and thereby Shan-tung Province came to be controlled not by an inland climate but by a littoral climate. In the writer's opinion, the brown earth found in the eastern part of Shan-tung Province was produced by the weathering and metamorphism of the loess bed due to this climatic change, in turn caused by a topographic change.

Meanwhile, epeirogenetic movements on a grand scale progressed. The isostasy of the earth's crust was kept in defined zones by faulting movements. The activity of basaltic magma was induced. Volcanic activity in the resulting so-called tension area was begun in the interior of the continent. The inland volcanic activity of Wu-ta-lien-ch'ih volcano and Erh-k'o volcano in North Manchuria and the Ch'i-hsing volcano group in South Manchuria, and others went through such conditions.

Wu-ta-lien-ch'ih volcano: This volcano is located north of the capital of Te-tu Prefecture, Hei-lung-chiang Province, and is composed of fourteen small volcanic cones. This volcano has been called "Wünhordongui" volcano since olden times. Of the fourteen cones, Lao-hei Shan and Huo-shao Shan were formed in the 1720 eruption (Ogura *et al*, 1936).

The basement rocks of this volcano group are granite, Cretaceous formation, and Pleistocene formation. On the flat plateau formed by these basement rocks, alkaline basic volcanic rocks were erupted in the following order: (1) hilly plateau lava, (2) shield-like plateau lava, (3) older volcanic cone lava, (4) Shihlung lava, and (5) younger volcanic cone lava (effused in the 1720 eruption). The chemical composition of the rock types belonging to each lava is tabulated in Table 18 (nos. 168–186).

The mode of activity of this volcano group and the kinds of volcanic rocks erupted during the activity are regarded as representative of the inland type of volcanic activity. The volcanology of this group will be briefly mentioned.

The hilly plateau lava of the first eruption is trachyandesite of the Banak type. There were several centers of eruption, and the area where the lava is distributed attains about 500 square kilometers.[16] The flat topography became hilly due to the eruption of this lava. Moreover, the height of the hills increased due to the second eruption. (The kind of lava is much the same as the lava of the first eruption.) However, the maximum height (in the center of eruption) is only 120 to 130 m. In the third eruption, 12 small volcanic cones of the homate type were built up on the hilly plateau lava flow. These cones are on a very small scale: the average base is several hundred meters in diameter and the height is less than 100 m. These cones are composed of stratified lava flows and scoria. However, as each cone has an explosion crater on the summit, it is known that the activity was relatively violent in the final stages of the activity. However, the ejecta are found scattered only around the crater, so the volcanic activity is regarded as having been fairly gentle.

With the above activity one cycle of volcanic activity came to an end, and later the second cycle began. The first stage of the second cycle was represented by the outflow of the Shihlung lava. This activity occurred in the central part of the volcanic district where there was no center of eruption from the first cycle. Lava flowed down on all sides and toward the south it flowed along the narrow valley. The lava flow is eight km long, though it is several hundred meters wide, and it has a form like a huge snake, hence the name 'Shih-lung' (stone dragon).[17] After the relatively gentle outflow of the Shihlung lava the younger volcanic cones of the fifth period of volcanic activity were formed. A reliable old record indicates, beyond doubt, that this was the eruption which built up Lao-hei Shan and Huo-shao Shan (Wu, 1721). The age of the outflow of the Shihlung lava previous to the above eruption is not known but it is inferred that the outflow occurred in historic times.

A noticeable fact concerning the activity of Wu-ta-lien-ch'ih volcano is the outflow of lava containing leucite during and subsequent to the period of formation of older volcanic cones (see Table 18). Other examples of volcanic rocks containing leucite and occurring in the interior of the continent are known elsewhere in the world. The Tertiary volcanic rocks in Yellowstone National Park are suitable for a comparative study with those from North Manchuria. It is believed to be unquestionable that those in the above locality belong to Tertiary, though they are known only as post-Eocene, but those in North Manchuria are the Holocene lavas. This is a very noteworthy fact from the volcanological and petrogenetical point of view.

In addition, it is not rare that accidental xenoliths are present in the lavas of this volcano. That is, granite, quartzite, and sandstone are found as xenoliths, and quartz and orthoclase have been known as captured crystals. The lavas of this volcano are a special instance in the Cenozoic alkaline petrographic province of

[16] The area is almost equal to the area of the inside of the Aso caldera.

[17] In Japan, advancing lava-flows were also likened to dragons. In ancient records on volcanic eruptions such accounts are found from time to time (Example: the 1783 eruption of Asama volcano).

Eastern Asia, in the sense that the lavas contain frequent accidental xenoliths. Lavas containing accidental xenoliths have been found in few other volcanoes. This is in remarkable contrast to the case of the andesites in Japan.

Stressing the presence of accidental xenoliths, particularly in the presence of granitic xenoliths, GORAI (1940) explained by selective assimilation (of basaltic parental magma) the genesis of leucitic volcanic rocks from Wu-ta-lien-ch'ih Volcano and Erh-k'o volcano, which will be mentioned later. Though this is an interesting explanation, many difficult points are contained in it. OGURA (1951) does not agree with Gorai's opinion, and it seems that he attributes the chemical characteristic of rich potassium to crystallization differentiation, but a detailed discussion has not yet been published.

Erh-k'o volcano: This volcano is located about 70 km south of Wu-ta-lien-ch'ih volcano, and is composed of three small cones. Tung Shan, the highest cone, is 110 m high (700 m in diameter at the base) and Hsiao-k'o Shan which is the lowest is only 18 m high (210 m in diameter at the base). Another cone called Hsi Shan, is 75 m high (550 m in diameter at the base). All are very small cones, but each cone has an explosion crater on its summit (OGURA and MATSUMOTO, 1938).

The basement rocks of this volcano are Cretaceous and Pleistocene. Being in a flat plain, it is said that Erh-k'o volcano, though it is small, can be viewed from scores of kilometers away in the plain area.

The volcanic activity was divided into two periods. In the first period leucite basanite (Table 17, no. 168) was erupted and formed a shield-like plateau. The area covered by the lava is 33 square km. The second lava was erupted on the first lava and formed volcanic cones. The lava constituting these volcanic cones is also leucite basanite (Table 17, no. 169), but it is mostly vesicular and scoriaceous.

There are no geologic data concerning the age of activity of Erh-k'o volcano except that it is younger than the Pleistocene formation in this area (yellowish brown clay bed and grayish white clay bed, and in places sand and gravel bed and yellowish brown or yellow sand bed). The age of activity probably correlates with the first cycle of activity of Wu-ta-lien-ch'ih volcano. There is no evidence that erosion and dissection took place.

In short, Erh-k'o Shan is a very small scale volcano and the area covered by the lava flow of the first eruption is estimated at only 33 square kilometers. Because of the occurrence of volcanic rock containing leucite, however, it is of great geologic significance.

Ch'i-hsing Shan volcano: Seven volcanic cones rising around Ling-yuan (Cheng-chia-chun), an important town in the center of the Manchurian plain, are collectively the Ch'i-hsing Shan volcano. Poli Shan, which is the highest of the seven cones, is 110 m high and Nao-pao Shan, which is the lowest, is 30 m high. Hence, this is also a small volcano. No cone, however, has a crater like that of Wu-ta-lien-ch'ih Volcano or Erh-ko Shan volcano. It is questionable whether some of them may be called volcanic cones. They may belong to the tholoide type of volcano. There is no evidence that the cones displayed an explosive activity. There is also no geologic evidence concerning their age. A clay bed and a sand bed, which seem to be younger Pleistocene or older Holocene are found in the vicinity of the cones. It is said that they form the basement of this volcano group (OGURA, SAWATARI and MURAYAMA, 1939).

The lavas of this volcano group are essentially the same. Generally speaking. the lavas are olivine basalts; leucite basanite occurs only in Nao-pao Shan. Their chemical composition is shown in Table 18. The lithologic character also differs from the lavas of Wu-ta-lien-ch'ih and Erh-k'o Shan volcanoes.

Lung-wan volcano group: This volcano group is located about 150 km WNW of Pai-t'ou Shan, and is composed of more than 35 volcanic cones lying scattered on the west side of the Lung-kang Mountains. Some of them have crater lakes. The cones consist mainly of scoriaceous lava and lava flows that were poured out before the formation of these cinder cones. There are four large lava flows which are 6, 8, 9, and 35 km long. The longest is a large lava flow which attained a maximum width of 5 km.

This lava flowed down the present valleys. This fact shows that the age of the activity was Holocene. The lithologic character also shows characteristics of Holocene basalts (Table 19).

The fact that there is a volcanic cone in which ejected granite blocks are found is very interesting. Furthermore, the basement of granite is exposed in parts of the crater bottom or crater wall. Hence, this is a fine example of volcanic activity displayed in a pure granite area. In this volcano, there is no leucite basalt, thereby differing from the Wu-ta-lien-ch'ih and Erh-k'o Shan volcanoes. As described above, a view advocated concerning the petrogenesis of leucite basalts is that of selective assimilation of granite. It is questionable whether or not such assimilation is possible. Even if it is possible, such assimilation does not always occur. It is considered that such assimilation may be limited by certain conditions. These problems are very interesting from the volcanological point of view, and for this study an examination of the lavas of Lung-wan volcano is also necessary. In this sense, this volcano is one of the important members in the Cenozoic alkaline petrographic province of Eastern Asia.

Fourteen volcanic areas, besides the above, have been identified in Manchuria (OGURA *et al*, 1936). Volcanoes in almost all of the above areas consist of basaltic lava. The only exception is Halhin volcano situated on the east side of the Ha-lun-erh-shan spring in the central part of the Great Hsing-an-ling Mountains. Liparite, tuff, and obsidian occur in this volcano (KIYONO and ENDŌ, 1935). It is supposed that the eruption may have occurred in the end of the Tertiary or the beginning of the Pleistocene.

In the Korean Peninsula, lavas which seem to be of Holocene age have not been reported. In Cheju-do, there are small conical volcanoes consisting of basaltic lavas rising in groups from place to place throughout the island. Judging from the geomorphological features, they are considered to represent Holocene volcanic activity. However, it is suspected that some of them may be volcano groups erupted in the Late Pleistocene or so, though there is no supporting geological clue.

The chemical composition of the basalts is shown in Table 20. Of these, no. 18 was previously known as tephrite, but the presence of nepheline has not been confirmed. The basalt was probably named on the basis of its chemical composition. From the chemical composition, no. 199 is also a noticeable rock type, and, in both basalts, the norm *ne* does not exceed 10 percent. As both have a low water content it cannot be considered that their large soda content is due to the presence of zeolites, and nepheline is probably present. The writer hopes to call investigators' attention to this problem in the future. Since the basalts contain olivine, the name tephrite is not appropriate. The writer would rather call them basanite. However, as described above, the presence of nepheline has not been confirmed, so, according to Lacroix's nomenclature, the writer provisionally calls them basanitoid.

The Daimanjisan lava (Table 21, no. 205) and the lava exposed at Misaki, Saigōmachi, both in Dōgo, the Oki Islands, are Holocene basalts. The southern extremity of the Daimanjisan lava reaches Tōgō, Tōgōmura, and faces Saigō Bay. In this locality, the lava overlies an Alluvial gravel bed, from which an ancient water-jar has been unearthed.[18] It is said that, judging from the mode of occurrence at the time it was unearthed, the jar had been naturally buried. This discovery serves as an important clue in determining the age of the gravel bed and the age when the Daimanjisan lava was erupted.

Tradition says that Takuhiyama in Dōzen, the Oki Islands, as shown by the name (Takuhiyama means a burning mountain), was in eruption in remote antiquity. On the Japan Sea side such as the San'in and Kinki districts where there is no geologic evidence which supports the above tradition, there are volcanoes such as Takurayama in Yakuno, and Kannabeyama in Hyōgo Prefecture and Kasayama in Yamaguchi Prefecture (Table 21, no. 207). Of these, in Takurayama and Kannabeyama a crater-like topography remains even now, and in Kasayama the topography of a volcanic cone is still evident. A volcanic bomb consisting of basalt was collected from a volcano in Shimonoseki City, and abundant volcanic bombs are found on Ondake and other small volcanic cones on Fukueshima, the Gotō Islands.

Summarizing the above geologic data, there is a volcanic zone consisting of Holocene basalt on the coasts of the Japan Sea including the adjacent islands in southwestern Japan.[19] It is noteworthy that in the so-called volcanic zone, very small scale volcanoes erupted sporadically here and there. This forms a remarkable contrast to the eruption of Pleistocene basalt which poured out a vast amount of lava and formed plateaus. The activity of basaltic magma in the Pleistocene is not an exception to the general law that is advocated by the writer. In the first stage,

[18] This jar was kept in the Shimane Prefecture Fisheries and Mercantile Marine School at the time the writer took part in the first investigation party (August 1925).

[19] It was mentioned above that Pleistocene plateau basalt is also developed in this region. The basalt and that described in this paragraph must be treated separately from the volcanological point of view.

lava plateaus were formed by fissure eruptions, and in the final stage, the type of eruption changed to local central eruptions.

Taking a general view of the activity of olivine basaltic magma in the inner zone of southwestern Japan after the Miocene, it is very interesting to note that at first the region where volcanic activity played an active part extended as far as the Median Dislocation Line, but eventually the region was reduced to the littoral zone of the Japan Sea where basaltic magma was erupted in a linear arrangement. It is inferred that in the intermediate period, volcanoes had a field of activity associated with the retrogressive tendency. It is believed that this fact shows that the geologic conditions under the effect of which basaltic magma came into being in the lower part of the earth's crust migrated gradually toward the northwest, that is, toward Korea and Manchuria.

In harmony with the retrogressive tendency of the activity of olivine-basaltic magma, the eruption of the San'in type hornblende andesites was inclined to decay. That is, the eruption of the rocks (produced only a) which was relatively active in the Middle Pleistocene was reduced to a very small scale effusion of lava in the volcanoes of Daisen, Sambesan, Futagoyama, Tsurumidake, Yufudake, Kujūsan, Kimpōsan, and Unzendake. In the Holocene, only a very small quantity of lava was erupted from Furuyake (1657) and Shin'yake (1792) in Unzendake. On the other hand in Aso volcano, from which the so-called Aso lava flowed out, extensive activity was displayed in the central cone in the Holocene, and frequent and violent activities have continued up to the present in Kirishimayama, Sakurajima, and the volcanic islands southwest of Kyūshū belonging to the Ryūkyū volcanic zone.

Volcanic activity in the alkaline petrographic province, however, did not subside in prehistoric times. That is, the following volcanic eruptions were recorded in historic times: Cheju-do (1002 and 1007), Paektu-san (1597 and 1702), and Wu-ta-lien-ch'ih (1720). Of these, except in the last-named one, lava did not issue forth and only explosive activity seems to have occurred. In this respect, it is noteworthy that in the activity of historic times the activity has migrated from Cheju-do to the interior of the continent. The formation of leucite basalt in the interior of the continent in the last period seems to be related with the locality and mode of activity and not with the age. At any rate, it is an interesting theme for study.

3. Summary of Volcanic Geology

The writer sketched the outline of the volcanology of the Cenozoic alkaline petrographic province of Eastern Asia in the previous chapter. A detailed description of the general geology of each region is omitted as the limited scope of the present paper does not permit it. Besides the areas described above, there are other volcanic areas which are believed to belong to the present petrographic province. As the geology of these areas has not been studied in detail, the areas were not treated in the previous chapter.

Therefore, in this chapter, only relatively important volcanological matters of this petrographic province will be summarized. Readers should refer to Table 1 while reading this chapter.

(1) Paleogene volcanic activity

The volcanic activity in the Paleogene paleocontinent, with the Mongolian plateau as the center, was very violent from the end of Eocene to Oligocene. The lavas consisted mainly of olivine basalts, with some analcite basalt. This activity extended as far as Fushun, South Manchuria, though it was on a small scale. Then, in the end of Oligocene (probably to the earliest Miocene) a great activity of basalts took place in the Kilchu—Myŏngch'ŏn district, Hamgyŏng-pukto, North Korea. The scale of this activity was far less than the above-mentioned activity of the Mongolian plateau, but it rivaled the activity of the Hawaii Islands (since Pleistocene). The lavas were also olivine basalt and analcite basalt.

In this age, the Japanese Islands, except northern Kyūshū, the San'in district, part of the Kanto district, and the greater part of Hokkaido, were connected with the paleocontinent, but there is no record of volcanic activity like that which occurred in the interior of the continent.

The basalts of this age are doubtlessly basalts of the alkaline rock series, and are typical plateau basalt. The eruption was of the Hawaiian type. Lavas of the remarkable magmatic differentiation type were not erupted, but trachyandesite and trachyte have been reported from the Mongolian region.

(2) Volcanic activity of Earliest and Middle Miocene

In the earliest Miocene, there occurred the above-mentioned activity of basalts in the Kilchu—Myŏngch'ŏn district, and after that the continental region entered a period of calm erosion and deposition. That is, in the Kilchu—Myŏngch'ŏn district, the marine deposites such as the P'yŏngnyuktong beds, the Hamjindong beds, and Manhodong beds were formed.

In Japan, however, it was an age of a complicated mixture of deposition and considerable volcanic activity. The lavas included basalt, andesite, dacite and rhyolite, and the entire calc-alkaline lithologic series. More than one magmatic cycle was repeated. Little local difference is found in the eruption sequence of the layered lavas, as far as the inner zone of Southwestern Japan is concerned.

It is interesting that this calc-alkaline petrographic province of Japan extended to the Yongil district in this age. A similar situation prevailed at the end of the Mesozoic. This resulted in the well-known igneous activity of the Tsushima basin.

The magmatic activity of the Japan type in the inner zone of Southwestern Japan ended with the activity of this age. After that, that is, during and following Late Miocene, the inner zone of southwestern Japan sometimes became a field of activity of the calc-alkaline rock series and sometimes a petrographic province of mixed rocks. It is interesting that, in this respect, the inner zone of southwestern Japan forms a distinct contrast with the Japan Sea side of northeastern Japan.[20]

[20] Concerning the igneous activity of the Japan Sea side of North-eastern Japan, the following paper was published after the completion of this paper: Tanai, T., and Shimbori, T., 1951, On

Another interesting fact which should not be ignored is the sporadic distribution of the small intrusions of so-called plutonic rocks such as gabbro and granites in the San'in district in the final period. The formation of small plutonic rock bodies in this period seems to have been a countrywide phenomenon in Japan and arouses our special interest.

(3) Activity of alkaline volcanic rocks from Late Miocene to the Latest Pliocene

The volcanic activity of this age, strictly speaking, is divided into the activity of the Late Miocene and that of the Pliocene. It is during the volcanic activity in Pliocene that remarkable rock types of alkaline trachyte and alkaline acidic rock were produced throughout this petrographic province.

The activity of the Late Miocene commenced with the effusion of areal basalt (B_1). This was the activity of the olivine-basaltic magma, and the area includes the following districts: Wei-ch'ang in Je-ho, Kilchu—Myŏngch'ŏn, Dōgo in the Oki Islands, the vicinity of Matsue, northern Kyūshū, and Shōdoshima in the Inland Sea. Of these, none of the exposures are very large except Wei-ch'ang. Of course, much of this is a result of erosion. According to the writer's petrographical study, this olivine-basaltic magma is inferred to be the parental magma of the neutral rocks which were erupted later. Not only neutral and acidic alkaline volcanic rocks but also basalts which were erupted several times are included. This is certainly one of the parental original magmas.

With this activity of olivine-basaltic magma, the calm age in the Kilchu—Myŏngch'ŏn district down to that time was ended. On the other hand, in the inner zone of southwestern Japan, the calc-alkaline petrographic province changed into the alkaline petrographic province. This phenomenon is, in the case of certain regions, called "petrographic revolution" by the writer.

Volcanic activity in the Late Miocene, however, cannot be said to have been very prominent. In the Kilchu—Myŏngch'ŏn district, after the formation of the so-called great Kilchu—Myŏngch'ŏn fault, an age of peneplanation continued. In Dōgo, trachyandesite and trachyte (potash trachyte) were erupted. In the Inland Sea zone, the first formation of sanukitic andesites occurred. In other districts, namely, in the districts where volcanic activity did not occur, peneplanation or sedimentation progressed.

In the Early Pliocene, basaltic activity extended to a wide region. The basalt (B_2) of this age was mainly plagioclase basalt having the phenocrysts not only of olivine but also of pyroxene and plagioclase. There occurred also limburgite and nepheline basalt. The above basalts were distributed throughout the whole region of the Cenozoic alkaline petrographic province of Eastern Asia, but it was in the Kilchu—Myŏngch'ŏn and P'aektu-san areas that great quantities of basalt were effused. In southwestern Japan, sanukitic andesite was produced.

The most magnificent display of magmatic activity in this period was the eruption of neutral or acidic alkaline volcanic rocks. The areas famous for this magmatic

the Tertiary igneous activity in the Japan Sea side of Northeastern Japan: *Science of the Earth*, no. 5, p. 15–22.

activity are P'aektu-san, Kilchu—Myŏngch'ŏn, Dōgo, Cheju-do, and Matsushima in Kumamoto Prefecture. There are some types belonging to pantellerite and comendite. In Dōgo, grorudite, paisanite, and tinguaite are associated species. It is noteworthy that these rocks which are rarely found elsewhere in the world occur in the region adjacent to the petrographic province of Japan. It must not be overlooked, however, that the alkaline petrographic province, in those days at least, reached the Inland Sea zone in the south.

(4) Pleistocene volcanic activity

The Pleistocene activity is divided into two periods. The eruption of basalt was repeated twice (B_3 and B_4) and formed plateaus. In places quartz-basalts occur and tholeiitic basalt is also mixed in.

In Paektu-san, the Kilchu—Myŏngch'ŏn district, and Ullŭng-do, a small activity of alkaline trachyte accompanied the basalt. On the other hand, in the inner zone of southwestern Japan, hornblende andesites are associated with this activity. In addition, it is noticeable that the hornblende andesites are from an olivine-basaltic magma contaminated by granite or an acidic rock like dacite. The hornblende trachyandesite in Cheju-do is an effusive rock of the same period, but its genesis must be thoroughly considered. In respect to the distribution of the volcanic zone, the writer entertains a doubt that the Dai-sen—Sambe volcanic zone continues to Cheju-do.[21)]

(5) Holocene volcanic activity

Volcanic activity in this age is known in the San'in district, northern Kyūshū, and Cheju-do. The activity in Manchuria is divided into two types: the activity which is associated with leucite basalt such as Wu-ta-lien-ch'ih volcano, Erh-k'o Shan, and Ch'i-hsing Shan, and that which is not associated with it (Lung-wan volcano is an example). Some geologists consider that the leucite basalt originated due to selective assimilation of granite, but it appears to be a problem for more deliberate study. In the Japanese Islands, it is interesting that small conical volcanoes of Dōgo, Kasayama in Yamaguchi Prefecture, Shimonoseki, Ondake on Fukueshima of the Gotō Islands, etc., are arranged approximately in a straight line. Irrespective of the geologic significance of the plateau, basalt in the Pleistocene was reduced to local activity of a central eruption on a very small scale in the Holocene, and the active region retreated to the zone close to the Japan Sea coast.[22)]

The volcanic activity in Japan in this age is well known, so its description is omitted in this paper. However, as far as southwestern Japan is concerned, the lavas of Aso, Kirishima, and Sakurajima volcanoes are trachyandesitic, and at

[21)] The writer holds a view that, even in the same volcanic zone, according to the geologic environments in the center activity, more or less different types of rock are produced. The writer considers that a volcanic zone is related not to the kind of rocks but to the geologic structure. Therefore, though sometimes there may be a case in which a continuous volcanic zone is represented by similar rocks, it is inconceivable that a volcano belongs to the same volcanic zone only by reason of the occurrence of similar rocks.

[22)] Note that the activity of olivine-basaltic magma extended to the Inland Sea zone in Late Miocene.

least differ from the pyroxene andesite in Hakone, Izu, and Ōshima, though these rocks have been called pyroxene andesites. In this respect, careful study is needed.

In the petrographic province in question, there have been volcanic activities in historic times. The recorded activities were those of Cheju-do (1002, 1007), Paektu-san (1597, 1702), and Wu-ta-lien-ch'ih Volcanos (1720). Of these, only Wu-ta-lien-ch'ih volcano emitted lava. Though the records on the activities are few, it is of keen interest that the activity in the above region had a tendency to gradually migrate toward the northwest.

(6) Migration of the activity of basaltic magma

There were at least six basaltic magma activities, large and small, in the Cenozoic alkaline petrographic province of Eastern Asia. Of these, the activities in the Paleogene or earliest Miocene are called B_0 and those after Late Miocene B_1 to B_5. B_1 to B_5 are closely related to the formation of neutral or acidic alkaline rocks and feldspathoid volcanic rocks, and they are also closely related to the volcanology of Japan. Therefore, the writer feels a keen interest in this fact.

Of these five activities, B_1 (Late Miocene) and B_2 (Early Pliocene) extended to the Inland Sea zone, but in the Pleistocene, though the activities are considered fissure eruptions forming lava plateaus, B_3 and B_4 were limited to the coastal regions from the San'in district to northern Kyūshū. The Holocene basalt (B_5) formed only small conical volcanoes built up by local eruptions such as Dōgo, Kasayama, Shimonoseki, Ondake in the Gogō Islands, etc.

What is the cause of migration of basaltic magma activity with age? To answer this will be a theme for future study. However, the following fact is one which should be considered in connection with this problem. The sanukitic andesites in the Inland Sea zone and its western extension and the San'in type hornblende andesites occur in the region considered the marginal zone of the continental basaltic magma region. In the writer's opinion, these rocks were produced from a migma of olivine-basaltic magma and the pre-existing rocks, and belong to the same genetic system as quartz basalt and tholeiitic basalt which occur also in the marginal zone.

According to this view, the cause of the migration of the activity of basaltic magma with time is considered to mean the migration of subsurface geologic conditions which produce and erupt basaltic magma. To explain this in greater detail, this means that the environments from which olivine-basaltic magma can be erupted as original magma gradually became nonexistent in the inner zone of southwestern Japan, and the above environments were replaced by the geologic environments which gave rise to secondary magma-like migma.

Pursuing this more closely, this seems to mean that the relatively stable tension region in southwestern Japan gradually evolved into a region of compression having the nature of a changeable zone. This is thought to be the result of a movement in the ocean floor which has underthrust the Japanese Islands from the Pacific side and has had an increasing effect since the Pleistocene or so.[23)]

23) This movement was inferred from the distribution of the epicenters of deep-focus earthquakes

(7) Geologic characteristics of the Cenozoic alkaline petrographic province of Eastern Asia

Geologic conditions in specific regions where alkaline rocks are produced has been a problem since HARKER's advocacy (1909) of the regional tension theory.

After HARKER, some scientists, entertained the idea that alkaline rocks occur in a tensional region, and, on the other hand, that calcalkaline rocks occur in a compressional region. They also considered that the occurrence of alkaline rocks in a region of special geotectonics is closely related to their genesis. Those who published their opinions on the petrogenesis of alkaline rocks are BECKE (1903), JENSEN (1908), SMYTHE (1913), STARK (1914), WINKLER (1914), EVANS (1915) and NIGGLI (1925). DALY (1918), on the contrary, published an opinion that alkaline rocks are developed in zones which were subjected to intense lateral pressure, while most calcalkaline rocks are found in a region where radial fissure lines are developed.

In opposition to these opinions, there are scientists who consider that there is no relation between the kind of rocks and geotectonics. SHAND (1938) is one of them. According to him, it is too radical an opinion to consider that alkaline rocks are related to special geotectonic structure, and volcanic activity, without exception, is related to faults.

No advance has been made concerning this problem since NIGGLI. In relatively recent times BOWEN (1938) published the following opinion on the relation between the alkaline volcanic rocks in the African Rift Valleys and the tectonic movements: it cannot be determined whether the zone of African Rift Valleys is a tension region like the former view or a compression region like the later view, since geologic evidence favors both views. We cannot be so bold as to connect such an uncertain fact with the chemical property of lavas.

After having examined the basis of the above views, the writer reached the following conclusion. That is, (1) the rocks should be treated by discriminating between volcanic rocks and plutonic rocks rather than by simply alkaline rocks and calcalkaline rocks. A result of such a treatment would be that it would not give rise to diverse opinions. (2) There is a slight confusion between the conception of a tension region or a compression region as an areal phenomenon and a region where normal faults or thrusts are developed as a local phenomenon. Consequently discussions must be made as to the above-mentioned opinions on the basis of the writer's judgement. In this paper, however, the discussions are omitted; instead, the Cenozoic alkaline petrographic province of Eastern Asia will be discussed.

The facts which can be surely pointed out as geologic characteristics of this petrographic province are as follows:

(a) From the viewpoint of the character of each rock series to which each rock belongs, Cenozoic basalt in the Eastern Asiatic continent belongs to the alkaline rock series almost without exception. Therefore, the Cenozoic alkaline petrographic

and discrimination of 'push' and 'pull' of the initial motion of earthquakes. The chains of active volcanoes in Japan are unquestionably related to this movement.

province of Eastern Asia includes an extensive region ranging from the eastern part of Siberia in the north to the coastal zone of the South China Sea in the south. However, the region where rocks having the characteristics of the alkaline rock series (TOMITA, 1933A) occur is limited to a relatively small region including the circum-Japan Sea alkaline petrographic province and Manchuria.

It has been an object of discussion whether the characteristics of geologic structure of such regions are related to the formation of alkaline rocks. Consequently, in this paper, discussion will be attempted with respect to the above region alone.

(b) In the Kilchu—Myŏngch'ŏn district and Dōgo, there was an age of marine deposition which ended in the Middle Miocene prior to the eruption of alkaline rocks. In the Kilchu—Myŏngch'ŏn district, the age of the marine deposition was followed by a period of upheaval and faulting. This period was followed by peneplanation. On the other hand, on Dōgo there is no evidence of peneplanation. Moreover, from Early to Middle Miocene, Dōgo was a field of volcanic activity in the calcalkaline petrographic province of the Japan Sea side type.

Judging from the results obtained by putting these facts together, the geologic hysteresis previous to the eruption of alkaline rocks is considered to be unrelated to the formation of alkaline rocks. Rather than the problem of this relationship, the problem arises as to under what geologic conditions olivine-basaltic magma—the parental magma of alkaline rocks—can intrude into the shallow part of the earth's crust without having its original condition changed.

(c) An example of deposition occurring to some extent in the course of the activity of alkaline rocks has been reported from the Kilchu—Myŏngch'ŏn district and Dōgo. The deposition, however, was not of the geosyncline type but rather of the inland type, and the deposition was not accompanied by folding movements. In this respect, it is remarkably different from the facts known for the Japan Sea side of northeastern Japan and, hence, must be regarded as of great importance.

However, this does not answer the question of the relation between these facts and the formation of alkaline rocks (alkaline trachyte, pantellerite, comendite, etc.) from the olivine-basaltic magma.

The possibility of the following facts alone is considered to be worthy of note: in the region which lacks deposition of the geosyncline type and folding movements associated with the deposition, that is, in the relatively stable region, olivine-basaltic magma which is the parental magma can work differentiation without suffering external effects (physical and chemical). However, in the disturbed region, the parental magma itself is possibly a secondary magma and the parental magma is liable to suffer external effects in the course of differentiation. As a matter of course, the following case may be included in this idea: according to the condition of the earth's crust, it may be possible that a rock type resembling calc-alkaline rock is produced by external effects in the course of differentiation of the alkaline rock series.

Such a problem is not related to this petrographic province alone, but is also generally related to petrogenesis of igneous rocks, hence it may be premature to come to any conclusion. The problem should instead be studied carefully from all sides.

Supplement

There are alkaline rock localities which were omitted from the correlation table (Table 1) and from the above descriptions because the time of eruption is not known, and for other reasons. These localities are described here for reference.

Otsurumizu in Kōzaki, Ōita Prefecture: This place has been famous for the occurrence of alkaline trachyandesite and a monchiquitic rock for a long time (Kozu, 1914). It is said that the mode of occurrence of these rocks seems to be dikes traversing the so-called Sambagawa system (consisting of chlorite schist, graphite schist and slate). From the facts that alkaline trachyandesite constitutes the main body and that the monchiquitic rock is glassy, these rocks have been inferred to be the marginal facies of the dikes. The chemical composition of these rock types is shown in Table 22 (nos. a and b).

It is not known whether these alkaline rocks from Otsurumizu belong to the Cenozoic alkaline petrographic province of Eastern Asia or are from the Inland Sea volcanic zone.

Hyŏnam, Kuk-tong, Tong-myŏn, Myŏngch'ŏn County, Hamgyŏng-pukto, Korea: With respect to the igneous body traversing the Heiroku-dō (P'yŏngnyuk-tong) beds and Kanchindo (Hamjin-dong) beds in the area, the composite intrusive sheet in Hyŏnam (about 4 km north of Myŏngch'ŏn) is a rare and interesting rock body in the Cenozoic alkaline petrographic province of Eastern Asia.

This rock body was first introduced by Tateiwa (1925) and Itō (1937) later described the details. This rock body intruded into the monoclinal Tertiary formation and is exposed for about 10 km along the river cliff. The distribution of the exposed part on a geologic map is incompletely ring-shaped. The thickness of the rock body exceeds 100 m but it thins abruptly on both ends. One end is cut by a fault and the other end splits into several dikes which pinch out. This rock body mainly consists of syenitic dolerite (Table 22, c and d), but in the vicinity of Hyŏnam, syenite which intruded later (Table 22, f) is found intercalated in the dolerite, and a contaminated rock type was produced in the boundary between both types. Moreover, syenitic aplite (Table 22, g) which intruded later, forms reticulated veins in the dolerite or syenite.

In the Hyŏnam area, several trachytic dolerite dikes, which intruded later than the above rock body, are developed. The dikes described by A. Lacroix (Table 22, e) seem to be those of this kind, and the lithologic character closely resembles that of Pleistocene basalt. It is believed that the rock constituting the Hyŏnam intruded sheet is Tertiary (Pliocene) in age.[24]

[24] This idea resulted from the writer's study of the evolution types of magma. Its detailed description is omitted in this paper.

Hoeryŏng and Chongsŏng districts, Hamgyŏng-pukto, Korea: In the Hoeryŏng area (ICHIMURA, 1924) and the Chongsŏng district (KŌZU and SETO, 1922) also, as in the above-mentioned Hyŏnam area, trachydolerite and alkaline syenite occur together. Results of chemical analyses of these types are shown in Table 23.

The noticeable type in this Hoeryŏng—Chongsŏng district is sodalite microsyenite. It has been known that a type containing sodalite is also found in trachydolerite (Table 23, k).

The feldspathoid group which occurs in the Cenozoic alkaline petrographic province of Eastern Asia is leucite, nepheline, and melilite, and the occurrence of sodalite minerals has not been reported from other regions.[25] The rocks in the district mentioned here distinctly traverse the Miocene series, and the age when the rocks intruded is considered Pliocene. Therefore, the rocks are members of this petrographic province.

Hence, it can be understood that a detailed petrogenetic study on various types in this district is both highly important and desirable.

P'i-tzu-wo and Ta-sha-ho in Kuan-tung Province and the vicinity of Ta-shih-ch'iao in Feng-t'ien Province, South Manchuria: From these places barkevikitic monchiquite has been reported (OGURA, 1933). The rock in Kuan-tung Province forms dikes traversing gneiss (pre-Sinian); the mode of occurrence of the rock in Kuo-ti Shan in Ta-shih-ch'iao is not known. The chemical composition of barkevikitic monchiquite from P'i-tzu-wo is shown in Table 24 (p).

There are no field data concerning the age determination necessary to confirm that these monchiquites belong to the petrographic province in question. However, according to Ogura's inference, the monchiquite in Kuo-ti Shan, Ta-shih-ch'iao, seems to traverse the quartz porphyry. If this quartz porphyry is of the same age as the Cretaceous monchiquite distributed in Jehol and North China, the monchiquite can be said to be a Cretaceous or post-Cretaceous intrusive rock.

On the other hand, the monchiquite from P'i-tzu-wo belongs from every chemical stand point to the same series as limburgite from Eastern Asia. That is, it is considered that the monchiquite in question and the limburgites belong to the same system of magmatic evolution; the former is a representative of dikes and the latter is a representative of effusive rocks.[26]

According to this view, it is inferred that the geologic age of monchiquite in question is the same as that of limburgites, that is, the Early Pliocene. Of the basalts in this area of the same age, the Pliocene basalts in the Shan-tung Peninsula are distributed from the northern end of the peninsula to Miao-tao and other islands and extend as far as Kuan-tung Province to the north through the neighboring

[25] The sodalite nepheline syenite in Poksin-san, P'yŏnggang County, Kangwŏn-do, Korea, is a famous example, but the geologic age seems to be the beginning of Mesozoic. (The result of age determination of allanite by means of the lead method is about 200 million years or less—personal communication from N. KOKUBU. Chemical Institute, Fac. Sci., Kyūshū Univ.) In this respect the above syenite does not belong to the Cenozoic alkaline petrographic province of Eastern Asia.

[26] A rock resembling monchiquite from Otsurumizu, Ōita, and alkaline trachyandesite both belong to a quite different series from limburgite.

islands. Hence, it is believed that in Kuan-tung Province also there was activity of basaltic magma in the same age as the Shan-tung Peninsula. Therefore, the above inference is considered reasonable.

Taiwan: Teschenite which occurs in Lu-k'u (the summit of the pass between K'ang-chieh-k'ang, Hsi-chih-chieh, Ch'i-hsing County, and Lu-k'u, Shih ting-chung, Wen-shan County) in the vicinity of T'ai-pei is a Miocene intruded sheet (ICHIMURA, 1929 and 1932) (Table 24, q, r, s).

According to YEN (1945) Miocene olivine basalt and basanite occur in the vicinity of Ma-wu-tu, Hsin-chu Province.

These basalts and the teschenite belong to the alkaline rock series, and it is beyond doubt that the rocks are constituents of the Cenozoic alkaline petrographic province of Eastern Asia as the age is Miocene or post-Miocene. The rocks, however, cannot be exactly correlated with the circum-Japan Sea alkaline petrographic province.

P'enghutao basalt also belongs to the Cenozoic alkaline petrographic province of Eastern Asia (KOTŌ, 1900).

Central China and South China: There are Pleistocene basaltic areas in An-hui and Chiang-su Provinces in the lower stream region of the Yang-tzu Chiang.[27] Of these, Nu Shan situated about 70 km east of Pang-fu, An-hui Province, has been known as a basaltic volcano. Moreover, in the Nan-ching—P'u-k'ou area, many Pleistocene basaltic tablelands (buttes) are distributed (the Fang Shan butte situated south of Nan-ching is most striking). These basalts, to our regret, have not been described in detail.

Concerning the distribution of the basalt, one opinion is that the basalt is a southeastern extension of the row of volcanoes extending from the Ta-t'ung Volcano group to the Mongolian plateau in the north-northwest. It is considered reasonable, however, to regard the area in question as the western extension of the San'in—Cheju-do volcanic zone. That is, it is considered that the zone of Pleistocene basaltic magma activity previous to the formation of the two seas—Huang-hai and Tung-hai—extended through the San'in district and Cheju-do to the lower reaches of the Yang-tzu Chiang.

On the other hand, there is a great lava plateau in the area extending from the Lei-chou Peninsula to the northern part of Hai-nan Tao—a representative in South China of the basalt distributed in the margin of the continent of Eastern Asia. Wei-chou Tao (Lat. 21° N, Long. 109°L) in Tung-ching Bay, an almost circular island 4 to 5 km in diameter, is a shield-like volcano, and there is an explosion crater (1 km in diameter) in the southern part (YAGI, 1949). The volcano consists of trachybasalt. The phenocrysts are olivine, but titanaugite, aegirine augite, and aegirine are found in the groundmass, and not only labrador-feldspar but also anorthoclase is found in the groundmass feldspar. The chemical

[27] The area about 100 km in diameter surrounded by Lake Hung-tse, Lake Kao-yu, Chin-p'u Railway, and the Yangtse River.

composition of the trachybasalt is shown in Table 24 (t). That is, this is an olivine trachybasalt distinctly belonging to the alkaline rock series.

Shan-hsi Province: In Shan-hsi Province, post-Triassic alkaline intrusive rocks occur in places. (It is said that the Triassic-Jurassic complex is traversed by intrusive rocks). The principal rock types are syenites such as åkerite and nordmarkite, but in Tzu-chin Shan, Lin-hsien, nepheline syenite, tinguaite, leucite syenite-porphyry, etc., are associated with the above rocks and in the area east of Lin-fen analcite syenite has been known.

The age of intrusion of these rocks is not exactly known. When NYSTROM (1927) published a synthesis of the alkaline rocks in Shan-hsi Province, he suggested that their age was not the same as the circum-Japan Sea alkaline petrographic province.[28] However, the writer cannot support his opinion for the following two reasons: (a) in Shan-hsi Province, there is no evidence of crustal movement by which igneous activity is considered to have been caused in the Tertiary, particularly in the Pliocene; (b) the Cretaceous crustal movements were remarkable throughout North China and the associated igneous activity was also active. In addition, in association with igneous activity, the intrusion of monzonite and åkerite occurred in the eastern margin of the Shan-hsi plateau (the area southwest of Hsing-t'ai, Ho-pei Province, and in the vicinity of Wu-an, Ho-nan Province). Thus, in the writer's opinion, the age of the alkaline intrusive rocks in question in Shan-hsi Province is Cretaceous and the activity belongs to the igneous activity associated with the well-known Yenshan movements. Therefore, these rocks are considered to have no relation with the Cenozoic alkaline petrographic province of Eastern Asia.

[28] At that time (1927) this petrographic province had been known through the following paper: YAMANARI, F., 1924, Soda-pyroxene in the Tertiary and post-Tertiary alkaline rocks from the environs of the Sea of Japan: *Jap. Jour. Geol. Geog.*, v. 3, nos. 3–4.

Table 2. Chemical Composition of Mongolian Basalts.

No.	1	2	3	4	No. / Norms	1	2	3	4
SiO_2	42.40	42.56	46.24	47.64	*or*	13.90	10.01	10.01	7.78
Al_2O_3	14.50	14.55	16.19	15.17	*ab*	8.12	14.54	23.06	27.77
Fe_2O_3	3.58	4.70	4.46	8.57	*an*	10.84	15.29	24.19	22.80
FeO	8.57	8.57	6.66	2.85	*ne*	17.75	11.71	2.84	—
MgO	6.17	7.54	7.27	7.63	*hl*	0.12	—	—	—
CaO	9.42	8.72	9.08	10.08	*wo*	11.49	8.93	7.31	8.70
Na_2O	4.90	4.31	3.36	3.28	*en*	6.80	5.70	5.20	11.50
K_2O	2.36	1.72	1.66	1.34	*fs*	4.09	2.64	1.45	—
TiO_2	2.13	2.28	2.02	2.02	*fo*	6.02	9.17	9.10	5.32
P_2O_5	1.31	1.03	0.51	0.65	*fa*	4.18	4.59	3.06	—
MnO	0.24	0.25	0.12	0.18	*mt*	5.34	6.73	6.50	4.18
H_2O+	3.70	2.97	1.37	0.38	*hm*	—	—	—	5.76
H_2O-	0.84	0.93	0.82	0.34	*il*	4.10	4.41	3.80	3.80
CO_2	n.d.	n.d.	n.d.	0.27	*ap*	3.02	2.35	1.34	1.68
Cl	0.07	n.d.	n.d.	n.d.					
Total	100.19	100.13	99.76	100.46	*or*	42	25	17	13
					ab	25	37	41	48
Analyst	RAOULT	RAOULT	RAOULT	RAOULT	*an*	33	38	42	39
					Q	14	10	10	21
					fo	51	60	68	79
					fa	35	30	22	0

1. Basanitoid; north entrance of Shen-wei-t'ai, Wan-ch'uan Hsien, Cha-ha-erh Province.
2. Basanitoid; Shan-p'o-pao, Wan-ch'uan Hsien, Cha-ha-erh Province.
3. Labradorite basalt, doleritic; near Han-no-pa pass, Wan-ch'uan Hsien, Cha-ha-erh Province.
4. Porphyritic andesine basalt; same locality as 3.

Table 1. Correlation of Cenozoic Alkaline Petrographic Provinces of Eastern Asia (Tomita, June 1951).

Age		Manchuria, Mongolia, western part of N. China (Tomita)	Shan-tung (Tomita)	Pai-t'ou Shan (Asano) Lung-wan volcano	Turyu-san (Kinosaki)	Kilchu, Myŏngch'ŏn (Yamanari, Tateiwa, Makiyama, Tomita)	Ullŭng-do (Tsuboi)	Cheju-do (Haraguchi)	Yŏnil (Tateiwa, Kobayashi)	Dōgo (Tomita)	Matsue (Tomita, Sakai)	Southwestern part of San'in (Tomita)	Northern Kyūshū (Tomita)	Setouchi district (Yamanari, Takai)	Age	
Alluvium	ua	1720 activity Wu-ta-lien-chih volcano, Erh-k'o Shan, and others	Late Alluvium	1702, 1597 activities	Younger fluviatile deposit	Younger fluviatile deposit		1007, 1002 activities Groups of small basalt cones		Late Alluvium Misaki basalt (B_5) Tōgō gravel	Alluvium	Late Alluvium Kasayama QB (B_5)	Onidake | Activities of Unzen, Kujū, and Tsurumi | Aso central cone		ua	Alluvium
	la	Loessic sand	Redeposited loess, brown soil	(Lung-wan volcano)	Older fluviatile deposit	Older fluviatile deposit					Nogi formation				la	
Pleistocene	ud	Loessic loam Ta-t'ung volcanic group	Loessic loam | Brown loam Loess and brownish gray loam | Brown sandy clay	Alkaline trachytic mud flow x Alkaline trachytic pumice	x	Alkaline trachyte (AT_4) Kuk-tong, Ŭngdŏk basalt (B_4)	Lapilli, pumice, leucite trachy-andesite x	x		x	x San'in-type hornblende andesites	San'in-type hornblende andesites	Aso lava San'in-type hornblende andesites Nagasa basalt 3		ud	Pleistocene
	md	Loess		x		Sangho-dong alkaline trachyte (AT_3) Kŭmsan formation	Alkaline trachytes x	Hornblende trachyandesites x			x		Hornblende andesite Obama formation		md	
	ld	Chou-k'ou-tien formation	Light red loam	Yen-chih basalt	Sindong-ni basalt	Ŏrang-ch'ŏn, Changdŏk basalt (B_3)	Trachybasalt	Basaltic agglomerate	2PA Yŏnil basalt	Ōminesan basalt (B_3)	Daikonjima QB	Kitanagato basalt	2PA Kitanagato basalt 2		ld	
	dp	San-men conglomerate	Basal conglomerate	x	Sindong-ni gravel	Namdae-ch'ŏn formation		Sŏgwip'o formation		x		Ōmijima gravel	Ōe formation	Setouchi series	dp	
Pliocene	up	T'aiyu formation: San-men formation Ching-lo formation Upper Yu-she series	x	Comenditic rocks	x Turyu-san tuff Moto-ri quartz porphyry	x Chungbong, Chuehbong comendite Saam formation			x	Phonolitic trachyte porphyry, grorudite, paisanite, comendites, Washigamine formation x	x	Hamada group			up	Pliocene
	mp	Lower Yu-she series		Pai-t'ou Shan alkaline trachyte	x Turyu-san alkaline trachyte	Ch'ilbosan AGP Puhyang alkaline rhyolite Alkaline trachyte (AT_2)		Halla-san alkaline trachytes		Alkaline trachyte (AT_2) Dakeyama formation Platy alkaline rhyolite Nakajima formation		x	Matsushima alkaline trachyte		mp	
	lp	x Hsueh-hua-shan trachybasalt Hsueh-hua-shan, Pao-te formations	Lu-hsi, Lin-ch'u, and Ch'i-hsia basaltic rocks Red clay	x Lao-hei-ting-tzu basalt	x Sŏkp'o basalt	Ŭngbong alkaline rhyolite Naesan-dong formation Alkaline trachyte (AT_1) Namyang-dong formation Chaedŏk-san basalt (B_2)				x	Trachybasalt (B_2) x	Nagahama, Daifunzan basalts	Sanukitic basalt 2 Nagasa basalt 1	Sanukitic basalt 2 Olivine-pyroxene basalt 2 Ikeda formation (upper)	lp	
Miocene	um	x Wei-ch'ang basalt and shale	x Shan-wang series			x Manho-dong formation (upper) Manho-dong basalt (B_1) Manho-dong formation (lower)	x	x	Yŏnil series x	Alkaline trachyte (AT_1) Hotokedani formation x Trachybasalt (B_1) Dōgo formation	Matsue formation Hornblende trachybasalt Tsuda formation Trachybasalt (B_1) Fujina formation	Tamasaki granite porphyry	Kaho City, Muroyama B	Sanukitic andesite 1 (orthorhombic pyroxene basalt) Olivine-pyroxene basalt 1 Ikeda formation (lower) Shōdo-shima, Kamiura B Sakate formation	um	Miocene
	mm					Hamjin-dong formation			P'omgong-ni volcanic rocks x	2PA (3) Nakayama formation x	Kimachi formation x	Hornblende andesite 2PA | Takayama Gb Karakane formation x		Hornblende andesite Mica andesite x Tsuyama series	mm	
	lm	x	x	x	Winam-dong formation P'yŏngnyuk-tong conglomerate	P'yŏngnyuk-tong formation			P'omgong-ni group: 2PA Rhyolite Conglomerate	Ochi group: 2PA (2) Rhyolite Basal conglomerate	2PA Ōmori formation	2PA Rhyolite x	2PA Yoroigadake lava	x Ishizuchiyama acidic lava x	lm	
	lmm		Wen-ho gravel and Ch'i-hsia gravel		x Yong-dong basalt	x Yong-dong basalt (BO)			Changgi group: Ŏil basalt and Ŏil formation Nultae-ri volcanic rocks Kamp'o conglomerate	Shimonaku basalt (BO) Rhyolite Andesite (1) Suki formation	Shinji series: Higashiyama basalt Tamatsukuri formation (upper) Andesite Tamatsukuri formation (lower)	Takayama metamorphic basalt Aburataniwan group x		Ishizuchiyama series x	lmm	
Oligocene		Meng-ku, Fan-chih, Fu-shun basalts and shale	x		Yong-dong formation	Yong-dong formation					Koura formation	Ashiya group	Sasebo group Pre-Sasebo Paleogene formation			Oligocene
Eocene		x Yuan-ch'u series P'ing-lu series Ch'ang-hsin-tien gravel	Kuan-chuang series		x	x			x	x	x	x		Ube coal-bearing formation x		Eocene
Note				"T'ien-ch'ih" at the top of the mountain seems to have been formed in Pleistocene; it must not be considered contemporaneous with eruption of alkaline trachyte and comenditic rocks.			No reliable data to determine exact geological age. Correlations were made on the basis of lithology and genetic nature of igneous rocks.	At the top of Halla-san is found a crater lake called Paengnok-tam. This crater lake was formed much later than the eruption of the Halla-san alkaline trachytic rocks.	2PA is two-pyroxene andesite.		QB is quartz basalt.	Only the correlatable data were used. Gb is gabbro.	Same as described on the left. "Nagasa" is an abbreviation of Nagasaki-Saga. DC is dacite, and B is basalt.	Little is known on the geology from Late Pliocene to Pleistocene.		

Table 3. Chemical Composition of Yong-dong Alkaline Basalts.

No.	5	6	7	8	9	10
SiO_2	43.48	43.52	44.32	44.90	47.82	49.52
Al_2O_3	16.78	9.83	12.51	18.57	18.85	16.42
Fe_2O_3	2.71	2.48	3.68	7.89	4.96	3.53
FeO	6.20	6.96	5.27	4.20	6.06	5.56
MgO	10.66	14.09	13.98	5.11	4.85	6.52
CaO	10.24	13.36	10.82	8.22	8.52	7.76
Na_2O	3.21	3.22	3.15	3.02	2.52	2.94
K_2O	0.69	0.87	0.80	3.33	2.43	2.35
TiO_2	1.04	1.01	1.18	1.03	1.47	1.32
P_2O_5	1.05	2.63	0.57	0.49	trace	1.09
MnO	0.17	0.17	0.20	0.79	0.14	0.15
H_2O+	2.79	2.23	2.71	1.62	1.60	1.74
H_2O-	0.54	0.31	1.04	0.52	0.95	1.09
Cl	n.d.	n.d.	0.10	n.d.	n.d.	n.d.
SO_3	n.d.	n.d.	0.03	n.d.	0.28	n.d.
Total	99.56	100.68	100.36	99.69	100.45	99.99
Anal.	TESHIMA	TESHIMA	RAOULT	USHIJIMA	GEOL. SURVEY, CHŌSEN	TESHIMA
Norms						
or	3.89	5.00	5.00	19.46	14.46	13.90
ab	16.77	9.17	11.53	13.10	20.96	24.63
an	29.47	9.73	17.51	27.52	33.08	21.96
ne	5.68	9.80	8.24	6.53	—	—
wo	5.80	16.70	13.57	3.94	3.83	3.83
en	4.10	12.00	10.60	3.30	7.90	16.00
fs	1.19	3.17	1.45	0.13	3.17	5.28
fo	13.11	16.24	17.08	10.15	2.94	0.21
fa	5.00	4.69	2.75	0.61	1.22	0.10
mt	3.94	3.71	5.34	11.37	7.19	5.10
il	1.98	1.98	2.28	1.98	2.74	2.43
ap	2.69	6.05	1.34	1.34	—	2.69
or	8	21	15	32	21	23
ab	33	38	34	22	31	41
an	59	41	51	46	48	36
Q	6	12	11	7	20	28
fo	71	68	77	88	56	53
fa	23	20	12	5	24	19

5 & 6. Olivine-analcite basalt; Yong-dong, Sŏ-myŏn, Myŏngch'ŏn-gun, Hamgyŏng-pukto, Korea (Tomita, T., 1928, *Shanghai Sci. Inst. Jour.*, sect. 2, v. 7, p. 58).

7. Olivine-analcite basalt; (Lacroix, A., 1928, *Geol. Soc. China Bull.*, v. 7, p. 58)

8. Olivine dolerite; Sindong-ch'ŏn, Changbaeng-myŏn, Kilchu-gun, Hamgyŏng-pukto, Korea (Tateiwa, I., 1925, *Geol. Atlas of Chōsen*, no. 4, p. 2).

9. Olivine dolerite; Yongdong-ch'ŏn (near Sindong-ch'ŏn), Changbaeng-myŏn, Kilchu-gun, Hamgyŏng-pukto, Korea.

10. Labradorite-olivine dolerite; Yong-dong (Tomita, T., 1931, *Shanghai, Sci. Inst. Jour.*, sect. 2, v. 1, p. 246).

Table 4. Chemical Composition of B_1.

No.	11	12	13	14	15	16	17	18	19
SiO_2	45.42	47.88	48.16	44.06	47.76	48.40	49.02	50.69	55.25
Al_2O_3	13.10	15.09	14.74	15.17	17.14	16.74	16.38	15.55	13.98
Fe_2O_3	4.51	3.59	2.75	3.64	2.64	0.52	3.28	3.90	1.06
FeO	7.66	8.59	7.45	10.98	6.05	8.87	6.29	3.24	7.56
MgO	9.30	4.96	6.55	7.76	8.43	7.38	10.24	4.56	2.06
CaO	10.62	8.82	10.06	9.62	12.27	8.20	8.75	11.23	7.00
Na_2O	2.82	3.31	3.28	2.25	2.33	2.78	2.49	3.37	3.72
K_2O	1.57	1.59	2.09	0.82	1.19	2.88	1.18	2.60	3.29
TiO_2	2.42	2.52	2.00	2.69	0.91	2.88	1.00	1.44	2.88
P_2O_5	0.50	0.58	0.41	0.75	0.85	0.92	0.44	0.94	0.35
MnO	0.23	0.19	0.16	0.22	0.17	0.15	0.19	0.20	0.15
H_2O+	0.76	1.71	2.00	1.37	0.44	0.07	0.30	0.69	2.78
H_2O-	0.43	1.21	0.42	0.45	0.36	0.10	0.66	2.08	0.46
CO_2	0.96	0.27	—	—	—	—	V_2O_3 0.03	—	—
Total	100.30	100.31	100.07	99.78	100.54	99.89	NiO 0.012 100.262	100.49	100.54
Anal.	RAOULT	RAOULT	RAOULT	USHIJIMA	TESHIMA	TESHIMA	KATSURA	TESHIMA	TESHIMA
Norms									*Q* 4.68
or	9.45	9.45	12.23	5.00	7.23	17.24	7.23	15.57	19.46
ab	20.83	27.77	21.22	18.86	19.39	21.48	20.96	26.46	31.44
an	18.35	21.68	19.18	28.91	32.80	24.46	30.02	19.74	11.68
ne	1.49	—	3.55	—	—	1.14	—	0.99	—
wo	10.21	6.96	11.72	5.80	9.40	4.18	4.41	12.76	8.47
en	7.20	8.50	7.30	7.90	6.90	13.67	14.40	10.50	5.20
fs	2.11	6.20	3.70	5.28	2.51	9.23	4.36	0.66	8.45
fo	11.27	2.73	6.37	8.05	9.94	11.27	7.84	0.63	—
fa	3.67	2.14	3.57	6.02	4.08	7.65	2.45	0.10	—
mt	6.50	5.34	4.18	5.34	3.71	0.70	4.87	5.57	1.62
il	4.56	4.71	3.80	5.17	1.67	5.47	1.98	2.74	5.47
ap	1.34	1.34	1.01	1.68	2.02	2.02	1.01	2.02	1.01
or	19	16	23	9	12	27	13	25	31
ab	43	47	40	36	33	34	36	43	50
an	38	37	37	55	55	39	51	32	19
Q	11	20	14	13	11	5	18	28	50
fo	67	44	55	50	63	56	62	67	18
fa	22	36	31	37	26	39	20	5	32

11. Andesine basalt; Wei-ch'ang Hsien, Je-ho Province (Lacroix, A., 1928, *Geol. Soc. China Bull.*, v. 7, p. 51).
12. Porphyritic andesine basalt; Hsiao-wan-wan-kou, Wei-ch'ang Hsien, Je-ho Province (Lacroix, A., 1928, *ibid.*, p. 48).
13. Andesine basalt, doleritic; (Lacroix, A., 1928, *ibid.*, p. 45).
14. Tephritic rock; Ichimuroyama, Takakura, Shōnaimura, Kahogun, Fukuoka Prefecture (Ueji, T., 1927, *Japan Assoc. Advancement Sci. Rept.*, no. 4, p. 351).
15. Olivine dolerite; Yamada, Goka-mura, Dōgo, Oki Islands (Tomita, T., 1951, *Fac. Sci., Kyūshū Univ., Research Rept.*, v. 3, no. 3, p. 86).
16. Hypersthene-augite-olivine-labradorite dolerite; east of Hatta, Dōgo, Oki Islands (Tomita, T., 1931, *Shanghai Sci. Inst. Jour.*, sect. 2, v. 1, p. 244).
17. Olivine dolerite; Kōnoura, Shōdoshima, Seto Inland Sea (Tomita, T., refer to 15).
18. Nonporphyritic trachyandesitic basalt; west of Kurada, Dōgo, Oki Islands (Tomita, T., 1935, p. 246).
19. Nonporphyritic vitreous trachyandesite; coast of Kama, Tōgō-mura, Dōgo, Oki Islands (Tomita, T., 1936, refer to reference 10, p. 114).

Table 5. Chemical Composition of AT_1.

No.	20	21	22	23	24
SiO_2	61.41	64.81	65.10	65.51	67.90
Al_2O_3	15.19	16.70	15.56	15.93	15.03
Fe_2O_3	2.03	1.34	2.01	1.17	2.03
FeO	1.33	2.57	2.79	2.12	1.67
MgO	trace	0.32	0.14	0.29	none
CaO	1.54	1.43	1.75	1.52	1.11
Na_2O	1.65	2.69	3.79	3.22	4.32
K_2O	4.33	7.07	6.53	6.99	5.85
TiO_2	0.75	0.75	0.76	0.69	0.66
P_2O_5	0.31	0.27	0.25	0.28	0.23
MnO	0.06	0.11	0.12	0.05	0.03
H_2O+	7.44	0.42	0.31	1.04	0.48
H_2O-	3.08	1.09	0.46	0.69	0.45
Total	99.12	99.57	99.57	99.50	99.76
Anal.	Teshima	Teshima	Teshima	Teshima	Teshima
Norms					
Q	32.64	17.76	14.16	11.76	18.60
C	5.61	2.65	—	1.02	—
or	25.58	42.26	38.36	41.14	34.47
ab	14.15	23.06	31.96	27.25	36.15
an	5.84	5.00	6.39	5.56	4.45
wo	—	—	—	—	0.12
en	—	0.80	0.40	0.70	—
fs	—	2.64	2.24	1.72	0.26
mt	2.09	1.86	3.02	1.86	3.02
hm	0.64	—	—	—	—
il	1.52	1.37	1.52	1.37	1.22
ap	0.67	0.67	0.67	0.67	0.34
or	56	60	50	56	46
ab	31	33	42	37	48
an	13	7	8	7	6
Q	100	87	88	87	99
fo	0	3	2	4	0
fa	0	10	10	9	1

20. Pumice of plagioclase-anorthoclase trachyte; foot-hill ESE of Mt. Yokoo, Dōgo, Oki Islands (Tomita, T., 1935, *Shanghai Sci. Inst.* Jour., sect. 2, v. 1, p. 252).
21. Plagioclase-anorthoclase trachyte; about 3 km south of Nawashiroda, Goka-mura, Dōgo, Oki Islands (Tomita, T., *ibid.*, p. 254).
22. Banded andesine-anorthoclase—sola-diopside-anorthoclase trachyte; Kōji, Goka-mura, Dōgo, Oki Islands (Tomita, T., *ibid.*).
23. Plagioclase-anorthoclase trachyte (rhyolitic); south shore of Omosu-wan, Dōgo, Oki Islands (Tomita, T., *ibid.*).
24. Plagioclase-anorthoclase trachyte (rhyolitic); a sea cliff opposite Suzume-jima, Nakamura, Dōgo, Oki Islands (Tomita, T., *ibid.*, p. 256).

Table 6. Chemical Composition of B_2 Dolerite.

No.	25	26	27	28	29	30
SiO_2	46.54	49.01	49.50	50.24	50.43	51.13
Al_2O_3	14.41	15.02	16.71	15.06	15.18	16.46
Fe_2O_3	7.07	5.02	3.52	6.32	2.77	3.41
FeO	4.49	6.89	8.86	7.68	8.92	8.16
MgO	4.88	6.31	4.04	4.05	4.98	2.88
CaO	8.81	7.86	7.68	8.08	8.96	5.30
Na_2O	5.07	3.38	3.24	3.52	3.13	4.14
K_2O	1.18	2.20	1.30	1.80	1.52	3.26
TiO_2	3.46	2.65	2.50	2.18	2.90	1.66
P_2O_5	1.88	0.76	0.64	0.34	0.49	1.27
MnO	0.15	0.27	0.20	0.05	0.21	0.46
H_2O+	0.96	0.08	0.93	0.30	0.01	0.35
H_2O-	1.18	0.17	0.55	0.26	0.11	0.21
CO_2	n.d.	0.35	0.27	n.d.	0.29	0.89
SO_3	n.d.	n.d.	n.d.	0.69	n.d.	n.d.
Total	100.08	99.97	99.94	100.57	99.90	99.56
Anal.	Teshima	Murata	Murata	?	Murata	Murata
Norms						
Q	—	—	1.92	3.24	0.72	0.24
or	7.23	12.79	7.78	10.56	8.90	19.46
ab	36.68	28.82	27.25	29.34	26.72	34.58
an	12.79	19.18	27.24	20.29	22.80	16.96
ne	3.41	—	—	—	—	—
wo	7.89	5.92	3.13	5.10	7.54	3.48
en	6.80	10.40	10.10	10.10	12.50	7.20
fs	—	3.04	9.64	5.55	9.64	2.38
fo	3.78	3.78	—	—	—	—
fa	—	1.22	—	—	—	—
mt	4.87	7.19	5.10	9.05	4.18	4.87
hm	3.68	—	—	—	—	—
il	6.69	5.17	4.71	4.10	5.47	3.19
ap	4.37	2.02	1.34	0.67	1.34	3.02
or	13	21	12	17	15	27
ab	65	47	44	49	46	49
an	22	32	44	34	39	24
Q	19	21	33	36	29	30
fo	81	60	33	40	38	51
fa	0	19	34	24	33	19

25. Olivine trachyandesitic basalt; Ksueh-hwa Shan, Ching-hsing Hsien, Ho-pei Province (Tomita, T., 1933, *Shanghai Sci. Jour.*, sect., 2, v. 1, p. 5).
26. Labradorite-augite-olivine dolerite; Paektu-san (Ogura, T., 1951, Chemical composition of the Manchurian igneous rocks, no. 118, *in* Geology and Mineral Resources of the Far East).
27. Augite-olivine-labradorite basalt; north of Shih-erh-tao-kou, Chang-pai Hsien, in the foothills of Paektu-san (Ogura, T., *ibid.*, no. 115).
28. Sŏkp'ŏ basalt; Kuryongso, Yongch'ŏl-li, Puktuil-myŏn, Tanch'ŏn-gun, Hamgyŏng-namdo, Korea (Kinosaki, Y., 1937, *Geological Atlas of Chōsen*, no. 14, p. 17).
29. Olivine augite-labradorite basalt; same as 27 (Ogura, T., *ibid.*, no. 109).
30. Trachyandesite; pass south of Ma-an Shan, P'aektu-san (Ogura, T., *ibid.*, no. 79).

Table 7. Chemical Composition of B_2 (Limburgites).

No.	31	32	33	34	35	36
SiO_2	42.64	42.93	43.26	42.52	42.80	42.98
Al_2O_3	12.32	10.71	13.40	12.72	14.01	13.67
Fe_2O_3	5.56	6.03	3.06	4.06	4.79	4.13
FeO	7.85	6.14	8.36	7.98	7.84	9.45
MgO	9.14	11.48	11.98	9.69	5.79	7.89
CaO	11.38	11.21	11.76	9.92	8.94	10.06
Na_2O	3.58	2.42	3.44	3.37	3.80	4.27
K_2O	1.39	1.98	1.03	2.09	3.57	2.11
TiO_2	3.44	2.48	1.75	3.46	2.22	3.18
P_2O_5	0.57	1.38	0.55	0.27	1.43	0.87
MnO	0.06	1.23	0.21	0.20	0.22	0.21
H_2O+	2.07	} 2.78	1.11	2.58	4.20	0.52
H_2O-	0.46		0.71	0.67	0.52	0.16
CO_2	n.d.	n.d.	n.d.	0.52	n.d.	0.64
Cl	n.d.	n.d.	n.d.	n.d.	n.d.	0.07
Total	100.46	100.77	100.62	100.05	100.13	100.34
Anal.	RAOULT	YOKOYAMA	HARUMOTO	RAOULT	RAOULT	RAOULT
Norms						
or	8.34	11.68	6.12	12.23	21.13	12.23
ab	8.38	10.48	3.67	7.86	7.07	10.35
an	13.34	12.51	18.07	13.34	10.56	12.79
ne	11.93	5.40	13.63	11.08	13.49	13.13
hl	—	—	—	—	—	0.35
wo	16.59	14.15	15.20	12.99	10.32	11.48
en	12.50	10.90	10.40	9.50	6.50	7.30
fs	2.38	1.72	3.56	2.24	3.17	3.43
fo	7.28	12.46	13.72	10.29	5.60	8.68
fa	1.53	2.04	5.20	2.75	3.06	4.38
mt	8.12	8.82	4.41	6.03	6.96	6.03
il	6.54	4.71	3.34	6.69	4.26	6.08
ap	1.34	3.36	1.34	0.67	3.36	2.02
or	28	34	22	37	54	35
ab	28	30	12	23	18	29
an	44	36	65	40	28	36
Q	18	14	12	14	12	12
fo	68	74	64	68	65	58
fa	14	12	24	18	23	30

31. Limburgite; Ch'i-hsing Shan, T'ai-an Hsien, Shan-tung Province (Lacroix, A., 1928, *Geol. Soc. China Bull.*, v. 7, p. 48).
32. Limburgite; Taifun-san, Iwami Province (H. S. Washington, 1917, U.S.G.S. Prof. paper, no. 99, p. 625).
33. Limburgite; Kasegizuka near Tsuyama, Okayama Prefecture (Harumoto, A., 1951, A lecture delivered at the 58th general meeting, *Geol. Soc. Japan*).
34. Limburgite; Kauo-tch'eng-chan, southwest of Lin-hsi Hsien, Je-ho Province (Lacroix, A., 1928) [in #31 above].
35. Limburgite; Mu-ling Ho, Chi-lin Province (Lacroix, A., 1929, *Geol. Soc. China Bull.*, v. 8, p. 55).
36. Limburgite; Ta-li-po, Ching-p'eng Hsien, Je-ho Province (Lacroix, A., 1928, [in #31 above], p. 48).

Table 8. Chemical Composition of B_2 (Nepheline Basalts).

No.	37	38	39	40	41	42	43	44	45	46
SiO_2	41.13	44.98	34.26	34.98	35.47	35.50	35.66	35.93	35.96	36.00
Al_2O_3	12.00	15.56	11.89	11.18	11.04	11.12	11.97	13.26	14.18	12.87
Fe_2O_3	4.27	5.15	7.55	5.99	7.30	5.23	5.19	5.59	6.43	5.55
FeO	9.94	7.30	8.20	8.83	9.01	6.75	9.69	10.06	8.55	9.68
MgO	9.42	3.31	8.01	8.36	9.22	8.55	8.35	7.90	7.14	8.68
CaO	10.97	9.20	14.75	13.52	14.16	15.00	14.39	13.37	14.00	16.28
Na_2O	5.22	5.34	4.16	4.22	3.62	5.41	3.65	4.92	2.44	3.64
K_2O	2.24	1.29	1.72	3.99	1.97	0.86	1.89	2.92	0.92	1.85
TiO_2	2.62	2.89	2.30	2.39	2.38	1.95	3.74	2.28	2.35	1.74
P_2O_5	1.32	0.43	2.36	2.53	1.75	2.43	1.37	2.39	2.17	1.55
MnO	0.17	0.23	0.34	0.26	0.40	0.27	0.30	0.34	0.33	0.31
H_2O+	0.68	3.77	3.49	2.49	2.98	4.88	4.04	0.57	4.43	2.03
H_2O-	0.27		0.54	1.14	0.32	1.19		0.26	1.13	0.59
CO_2	n.d.	n.d.	0.29	n.d.	0.13	0.45	n.d.	0.15	0.20	n.d.
Cl	n.d.	n.d.	0.18	n.d.	0.12	0.17	n.d.	n.d.	n.d.	n.d.
S	n.d.	0.04	0.07	0.10	0.14	0.08	n.d.	n.d.	n.d.	n.d.
Total	100.25	99.49		100.00			100.24	99.94	100.23	100.77
Anal.	HARUMOTO	SHIMIZU & OHASHI	SAITO	SUGAWARA, OANA, & KAYAMA	SAITO	SAITO	YOKOYAMA	TANAKA	TANAKA	HARUMOTO
Norms										
or	12.79	7.78	—	—	—	—	—	—	5.56	—
ab	2.10	23.06	—	—	—	—	—	—	—	—
an	3.06	14.73	8.90	—	8.06	3.34	10.84	5.56	25.02	13.07
lc	—	—	7.85	18.75	9.16	4.36	8.72	13.52	—	8.72
ne	22.72	11.93	19.03	19.03	16.47	24.71	16.76	22.44	11.08	16.79
ac	—	—	—	0.46	—	—	—	—	—	—
wo	17.98	11.72	10.67	3.48	11.37	15.08	10.56	6.61	12.64	7.54
en	11.60	7.00	7.60	2.10	7.90	10.90	7.10	4.00	8.30	4.70
fs	5.15	4.09	2.11	1.19	2.51	2.77	2.64	2.24	3.43	2.38
fo	1.40	0.91	8.68	13.16	10.64	7.00	9.66	11.06	6.72	11.90
fa	4.18	0.51	2.65	8.87	3.67	1.94	4.08	6.63	2.96	6.53
cs	—	—	7.22	12.99	7.40	5.93	8.08	8.77	—	12.38
mt	6.26	7.42	11.14	—	10.67	7.66	7.66	7.89	9.28	8.12
il	5.02	5.47	4.41	4.56	4.56	3.80	6.99	4.41	4.41	3.34
ap	3.02	1.01	5.71	6.05	4.03	5.71	3.36	5.71	5.04	3.70
cc	—	—	—	—	—	—	—	0.30	0.10	—
Q	17	33	8	14	10	4	9	10	14	9
ne	64	57	71	50	64	85	66	63	67	66
kp	19	10	21	36	26	11	25	27	19	25
Q	6	24	13	3	9	17	12	7	16	8
fo	63	47	67	58	75	65	62	58	58	59
fa	31	29	20	39	16	18	26	35	26	33

37. Nepheline basalt; Lao-chai Shan, near T'ang-shan, Ch'i-hsia Hsien, Shan-tung Province (Harumoto, A., 1949, *Chigaku*, Kyōto Univ., v. 1, no. 1, p. 42).
38. Nepheline basalt (manchurite); Ts'ao-tzu-erh (Tsao-shi-err), Ying-e-men (Yingemen), Ch'ing-yuan Hsien, Feng-tien Province (Kotō, B., 1912, *Tōkyō Univ., Coll. Sci. Jour.*, v. 32, p. 11), (Lacroix, B., 1929, *Geol. Soc. China Bull.*, v. 8, p. 51).
39. Nepheline basalt; in the vicinity of Nagahama, Iwami Province (newly analyzed by Nobufusa Saito).
40. Nepheline basalt; same locality as above (Sugawara, S., Oana, S., and Toyama, T., 1945, *Tōkyō Imp. Acad. Proc.*, v. 20, p. 722).
41. Nepheline basalt; same locality (newly analyzed by N. Saitō).
42. Nepheline basalt, same locality (newly analyzed by N. Saitō).
43. Nepheline basalt; same locality (H. S. Washington, 1917, U.S.G.S. Prof. paper, no. 99, p. 699).
44. Nepheline basalt, same locality (Ichikawa, W., 1928, unpublished graduation thesis (MS), Tōkyō Imp. Univ., p. 55).
45. Nepheline basalt; same locality (Ichikawa, W., *ibid.*, p 56).
46. Melilite-nepheline basalt; vicinity of Takano village (Harumoto, A., 1949, *Geol. Soc. Japan Jour.*, v. 55, p. 148).

Table 10. Chemical Composition of the Rocks From Kilchu and Myŏngch'ŏn Districts.

No.	73	74	75	76	77	78	79	80	81	82	83	84
SiO_2	63.52	67.88	68.04	68.17	72.54	73.13	73.21	73.38	74.28	74.30	74.65	75.18
Al_2O_3	15.80	13.47	12.83	12.47	11.79	12.78	14.55	11.88	12.48	10.40	10.43	11.40
Fe_2O_3	3.47	2.46	2.50	0.05	2.82	2.87	0.40	2.32	0.74	2.75	3.38	1.25
FeO	2.89	3.27	3.72	0.98	1.91	1.29	2.39	1.91	2.03	2.15	1.30	2.45
MgO	0.45	tr.	0.80	0.50	tr.	0.22	1.22	tr.	0.17	0.37	0.08	tr.
CaO	1.23	1.14	2.23	0.66	0.52	0.05	1.10	0.54	0.70	0.32	0.46	0.48
Na_2O	5.65	5.72	3.99	7.89	4.44	3.71	2.69	4.08	2.75	4.19	4.13	3.92
K_2O	5.50	4.35	5.48	6.10	4.87	5.14	3.80	5.05	5.81	5.03	4.97	4.68
TiO_2	tr.	0.36	none	tr.	0.40	0.23	0.06	0.28	0.43	0.37	0.23	0.24
P_2O_5	tr.	0.07	none	tr.	0.06	none	0.01	0.08	none	0.04	0.01	0.06
MnO	0.05	0.18	tr.	none	0.13	0.05	0.23	0.10	tr.	0.09	n.d.	0.14
H_2O+	0.43	0.57	0.58	2.82	0.53	0.25	0.38	0.30	0.91	0.50	0.21	0.30
H_2O-		0.67	0.32	1.10	0.27	0.16	0.18	0.14	0.17	0.40	0.25	0.35
SO_3	1.12	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Total	100.11	100.14	100.49	100.74	100.28	99.88	100.22	100.06	100.47	100.91	100.10	100.45
Anal.	Chōsen U.G.	Raoult	Seto	Seto	Raoult	Ushijima	Seto	Raoult	Seto	Yagi	Seto	Raoult
Norms												
Q	6.18	16.44	17.64	19.08	27.54	31.62	36.78	29.04	36.96	30.72	31.68	32.52
C	—	—	—	—	—	1.02	3.98	—	0.41	—	—	—
or	32.80	26.13	32.80	36.14	28.91	30.02	22.24	30.02	34.47	29.47	29.47	27.80
ab	47.68	44.54	34.06	30.39	33.54	31.44	23.06	33.01	23.06	25.68	25.68	32.49
an	1.39	—	0.28	—	—	0.28	5.56	—	3.61	—	—	—
ac	—	3.23	—	—	3.70	—	—	1.39	—	8.32	8.32	0.46
ns	—	—	—	4.76	—	—	—	—	—	0.12	—	—
wo	1.86	0.35	4.52	1.51	1.04	—	—	0.35	—	0.70	0.93	1.04
en	1.10	—	2.00	1.30	—	0.60	3.10	—	0.40	0.90	0.20	—
fs	2.51	4.49	4.62	1.85	1.72	—	4.22	1.58	2.38	3.43	1.58	3.43
mt	5.10	2.09	3.71	—	2.32	3.71	0.70	2.55	1.16	—	0.70	1.62
il	—	0.76	—	—	0.76	0.46	0.15	0.61	0.76	0.76	0.46	0.46
ap	—	0.34	—	—	—	hm 0.32	—	0.34	—	—	—	—
or	40	37	49	54	46	49	44	48	56	53	53	46
ab	58	63	51	56	54	51	45	52	38	47	47	53
an	2	0	0	0	0	0	11	0	6	0	0	1
Q	72	83	79	90	95	99	88	96	95	91	96	93
fo	8	0	6	4	0	1	5	0	1	2	0	0
fa	20	17	15	6	5	0	7	4	4	7	4	7

73. Tōryū-san alkali-trachyte; Kusŏktŏk, Yongch'ŏl-li, Puktuil-myŏn, Tanch'ŏn-gun, Hamgyŏng-namdo, Korea (Kinosaki, Y., 1932, *Geologic Atlas of Chōsen*, no. 14, p. 17).
74. Trachytes à silice libre (2e facies); Tongho-dong, Hago-myŏn, Myŏngch'ŏn-gun, Hamgyŏng-pukto, Korea (Lacroix, A., 1927, *Comptes Rendus*, Tome 185, p. 1414).
75. Aegirin-augite-anorthoclase trachyte (Chongam-san hakutoite); Tongho-dong, Hago-myŏn, Myŏngch'ŏn-gun, Hamgyŏng-pukto (Kōzu, S., and Seto, K., 1926, Proc. 3rd Pan-Pacific Sci. Cong. Tōkyō, v. 1, p. 781).
76. Spherulitic trachyte-pitchstone (at the base of the Mokchin purplish alkali-trachyte); Wŏnsŏk-tong, Sanggo-myŏn, Myŏngch'ŏn-gun, Hamgyŏng-pukto (Kōzu, S., and Seto, K., 1929, Abstract from the paper of the 4th Pacific Sci. Cong. Java, v. 2, B, p. 1067).
77. Comendite (facies à lithophyses); Chaedŏk-san, Myŏngch'ŏn-gun, Hamgyŏng-pukto (Lacroix, A., 1927 [item 74], p. 1413).
78. Comendite (Puhyang alkali rhyolite); Ch'ondŏng-ni, Myŏngch'ŏn-gun, Hamgyŏng-pukto (Yamanari, F., 1925, *Geologic Atlas of Chōsen*, no. 3, p. 10).
79. Comendite; Kapsan, Unhŭng-myŏn, Kapsan-gun, Hamgyŏng-namdo (Kōzu, S., and Seto, K., 1929, p. 1067).
80. Comendite (facies à lithophyses); Kaesim-dong, Myŏngch'ŏn-gun, Hamgyŏng-pukto (Lacroix, A., 1929, p. 1413).
81. Sohō (Silbong) moonstone rhyolite; Kwangsŏk-ch'on, Sanggo-myŏn, Myŏngch'ŏn-gun, Hamgyŏng-pukto (Yamanari, F., 1925, p. 10).
82. Comendite (aphanitic); Sintoyong near Ch'ilbo-san, Myŏngch'ŏn-gun, Hamgyŏng-pukto (Yagi, K., 1950, *Kagaku*, [Science], v. 20, no. 2, p. 84).
83. Comendite; Kapsan, Unhŭng-myŏn, Kapsan-gun, Hamgyŏng-namdo (Kōzu, S., and Seto, K., 1922, *Geol. Soc. Japan Jour.*, v. 29, p. 216).
84. Comendite (facies micro-granulitique); K'ach'i-bong (Chak-pong), Myŏngch'ŏn-gun, Hamgyŏng-pukto (Lacroix, A., 1927 [item 74], p. 1413).

Table 11. Chemical Composition of the Rocks From Kilchu and Myŏngch'ŏn Districts.

No.	A	B	C	D	E	F
SiO_2	67.74	68.17	69.88	70.19	73.26	74.27
Al_2O_3	19.03	16.77	15.50	15.17	15.03	16.92
Fe_2O_3	2.28	2.44	3.66	2.01	0.96	0.98
FeO	1.54	2.00	2.12	2.46	1.46	2.28
MgO	0.08	0.12	0.36	0.28	tr.	0.51
CaO	0.61	0.42	0.27	0.24	tr.	1.30
Na_2O	3.16	2.99	1.96	1.76	3.34	3.26
K_2O	4.66	4.55	3.74	5.74	5.06	0.51
TiO_2	0.45	0.25	0.16	none	none	none
P_2O_5	tr.	tr.	tr.	tr.	tr.	tr.
MnO	0.15	0.09	0.23	0.22	tr.	tr.
H_2O+	0.57	0.87	0.91	0.38	} 0.46	0.41
H_2O-	0.23	0.55	0.55	0.26	}	0.19
SO_3	tr.	0.39	0.59	tr.	n.d.	n.d.
Total	100.50	99.61	99.90	99.66	99.66	100.63
Anal.	Chōsen U.G.	C.U.G.	C.U.G.	C.U.G.	C.U.G.	Seto
Norms						
Q	29.76	23.22	37.02	29.70	31.18	49.14
C	7.55	—	3.37	3.98	3.88	8.67
or	27.80	27.24	21.68	33.92	30.02	2.78
ab	26.72	25.15	16.77	23.58	28.82	27.77
an	3.06	18.90	13.34	1.11	—	6.39
wo	—	0.81	—	—	—	—
en	0.20	0.30	0.90	0.70	—	1.30
fs	0.40	1.45	0.92	3.17	1.85	1.58
mt	3.25	3.48	5.34	3.02	1.39	1.39
il	0.91	0.46	0.30	—	—	—

A. Alkaline granite porphyry; Maegong-ni, Sanggo-myŏn, Myŏngch'ŏn-gun, Hamgyŏng-pukto (*Mineral Survey Chōsen, Bull.*, v. 3, no. 3, p 52, 1927).

B. Kom-san hakutoite; Kwangji-bong, Ungp'yŏng-myŏn, Kilchu-gun, Hamgyŏng-pukto (*Ibid.*, p. 52).

C. Chŭng-bong moonstone rhyolite; Kwangsŏk-ch'on, Hago-myŏn, Myŏngch'ŏn-gun, Hamgyŏng-pukto (*Ibid.*, p. 52). (See Table 10, no. 80).

D. Chak-pong comendite; Samp'o-bong, Sanggo-myŏn, Myŏngch'ŏn-gun, Hamgyŏng-pukto (*Ibid.*, p. 52). (See Table 10, no. 83).

E. Quartz trachyte; Saengyang-ni, Chasŏ-myŏn, Samsu-gun, Hamgyŏng-namdo (*Ibid.*, p. 52).

F. Obsidian; Sŏngmak-tong, Hago-myŏn, Myŏngch'ŏn-gun Hamgyŏng-pukto (Kōzu, S., and Seto, K., 1929, Abstract of paper from the 4th Pacific Sci. Cong. Java, v. 2, B, p. 1067).

Table 12. Chemical Composition of Neutral, Acid and Alkaline Rocks of Oki Islands.

No.	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110
SiO_2	64.51	65.37	66.55	67.51	69.11	70.57	71.32	71.37	71.77	71.94	72.21	72.73	73.14	73.39	73.39	73.71	73.90	74.53	67.82	69.90	70.43	70.90	73.80	61.15	57.14	62.88
Al_2O_3	14.18	15.63	17.27	13.69	15.53	15.15	13.16	14.72	13.28	14.27	11.20	9.57	12.28	11.37	14.57	10.17	13.88	12.84	11.94	15.14	11.90	10.42	9.91	19.24	18.05	17.47
Fe_2O_3	3.42	3.03	1.16	1.68	0.70	1.87	0.83	1.08	1.23	1.78	2.25	3.86	1.91	2.10	0.27	1.30	0.50	0.45	2.26	2.35	3.89	2.56	2.35	1.96	2.80	1.17
FeO	2.81	1.48	0.13	2.83	2.48	0.16	2.79	1.38	1.57	0.94	2.66	3.24	2.20	2.97	0.31	1.08	0.27	1.76	2.38	1.08	1.76	3.77	3.60	2.38	2.59	2.94
MgO	0.21	0.03	none	0.18	0.07	0.16	0.04	0.36	tr.	0.05	0.08	0.26	0.04	none	none	tr.	tr.	0.05	0.04	tr.	0.17	0.09	0.09	tr.	1.42	0.73
CaO	1.49	1.59	0.69	0.61	1.20	0.50	0.23	1.36	0.45	0.12	0.27	0.07	0.19	0.23	0.55	0.23	0.47	0.39	0.21	1.20	0.19	0.17	0.07	1.08	4.03	2.17
Na_2O	4.37	3.98	6.62	4.65	4.08	4.48	4.23	3.74	4.60	4.69	4.29	4.71	4.67	4.26	5.66	4.27	4.04	3.71	5.03	2.75	3.51	3.93	4.43	7.21	5.27	4.55
K_2O	5.75	6.47	5.74	5.45	5.43	6.04	4.94	5.69	5.17	5.37	4.81	4.37	4.34	4.19	4.38	4.56	5.63	5.44	4.85	4.81	4.81	4.72	4.38	4.93	4.71	5.80
TiO_2	0.59	0.35	0.89	0.53	0.46	0.40	0.24	0.04	0.22	0.29	0.44	0.24	0.40	0.45	0.25	0.10	0.58	0.15	0.19	0.22	0.36	0.23	0.28	0.28	1.82	0.91
P_2O_5	0.05	tr.	0.35	0.05	tr.	0.09	0.05	0.12	0.75	0.08	0.10	none	tr.	0.27	0.09	none	tr.	tr.	tr.	tr.	0.03	0.02	0.18	tr.	0.59	0.31
MnO	0.03	0.11	tr.	0.01	0.05	tr.	0.09	0.06	0.03	tr.	0.10	0.13	0.08	0.11	none	0.03	none	0.06	0.11	0.03	0.21	0.11	0.12	0.17	tr.	tr.
H_2O+	2.48	0.94	0.31	2.77	1.10	0.97	1.31	0.33	0.25	0.29	1.45	0.16	0.19	0.75	0.22	3.62	0.32	0.16	4.17	0.77	1.22	1.18	0.33	1.01	2.06	1.55
H_2O-		0.62	0.61		0.22		0.43	0.10	0.24	0.40		0.12	0.17	0.11	0.16	0.46	0.29	0.02	0.81	1.61	1.66	1.74	0.15	0.22		
Total	99.89	99.60	100.32	99.96	100.43	100.39	99.76	100.35	99.56	100.22	99.86	99.46	99.61	100.20	99.85	99.53	99.88	99.56	99.81	99.86	100.14	99.84	99.69	99.63	100.48	100.48
Anal.	Yokoyama	Teshima	Teshima	Yokoyama	Teshima	Yokoyama	Teshima	Endō	Teshima	Teshima	Yokoyama	Teshima	Teshima	Teshima	Teshima	Teshima	Teshima	Teshima	Teshima	Teshima	Tanaka	Tanaka	Teshima	Teshima	Yokoyama	Yokoyama
Norms																										
Q	14.28	14.22	6.42	17.52	20.70	20.64	22.02	24.00	24.12	24.00	28.62	31.62	28.38	31.08	22.98	34.14	27.96	29.88	20.64	32.82	30.96	28.44	31.92	—	0.30	7.44
C	—	—	0.20	—	0.82	0.71	0.82	0.20	—	0.71	—	—	—	—	—	—	0.31	—	—	3.16	0.61	—	—	—	—	—
or	33.92	38.36	33.92	32.25	31.69	35.58	28.91	33.92	30.58	31.69	28.36	26.13	25.58	25.02	26.13	27.24	33.36	32.25	28.91	28.36	28.36	27.80	26.13	28.91	27.80	34.47
ab	36.68	34.06	55.54	39.30	34.58	37.73	35.63	31.44	38.77	39.82	30.92	26.72	39.30	35.11	47.68	26.72	34.06	31.44	34.06	23.58	29.87	27.25	26.20	55.81	44.54	38.25
an	2.22	5.28	—	0.28	5.84	1.67	0.28	5.84	0.28	—	—	—	—	—	1.39	—	2.22	1.95	—	5.84	0.83	—	—	5.56	11.68	10.29
ac	—	—	—	—	—	—	—	—	—	—	4.16	11.09	—	0.92	—	3.72	—	—	6.47	—	—	5.08	6.93	ne 2.70	—	—
ns	—	—	—	—	—	—	—	—	—	—	—	0.12	—	—	—	1.22	—	—	0.24	—	—	—	0.85		—	—
wo	2.21	1.16	—	0.81	—	—	—	—	0.81	—	0.23	—	0.46	—	0.23	0.46	—	—	0.46	—		0.35	—	fo —	1.86	—
en	0.50	0.10	—	0.50	0.20	0.40	0.10	0.90	—	0.10	0.20	0.70	0.10	—	—	—	—	0.10	0.10	—	0.40	0.20	0.20		3.70	1.80
fs	1.45	—	tn 0.59	2.77	3.30	—	4.22	1.72	0.92	—	4.09	5.68	0.40	3.30	—	1.85	—	2.77	2.78	—	—	6.21	6.20	fa 1.84	—	2.90
mt	4.87	3.94	ru 0.48	2.55	0.93	—	1.16	1.62	1.86	2.09	1.16	—	2.78	2.55	0.23	—	—	0.70	—	2.78	5.10	1.16	—	3.02	3.02	1.86
hm	—	0.32	1.12	—	—	1.76	—	—	—	0.16	—	—	—	—	0.16	—	0.48	—	—	0.48	0.32	—	—	—	0.80	—
il	1.06	0.76	0.30	1.06	0.91	0.30	0.46	—	0.46	0.61	0.91	0.46	0.76	0.91	0.46	0.15	0.61	0.30	0.46	0.46	0.76	0.46	0.61	1.34	3.50	1.67
ap	—	—	1.01	0.34	—	ru 0.24 ap 0.34	0.34	0.34	0.81	2.02	0.34	—	—	0.40	0.34	—	ru 0.32	—	—	—	—	—	—	—	1.34	0.67
or	47	49	37	45	44	48	45	48	44	44	48	50	39	42	35	50	48	49	46	49	48	51	50	32	33	42
ab	50	44	62	55	48	50	55	44	56	56	52	50	61	58	63	50	49	48	54	41	51	49	50	62	53	46
an	3	7	1	0	8	2	0	8	0	0	0	0	0	0	2	0	3	3	0	10	1	0	0	6	14	12
Q	91	100	100	88	89	99	87	93	96	100	93	88	95	92	100	92	100	93	91	100	99	86	87	0	35	71
fo	2	0	0	2	1	1	0	2	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	65	10
fa	7	0	0	10	10	0	13	5	4	0	7	11	5	8	0	8	0	7	9	0	0	14	13	100	0	19

85. Olivine-bearing soda diopside-anorthoclase trachyte; Utagitōge, Chūjōmura, Dōgo (Kōzu, S., 1913, *Sci. Rep. Tōhoku Imp. Univ.*, 2nd ser., v. 1, p. 45).
86. Soda diopside-bearing anorthoclase trachyte; west of Kaminishi, Chūjōmura, Dōgo (Tomita, T., 1935, *Jour. Shanghai Sci. Inst.*, sect. 2, v. 1, p. 254).
87. Groundmass of anorthoclase trachyte; Inushimazaki, Tōgōmura, Dōgo (Tomita, T., *ibid.*, p. 256).
88. Less quartzose comendite; Nakamura, Dōgo (Kōzu, S., *loc. cit.*, p. 39).
89. Soda diopside-bearing anorthoclase hyalotrachyte; Uzumoriyama, Isomura, Dōgo (Tomita, T., *ibid.*, p. 258).
90. Platy anorthoclase liparite; Terayama, Saigōmachi, Dōgo (Kōzu, S., *loc. cit.*, p. 42).
91. Anorthoclase felsite; Tonomejima, Ōhisa, Dōgo (Tomita, T., 1936, *Jour. Shanghai Sci. Inst.* sect. 2, v. 2, p. 120).
92. Obsidian; Dōgo.
93. Anorthoclase felsite; Nishida, Isomura, Dōgo (Tomita, T., 1936, p. 120).
94. Anorthoclase liparite; Tonomejima, Ōhisa, Tōgōmura, Dōgo (Tomita, T., 1936, p. 120).
95. Anorthoclase-quartz liparite (comenditic); Higashitani, Motoya, Nakamura, Dōgo (Kōzu, S., 1913, *Jour. Geol.*, v. 21, p. 66; Kōzu, S., p. 37).
96. Non-porphyritic-alkali liparite (comenditic); northwest of Takagamine, Dōgo (Tomita, T., 1936, p. 260).
97. Anorthoclase-quartz liparite (comenditic); Maokudani, Nakamura, Dōgo (Tomita, T., 1935, p. 260).
98. Aegirite-alkali hornblende-anorthoclase-quartz liparite; Okukitadani, Chōshi, Chūjōmura, Dōgo (Tomita, T., 1936, p. 122)
99. Anorthoclase felsite; Kamo, Isomura, Dōgo (Tomita, T., 1935, p. 260).
100. Alkaline liparite-perlite; between Yamada and Hisami, Gokamura, Dōgo (Tomita, T., 1936, p. 120).
101. Anorthoclase felsite; shore opposite Nishida, Isomura, Dōgo (Tomita, T., 1935, p. 260)
102. Anorthoclase liparite-obsidian; south of Hisami, Gokamura, Dōgo (Tomita, T., 1935, p. 260).
103. Biotite-bearing anorthoclase-quartz hyalophyre; Minamitani, Ushiki, Fusemura, Dōgo (Tomita, T., 1936, p. 123).
104. Biotite-bearing anorthoclase-quartz porphyry; Minamitani, Ushiki, Fusemura, Dōgo (Tomita, T., 1936, p. 123).
105. Soda sanidine-bearing quartz prophyry (grorudite); Maokudani, Nakamura, Dōgo (Tomita, T., 1935, p. 258).
106. Blue hornblende-bearing anorthoclase hyalo-quartz porphyry (paisanite); Maokudani, Nakamura, Dōgo (Tomita, T., 1935, p. 258).
107. Blue hornblende-anorthoclase-quartz porphyry; Maokudani, Ōhisa, Tōgōmura, Dōgo (Tomita, T., 1936, p. 123).
108. Anorthoclase-phonolitic trachyte porphyry (tinguaite-porphyry); Tokageiwa, ssw of Kazuoyama, Dōgo (Tomita, T., 1935, p. 252).
109. Hornblende-bearing andesine-anorthoclase trachyte; Mimiura, Dōzen (Kōzu, S., 1913, *Sci. Rep. Tōhoku Imp. Univ.*, 2nd ser., v. 1, p. 48).
110. Olivine-bearing oligoclase-anorthoclase glassy trachyte; Takuhisan, Dōzen (Kōzu, S., *ibid.*, p. 47).

Table 13. Chemical Composition of Neutral and alkaline Rocks of Matsushima and Cheju-do.

No.	111	112	113	114	115	116	117	118	119	120	121
SiO_2	62.36	63.74	64.61	64.62	54.28	54.87	56.19	56.34	59.51	60.65	61.36
Al_2O_3	17.95	14.28	17.53	17.90	17.82	17.91	16.12	17.43	18.52	18.20	18.12
Fe_2O_3	1.55	3.11	1.46	1.86	2.66	4.68	2.44	3.52	2.84	4.00	2.08
FeO	2.62	3.62	1.48	1.84	6.95	3.51	5.50	6.46	2.68	0.62	2.14
MgO	0.72	1.90	tr.	0.16	1.57	1.21	3.07	0.84	0.78	0.86	0.06
CaO	2.75	2.20	4.22	2.31	6.49	7.38	7.63	3.80	4.19	6.81	3.21
Na_2O	5.60	4.79	5.33	5.19	3.91	4.58	4.39	5.10	5.02	4.54	6.08
K_2O	4.16	4.50	4.95	5.25	3.40	3.20	2.30	3.32	3.16	3.08	4.95
TiO_2	0.66	1.07	0.43	0.27	1.23	1.33	2.14	0.94	1.13	0.44	0.37
P_2O_5	0.29	0.16	n.d.	0.02	0.29	1.02	0.55	1.24	0.14	0.98	0.23
MnO	0.48	0.17	0.19	0.08	0.18	n.d.	0.30	0.25	0.22	n.d.	0.12
H_2O+	0.87	0.03	0.26	0.18	0.37	0.77	0.47	1.02	1.37	0.21	1.75
H_2O-		0.25	0.12	0.14						0.12	
CO_2	n.d.	tr.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S	n.d.	0.06	n.d.	n.d.	SO_3 0.09	n.d.	n.d.	n.d.	SO_3 0.10	n.d.	n.d.
Total	100.01	99.88	100.58	99.82	99.24	100.46	101.10	100.29	99.66	100.51	100.47
Anal.	TAKAYANAGI	?	SETO	HARAGUCHI	HARAGUCHI	HARAGUCHI	HARAGUCHI	HARAGUCHI	HARAGUCHI	SETO	HARAGUCHI
Norms											
Q	6.48	11.10	7.98	8.82	1.14	3.48	3.96	4.44	8.10	10.98	1.38
C	—	—	—	—	—	—	—	1.33	—	—	—
or	24.46	26.69	29.47	31.14	20.02	18.90	13.34	19.46	18.90	18.35	29.47
ab	47.16	40.35	44.54	44.01	33.01	38.77	37.20	42.97	42.44	38.25	51.35
an	11.68	4.17	9.45	9.73	21.13	18.63	17.51	11.40	18.35	20.02	6.95
wo	—	2.44	4.76	0.70	3.83	4.87	6.96	—	0.70	3.01	3.37
en	1.80	4.80	—	0.40	3.90	3.00	7.70	2.10	2.00	2.20	0.20
fs	3.30	2.51	1.32	1.32	8.97	0.40	5.02	7.92	1.19	—	1.72
mt	2.32	4.41	2.09	2.78	3.94	6.73	3.48	5.10	4.18	0.70	3.02
hm	—	—	—	—	—	—	—	—	—	3.52	—
il	1.22	2.13	0.76	0.61	2.28	2.58	4.10	1.82	2.13	0.76	0.76
ap	0.67	0.34	—	—	0.67	2.35	1.34	2.69	0.34	2.35	0.34
or	29	37	35	37	27	25	19	26	24	24	34
ab	57	57	54	52	45	51	55	58	53	50	59
an	14	6	11	11	28	24	26	16	23	26	7
Q	67	71	89	88	31	65	45	48	80	88	80
fo	11	18	0	2	20	30	32	10	12	12	2
fa	22	11	11	10	49	5	23	42	8	0	18

111. Olivine-bearing soda diopside-anorthoclase trachyte; Matsushima, Hizen (Kōzu, S., 1911, *Jour. Geol.*, v. 19, p. 559).
112. Olivine-bearing soda diopside-anorthoclase trachyte;Matsushima, Hizen (Ōtsuki, Y., 1910, Explanatory text of the geological map of Iki, p. 28).
113. Fayalite-soda diopsidic aegirinaugite-anorthoclase trachyte;west wall of the crater, Halla-san, Cheju-do (Kōzu, S., and Seto, K., 1929, Abstract of Paper from the 4th Pacific Sci. Cong. Java, v. 2, B, p. 1067).
114. Ditto; same locality as above (Haraguchi, K., 1931, *Bull. Geol. Surv. Chōsen*, v. 10, part 1, p. 10).
115. Seikiho trachyandesite; Sŏgwip'o, U-myŏn, Cheju-do (Haraguchi, K., *ibid.*, p. 10).
116. Hornblende-bearing trachyandesite; Tondo-ak, Taejŏng-myŏn, Cheju-do (Haraguchi, K., *ibid.*, p. 10).
117. Ditto; Pyŏlto-bong, Cheju-myŏn, Cheju-do (Haraguchi, K., *ibid.*, p. 10)
118. Kaianri (Haeal-li) trachyandesite; Cheju-do (Haraguchi, K., *ibid.*, p. 10).
119. Sambōsan (Sanbang-san) trachyandesite; Pong-san, Chung-myŏn, Cheju-do (Haraguchi, K., *ibid.*, p. 10).
120. Oligoclase andesite; same locality as above (Kōzu, S., and Seto, K., 1929 p. 1067).
121. Aegirinaugite-bearing trachyte; Sam-do, Cheju-do (Haraguchi, K., 1931 p. 10)

Table 14. Chemical Composition of B_3.

No.	122	123	124	125	126	127	128	129	130	131	132	133	134
SiO_2	47.52	47.63	49.05	44.22	45.46	45.75	47.54	48.01	48.42	49.03	49.29	52.19	52.39
Al_2O_3	15.67	16.65	14.35	16.14	15.04	17.15	15.34	18.59	11.43	14.43	18.49	19.74	15.62
Fe_2O_3	7.81	4.16	3.02	7.01	3.17	3.06	3.84	6.82	3.42	1.29	2.38	4.72	1.50
FeO	4.47	8.83	10.57	5.13	6.39	7.27	6.98	6.07	8.67	9.40	6.77	6.28	8.06
MgO	3.78	4.89	4.25	5.46	8.58	3.13	5.28	5.26	8.60	11.93	6.09	2.24	6.92
CaO	8.18	7.38	8.66	9.68	10.55	7.30	11.79	8.48	11.64	7.28	8.14	6.99	8.68
Na_2O	4.17	3.59	3.23	2.84	3.81	6.04	3.16	2.59	3.31	3.14	3.93	3.48	3.43
K_2O	2.22	1.95	1.40	1.41	1.38	1.46	1.15	1.86	0.72	1.24	1.79	2.04	0.79
TiO_2	4.16	3.19	3.19	3.80	3.17	3.21	2.53	0.48	2.64	1.71	2.22	n.d.	1.47
P_2O_5	0.76	0.57	0.57	0.90	1.08	1.69	0.63	0.33	0.36	0.44	tr.	n.d.	0.33
MnO	0.21	0.21	0.27	0.30	0.16	0.18	0.17	0.12	0.21	tr.	0.22	0.06	0.13
H_2O+	0.68	0.40	0.34	0.09	0.74	1.44	1.03	1.47	0.54	0.73	0.88	1.25	0.22
H_2O-	0.30	0.26	0.20	2.58	0.16	1.69	0.71	0.60	0.44				0.24
CO_2	n.d.	0.23	0.73	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Total	99.93	99.94	99.83	99.56	99.69	99.37	100.15	100.68	100.40	100.62	100.20	98.99	99.78
Anal.	Raoult	Murata	Murata	Teshima	Teshima	Teshima	Teshima	Endō	Teshima	Yokoyama	Sugiura	Ōno	Yamaguchi
Norms													
Q	—	—	0.12	—	—	—	—	2.34	—	—	—	3.06	—
or	12.79	11.68	8.34	8.34	8.34	8.90	7.23	11.12	3.89	7.23	10.56	11.12	5.00
ab	33.01	30.39	27.25	24.10	17.82	32.49	19.91	22.01	25.41	26.72	27.77	29.34	28.82
an	17.79	23.63	20.57	26.97	19.74	15.57	23.91	33.36	14.46	21.41	27.52	32.25	24.74
ne	1.14	—	—	—	7.67	9.94	3.69	—	1.28	—	2.84	—	—
wo	7.19	3.94	7.89	6.50	10.56	3.94	12.99	2.90	16.93	4.99	5.34	1.04	6.84
en	6.20	2.60	10.60	10.50	8.00	2.20	8.40	8.80	11.10	5.40	3.40	5.60	16.20
fs	—	1.98	12.14	—	1.45	1.58	3.70	4.75	4.62	2.37	1.58	7.92	10.82
fo	2.31	1.26	—	2.24	9.45	3.92	3.36	—	7.28	17.08	8.26	—	0.77
fa	—	0.92	—	—	2.04	3.37	1.63	—	3.47	8.57	4.28	—	0.51
mt	3.02	6.03	4.41	6.26	4.64	4.41	5.57	9.98	4.87	1.86	3.48	6.73	2.09
hm	5.76	—	—	2.72	—	—	—	—	—	—	—	—	—
il	7.90	6.08	6.08	7.30	6.08	6.08	4.71	0.91	5.02	3.19	4.26	—	2.74
ap	2.02	1.34	1.34	2.02	2.69	4.03	1.34	0.67	1.01	1.01	—	—	0.67
or	20	18	15	14	18	16	13	17	9	13	16	15	9
ab	52	46	48	41	40	57	44	33	58	48	42	40	49
an	28	36	37	45	42	27	43	50	33	39	42	45	42
Q	22	18	26	25	13	10	20	38	14	7	8	39	26
fo	78	46	33	75	72	57	54	39	71	62	61	24	43
fa	0	36	41	0	15	33	26	23	15	31	31	37	31

122. Olivine-labradorite-bearing trachybasalt; Mutu-bong (about 16 km ESE of P'aektu-san) (Lacroix, A., 1928, *Bull. Geol. Soc. China.* v. 7, p. 58).
123. Trachybasalt; Andugal parasitic volcano, Paektu-san (Ogura, T., 1951, *Chemical composition of the igneous rocks of Manchuria, in* Geology and Mineral Resources of the Far East).
124. Olivine-oligoclase basalt; Taeyŏnji-bong, P'aektu-san (Ogura, T., *ibid.*).
125. Olivine-labradorite basalt; Noridabana, Nakamura, Dōgo, Oki Island (Tomita, T., 1935, *Jour. Shanghai Sci. Inst.*, sect 2, v. 1, p. 240).
126. Augite-bearing titanaugite-olivine basalt; Suzumejima, Nakamura, Dōgo, (Tomita, T., *ibid.*, p. 242).
127. Groundmass of olivine-labradonite-augite-bearing kaersutite basalt; Chikaishi, Chūjōmura, Dōgo (Tomita, T., *ibid.*, p 242).
128. Olivine-titanaugite-labradorite trachybasalt; SE foothill of Taihōsan, Dōgo (Tomita, T., *ibid.*, p. 242).
129. Labradorite-bearing olivine-biotite trachybasalt; Mutsurejima, Nagato (Kōzu, S., Yoshimoto, B., 1929, *Japanese Assoc. Mineralogists, Petrologists, and Economic Geologists, Jour.*, v. 1, p. 159).
130. Augite-labradorite-olivine trachybasalt; top of Taihōsan, Dōgo (Tomita, T., *loc. cit.*, p. 244).
131. Hypersthene-bearing olivine trachybasalt; Shimomotoya, Nakamura, Dōgo (Kōzu, S., 1913, *Sci. Rep. Tōhoku Imp. Univ.*, 2nd ser., v. 1, p. 51).
132. Olivine trachybasalt; Tajima Gembudō (H. S. Washington, 1917, U.S.G.S. Prof. Paper, no. 99, p. 513).
133. Trachybasalt; Mawatarijima, Hizen (Kōzu, S., 1911, *Jour. Geol.*, v. 19, p. 574).
134. Quartz-basalt excluding quartz xenocrysts; Daidonjima, Izumo (Sakai, S., 1929, Geol. Soc. Japan Jour., v. 46, p. 275).

Table 15. Chemical Composition of Volcanic Rocks of Ullŭng-do.

No.	135	136	137	138	139	140	141	142	143	144
SiO_2	47.82	52.75	56.57	57.61	57.91	59.11	60.63	61.52	61.65	62.30
Al_2O_3	17.57	16.61	19.21	18.70	18.22	19.02	18.80	18.48	18.15	17.89
Fe_2O_3	3.06	2.98	1.90	3.51	1.90	1.82	1.01	2.65	1.77	1.13
FeO	6.22	4.22	3.31	1.77	3.20	2.68	3.96	1.49	2.40	2.38
MgO	3.20	2.81	1.37	1.05	1.01	1.05	0.15	0.58	0.11	0.15
CaO	8.28	5.11	3.57	2.66	3.58	2.51	1.11	1.32	1.23	1.26
Na_2O	3.62	5.38	5.80	6.45	4.98	5.83	7.67	6.70	5.30	8.06
K_2O	3.47	4.58	6.06	5.77	6.69	5.69	5.60	6.14	5.67	5.41
TiO_2	3.35	1.83	1.42	1.18	0.65	0.83	0.66	0.56	0.59	0.49
P_2O_5	0.93	0.49	0.36	0.35	0.48	0.18	0.07	0.03	0.29	0.20
MnO	0.15	0.10	0.10	0.07	0.27	0.14	0.02	0.17	1.45	0.21
H_2O+	1.59	2.89	0.15	0.41	0.82	0.94	0.14	0.64	0.68	0.30
H_2O-	0.85	0.63	0.15	0.11	0.38	0.43	0.30	0.35	0.59	0.29
ZrO_2	n.d.	n.d.	n.d.	n.d.	0.07	n.d.	n.d.	n.d.	0.04	n.d.
Total	100.11	100.38	99.97	99.64	100.16	100.23	100.12	100.63	99.92	100.07
Anal.	Harumoto	Harumoto	Harumoto	Harumoto	Ōhashi	Ushijima	Harumoto	Ushijima	Ōhashi	Oyama
Norms										
Q	—	—	—	—	—	—	—	—	5.10	—
C	—	—	—	—	—	—	—	—	1.84	—
or	20.57	27.24	35.58	33.92	39.48	33.92	33.36	36.14	33.92	31.69
ab	23.58	30.92	36.15	40.35	33.54	44.01	46.63	49.78	44.54	49.78
an	21.41	7.51	8.34	5.00	7 23	8.62	—	2.22	3.89	—
ne	3.69	7.95	7.10	7.67	4.83	2.84	9.94	3.69	—	6.53
ac	—	—	—	—	—	—	—	—	—	3.23
ns	—	—	—	—	—	—	—	—	—	0.61
wo	5.92	5.92	0.70	2.20	2.44	1.28	1.97	1.74	—	2.20
en	4.20	4.10	0.40	1.90	1.00	0.90	0.20	1.00	0.30	0.20
fs	1.19	1.32	0.26	—	1.45	0.26	1.98	—	4.75	2.24
fo	2.66	2.03	2.10	0.49	1.05	1.73	0.14	—	—	0.14
fa	0.82	0.71	1.63	—	1.73	0.21	2.65	—	—	1.33
mt	4.41	4.41	2.78	2.55	2.78	2.55	1.39	3.94	2.55	—
hm	—	—	—	1.76	—	—	—	0.16	—	—
il	6.38	3.50	2.74	2.28	1.12	1.52	1.22	1.06	1.06	0.91
ap	0.96	1.34	1.01	1.01	1.68	0.34	0.34	—	0.67	0.34
or	31	42	45	43	49	39	42	46	41	39
ab	36	47	45	51	42	51	58	51	54	61
an	33	11	10	6	9	10	0	3	5	0
Q	20	19	4	19	12	12	10	30	62	17
fo	70	60	56	81	33	69	6	70	2	10
fa	10	21	40	0	57	19	84	0	36	73

135. Trachybasalt; To-dong, Nam-myŏn, Ullŭng-do (Harumoto, A., 1934, *Geol. Soc. Japan Jour.*, v. 41, p. 354).
136. Trachybasalt; Sŏdal-lyŏng, Sŏ-myŏn, Ullŭng-do (Harumoto, A., *ibid.*)
137. Trachyandestic vicoite; north side of Nan-bong, Ullŭng-do (Harumoto, A., *ibid*).
138. Hornblende trachyandesite; Sŏkp'o-dong, Chugam, Pung-myŏn, Ullŭng-do (Harumoto, A., *ibid.*)
139. Vulsinitic vicoite; Nan-bong, Ullŭng-do (Tsuboi, S., 1920, *Geol, Soc. Japan Jour.*, v. 27, p. 469).
140. Aegirinaugite-biotite trachyte; river bed, southwest of Sŏngin-bong, Nam-myŏn, Ullŭng-do (Harumoto, A., 1934).
141. Aenigmatite-aegirinaugite trachyte; Chatae, Sŏ-myŏng, Ullŭng-do (Harumoto, A., 1934).
142. Aegirinaugite trachyte; Haengnam, Nam-myŏn, Ullŭng-do (Harumoto, A., 1934).
143. Aegirinaugite phonolite (nepheline-tinguaite); SW foot-hill of Kwanmo-bong, Ullŭng-do (Tsuboi, S., 1920 p. 468).
144. Phonolite; north side of Ch'o-bong, Ullŭng-do (Harumoto, A., 1934).

Table 16. Chemical Composition of B_4.

No.	145	146	147
SiO_2	49.94	50.89	52.08
Al_2O_3	16.33	17.28	17.81
Fe_2O_3	2.32	1.75	1.53
FeO	7.63	7.34	8.30
MgO	4.80	4.88	7.01
CaO	9.82	11.56	8.08
Na_2O	1.44	2.77	3.16
K_2O	3.51	0.71	0.74
TiO_2	3.95	1.95	1.09
P_2O_5	none	0.23	—
MnO	0.02	0.81	0.15
H_2O+	none	0.10	0.22
H_2O-	0.18	0.29	—
Cl	tr.	tr.	n.d.
Total	99.94	100.56	100.17
Anal.	Seto	Seto	Mizuma
Norms			
Q	2.10	0.96	—
or	20.57	3.89	4.45
ab	12.05	23.58	26.72
an	27.80	32.80	32.25
wo	8.70	9.86	3.25
en	12.00	12.20	15.50
fs	5.55	10.17	11.09
fo	—	—	1.40
fa	—	—	1.02
mt	3.25	2.55	2.09
il	7.60	3.80	2.13
ap	—	0.34	—
or	34	7	7
ab	20	39	42
an	46	54	51
Q	28	30	25
fo	48	36	42
fa	24	34	33

145. Olivine basalt; Pangsong-ni, Ch'angdo-myŏn, Kŭmhwa-gun, Kangwŏn-do, Korea (Kōzu, S., and Seto, K., 1929, Abstract of Paper from the 4th Pacific Sci. Cong. Java, v. 2, B, p. 1067)
146. Potashandesine-olivine basalt (Yūtoku basalt); Mokchin-dong, Sanggo-myŏn, Myŏngch'ŏn-gun, Hamgyŏng-pukto, Korea (Kōzu, S., and Seto, K., *ibid.*).
147. Olivine basalt; Sangnong-ni, Suha-myŏn, Tanch'ŏn-gun, Hamgyŏng-namdo, Korea (Kinozaki, Y., 1938, *Geol. Atlas of Chōsen,* no. 19).

Table 17. Chemical Composition of Wu-ta-lien-chih and Erh-k'o-shan Lavas.

No.	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169
SiO_2	50.54	51.68	53.46	47.15	47.28	48.14	49.92	51.12	51.38	51.62	52.52	53.06	53.20	47.96	48.82	52.68	52.94	49.20	50.81	50.58	51.12	51.26
Al_2O_3	14.50	15.07	14.66	14.27	13.45	13.91	14.16	12.99	14.54	14.24	14.25	14.58	14.16	13.24	14.06	14.38	14.69	14.08	14.71	14.14	13.76	14.66
Fe_2O_3	2.31	2.95	1.78	9.32	7.00	9.10	7.90	4.36	8.06	2.07	2.70	7.50	3.00	2.93	0.48	1.43	0.89	1.52	2.36	4.48	1.28	7.84
FeO	6.96	5.74	5.89	1.44	3.43	2.00	1.42	5.39	0.85	6.44	5.15	3.14	6.97	7.87	8.47	7.76	8.05	6.89	6.20	4.61	6.70	1.30
MgO	7.41	5.90	6.16	7.78	8.44	8.86	7.43	6.01	6.34	6.36	6.76	4.27	6.62	7.48	7.56	6.38	6.08	8.26	7.43	6.68	6.95	4.21
CaO	7.01	5.20	5.92	8.32	7.72	7.22	6.61	5.84	6.16	5.88	6.16	4.76	5.05	8.02	7.35	5.82	6.01	7.75	6.65	5.74	6.44	6.27
Na_2O	3.57	4.26	3.33	3.25	4.56	3.31	3.23	3.24	3.72	4.89	3.35	4.19	2.60	3.79	4.22	3.36	3.35	4.18	3.56	4.08	4.22	4.54
K_2O	4.28	5.14	5.20	4.56	4.22	2.93	4.48	5.67	4.67	4.40	4.24	4.57	3.88	4.89	4.70	5.43	5.13	4.30	5.21	4.81	5.61	5.27
TiO_2	2.05	2.50	2.77	2.46	2.30	2.40	2.25	2.70	2.20	2.28	2.35	2.25	2.27	2.83	2.80	1.88	2.00	2.50	2.19	2.56	2.45	2.42
P_2O_5	1.06	1.21	0.92	1.07	0.75	1.01	1.20	0.98	1.13	0.82	0.74	0.90	1.25	1.03	1.12	1.10	1.01	1.05	1.06	1.04	1.06	1.14
MnO	0.15	0.08	0.01	0.18	0.08	0.09	0.14	0.06	0.07	0.10	0.07	0.08	0.14	0.02	0.14	0.15	0.15	0.12	0.14	0.10	0.12	0.08
H_2O+	0.69	0.40	0.27	0.79	0.77	0.83	0.98	1.02	0.64	0.73	1.54	0.69	0.50	0.37	0.13	0.11	0.32	0.11	0.29	1.16	0.39	1.03
H_2O-		0.13	0.10		0.34	0.17	0.16	0.16	0.14	0.19	0.38	0.21	0.18	0.05	0.07			0.07		0.10	0.10	0.61
Total	100.53	100.26	100.47	100.59	100.34	99.97	99.88	99.54	99.93	100.02	100.21	100.20	99.82	100.01	99.93	100.48	100.62	100.03	100.61	100.08	100.20	100.18
Anal.	Murata	Geol. Sur.	Sawatari	Murata	Geol. Sur.	Geol. Sur.	Geol. Sur.	Geol. Sur.	Geol. Sur.	Geol. Sur.	Geol. Sur.	Geol. Sur.	Geol. Sur.	Sawatari	Geol. Sur.	Murata	Murata	Geol. Sur. S. M. Ry	Murata	Geol. Sur. S. M. Ry	Geol. Sur. S. M. Ry	Geol. Sur. S. M. Ry
Norms																						
Q	—	—	—	—	—	—	—	—	—	—	—	—	3.30	—	—	—	—	—	—	—	—	—
or	25.58	30.02	30.58	26.69	25.02	17.24	26.69	33.36	27.24	26.13	25.02	27.24	22.80	28.91	27.80	31.69	30.02	25.58	30.58	28.36	33.36	31.14
ab	21.48	25.94	27.77	12.84	22.01	17.03	24.10	23.06	28.82	24.10	28.30	35.63	22.01	7.34	6.81	23.58	23.06	12.58	16.77	20.70	14.15	24.89
an	10.84	6.95	10.01	10.84	3.61	14.46	10.84	4.17	9.17	3.61	11.40	7.23	15.57	4.45	5.56	8.34	10.01	6.95	11.68	5.84	1.95	4.17
ne	4.54	5.54	—	8.09	9.09	5.82	1.70	2.27	1.42	9.37	—	—	—	13.35	15.62	2.56	2.84	12.21	7.10	7.52	11.64	7.24
wo	6.84	4.76	5.68	8.58	3.48	6.15	5.22	7.66	4.06	8.35	6.15	4.52	0.46	12.06	9.74	5.45	5.68	10.09	5.80	9.16	9.28	6.84
en	4.50	3.40	4.30	7.40	3.00	22.20	4.50	6.00	3.50	5.50	8.30	7.50	16.60	8.00	5.90	3.20	3.00	6.80	4.00	7.70	6.00	5.90
fs	1.85	0.92	1.32	—	—	—	—	0.79	—	2.24	1.72	—	6.86	3.17	3.30	1.98	2.51	2.51	1.32	0.26	2.64	—
fo	9.80	7.98	7.77	8.40	12.67	—	9.87	6.30	8.68	7.28	6.02	2.24	—	7.49	9.10	8.96	8.54	9.43	10.22	6.30	7.98	3.22
fa	4.69	2.45	2.75	—	—	—	—	0.82	—	3.16	1.43	—	—	3.26	5.81	6.32	6.53	3.98	3.57	0.31	7.34	—
mt	3.25	4.41	2.55	—	4.41	—	—	6.50	—	3.02	3.94	3.71	4.41	4.18	0.70	2.09	1.39	2.09	3.48	6.50	1.86	—
hm	—	—	—	9.28	4.00	9.12	7.84	—	8.16	—	—	4.96	—	—	—	—	—	—	—	—	—	7.84
il	3.80	4.71	5.17	3.50	4.41	4.41	3.19	5.17	1.98	4.41	4.41	4.26	4.26	5.32	5.32	3.65	3.80	4.71	4.26	4.86	4.56	2.89
tn	—	—	—	1.57	—	0.20	1.37	—	2.94	—	—	—	—	—	—	—	—	—	—	—	—	2.16
ap	2.69	2.69	2.02	2.69	1.68	2.35	2.69	2.35	2.69	2.02	1.68	2.02	3.02	2.35	2.69	2.69	2.35	2.69	2.69	0.34	2.69	2.69
or	44	48	45	53	49	35	43	55	42	48	39	39	38	71	69	50	48	57	52	52	67	52
ab	37	41	40	25	44	35	39	38	44	45	44	51	36	18	17	37	36	28	28	38	29	41
an	19	11	15	22	7	30	18	7	14	7	17	10	26	11	14	13	16	15	20	10	4	7
Q	6	9	10	14	6	30	9	15	9	12	16	23	38	14	10	7	11	11	8	16	10	19
fo	64	79	67	86	94	70	91	75	91	61	68	77	36	60	55	55	50	63	68	80	51	81
fa	30	12	23	0	0	0	0	10	0	27	16	0	26	26	35	38	39	26	24	4	39	0

148. Olivine-anorthoclase banakite (plateau lava); Shih-to-fang-tzu, Wu-ta-lien-chih, Lung-chiang Province (Ogura, T., Matsuda, K., Nakagawa, T., Matsumoto, M., and Murata, K., 1936, *Report on volcanoes in Manchuria*, no. 1, p. 51: Ryojun Coll. Eng.).
149. Anorthoclase banakite (shield plateau lava); Wei-shan-lien (Ogura, T., 1951, *Chemical composition of the Manchurian igneous rocks, in* Geology and Mineral Resources of the Far East, no. 100).
150. Anorthoclase banakite (shield plateau lava); Sh'ih-t'ang, Lung-chiang Province (Ogura, T., and others, 1936, p. 52).
151. Leucite absarokite (older volcanic cone), light brown, vesicular, massive lava; Tung-lung-men Shan, Lung-chiang Province (Ogura, T., and others, 1936, p. 55).
152. Leucite-olivine banakite (older volcanic cone), light grayish brown, vesicular, massive shield plateau lava; Mo-la-pu Shan, Lung-chiang Province (Ogura, T., 1951, no. 137).
153. Leucite absarokite (older volcanic cone), reddish brown, vesicular, massive lava; Tung-chao-te-pu Shan, Lung-chiang Province (Ogura, T., 1951, no. 127).
154. Olivine absarokite (older volcanic cone), reddish brown, vesicular, massive lava; Pi-chia Shan, Lung-chiang Province (Ogura, T., 1951, no. 113).
155. Leucite absarokite (older volcanic cone), brownish gray minutely vesicular, massive lava; Yao-chuan Shan, Lung-chiang Province (Ogura, T., 1951, no. 105)
156. Leucite-olivine banakite (older volcanic cone), brownish, finely vesicular, massive lava; Pei-ko-la-ch'iu Shan, Lung-chiang Province (Ogura, T., 1951, no. 102).
157. Glassy banakite, (older volcanic cone), black scoriaceous ejecta; Wei-shan, Lung-chiang Province (Ogura, T., 1951, no. 101).
158. Glassy banakite (older volcanic cone), black scoriaceous ejecta; Lung-men Shan, Lung-chiang Province (Ogura, T., 1951, no. 98).
159. Trachyandesite (older volcanic cone), reddish brown vesicular massive lava; Hsi-chiao-te-pu Shan, Lung-chiang Province (Ogura, T., 1951, no. 95).
160. Olivine trachybasalt (older volcanic cone), black porous scoriaceous ejecta; Wo-hu Shan, Lung-chiang Province (Ogura, T., 1951, no. 94).
161. Leucite trachyte, spinal shihlunite flow; south of Lao-hei Shan, Lung-chiang Province (Ogura, T., and others, 1936, p. 64).
162. Leucite trachyte, spinal shihlunite lava flow (the same type as no. 181 ?); south of Lao-hei Shan, Lung-chiang Province (Ogura, T., 1951, no. 120).
163. Shihlunite proper, shihlunite lava flow; northern foot-hill of Lao-hei Shan, Lung-chiang Province (Ogura, T., and others, 1936, p. 63).
164. Shihlunite proper, Shihlunite flow; Shih-to-fang-tzu, Lung-chiang Province (Ogura, T., 1936).
165. Shihlunite proper (younger volcanic cone), black vesicular massive lava flow; Huo-shao Shan, Lung-chiang Province (Ogura, T., 1951, no. 116).
166. Shihlunite proper (younger volcanic cone), black vesicular massive lava flow; Lao-hei Shan, Lung-chiang Province (Ogura, T., and others, 1936, p. 65).
167. Leucite shihlunite, black lava; crest of Tung Shan, Erh-k'o Shan, K'o-tung Hsien, Lung-chiang Province (Ogura, T., and Matsumoto, M., 1938).
168. Leucite basanite (shield plateau lava); Ho-chia-t'un, Lung-chiang Province (Ogura, T. and Matsumoto, M., 1938, p. 10).
169. Leucite basanite (Erh-k'o Shan lava); summit of Erh-k'o Shan, Lung-chiang Province (Ogura, T. and Matsumoto, M., 1938, p. 11).

Table 18. Chemical Composition of Ch'i-hsing Shan Lavas.

No.	170	171	172	173	174	175	176	177
SiO_2	40.86	42.23	44.96	45.71	45.96	46.20	47.49	48.31
Al_2O_3	12.97	12.46	12.28	14.03	15.69	14.87	18.24	16.95
Fe_2O_3	4.87	2.89	2.24	2.01	0.53	1.61	3.15	1.22
FeO	9.85	10.93	11.47	11.01	10.76	10.69	7.13	8.99
MgO	9.98	11.81	10.64	9.66	10.22	10.05	4.52	6.65
CaO	8.67	10.30	7.39	9.05	9.47	9.07	10.97	9.68
Na_2O	4.56	3.91	3.95	3.17	2.71	2.91	3.66	3.69
K_2O	1.60	1.73	1.33	2.12	1.70	1.62	2.03	2.10
TiO_2	2.86	2.02	2.36	2.10	1.80	1.86	1.94	1.42
P_2O_5	0.89	0.71	0.91	0.47	0.42	0.40	0.33	0.53
MnO	0.17	0.19	0.20	0.16	0.14	0.21	0.20	0.19
H_2O+	1.50	} 1.50	1.41	} 0.68	} 0.82	} 0.88	} 0.87	} 0.85
H_2O-	0.96		0.79					
Total	99.74	100.68	99.93	100.17	100.22	100.37	100.53	100.58
Anal.	GEOL. SUR. S. M. RY	SAWAYAMA	GEOL. SUR. S. M. RY	SAWAYAMA	SAWAYAMA	SAWAYAMA	SAWAYAMA	SAWAYAMA
Norms								
or	9.45	8.34	7.78	12.23	10.01	9.45	6.12	12.23
ab	6.81	—	20.96	11.53	12.31	15.72	25.15	18.86
an	10.29	11.68	11.95	17.79	25.58	22.80	30.02	23.91
lc	—	1.31	—	—	—	—	—	—
ne	17.04	17.89	6.82	8.24	5.82	4.83	3.12	6.53
wo	11.37	14.50	8.00	10.21	7.77	8.12	9.40	8.47
en	7.60	9.10	4.80	5.90	4.50	4.70	5.40	4.50
fs	2.90	4.49	2.77	3.83	2.90	3.04	3.56	3.70
fo	12.18	14.28	15.26	12.81	14.84	14.28	4.13	7.77
fa	5.10	7.96	8.98	8.87	10.61	9.79	3.16	7.55
mt	7.19	4.18	3.25	3.02	0.70	2.32	4.64	1.86
il	5.32	3.80	4.41	3.95	3.50	3.50	3.65	2.74
ap	2.02	1.68	2.02	1.01	1.01	1.01	0.67	1.34
or	35	42	19	29	21	19	10	22
ab	26	0	52	28	26	33	41	34
an	39	58	29	43	53	48	49	44
Q	11	17	6	8	6	7	15	9
fo	63	53	59	54	55	55	49	47
fa	26	30	35	38	39	38	36	44

170. Olivine trachybasalt; Po-po-t'u Shan, Ch'i-hsing Volcano (Ogura, T., Sawatari, M., and Murayama, K., 1939, *Report of volcanoes in Manchuria.* no. 30, p. 27: Ryojun Coll. Eng.).
171. Leucite basanite; Nao-po Shan, Ch'i-hsing Volcano (Ogura, T., and others, 1936 p. 29).
172. Olivine trachybasalt; Po-li Shan, Ch'i-hsing Volcano (Ogura, T., and others *ibid.*, p. 25).
173. Olivine trachybasalt; Shih-t'ou Shan, Ch'i-hsing Volcano (Ogura, T., and others, *ibid.*, p. 32).
174. Olivine trachydolerite; Hsiao-t'u-k'o-erh-t'sai Shan, Ch'i-hsing Volcano (Ogura, T., *ibid.*, p. 30).
175. Olivine trachybasalt; Hsi-ha-la-pa Shan, Ch'i-hsing Volcano (Ogura, T., *ibid.*, p. 25).
176. Olivine trachydolerite; Ta-t'u-k'o-erh-t'sai Shan, Ch'i-hsing Volcano (Ogura, T., *ibid.*, p. 31).
177. Olivine trachybasalt; Tuhg-ha-la-pa Shan, Ch'i-hsing Volcano (Ogura, T., *ibid.*, p. 24).

Table 20. Chemical Composition of Holocene Lavas of Cheju-do.

No.	198	199	200	201	202	203	204
SiO_2	43.41	46.86	47.60	48.33	49.61	50.02	51.50
Al_2O_3	15.52	16.37	14.77	16.13	15.20	15.08	15.45
Fe_2O_3	3.99	6.01	2.78	4.60	6.81	6.42	1.82
FeO	8.15	6.04	8.58	7.39	6.66	7.11	8.17
MgO	6.78	4.25	4.64	4.13	5.04	5.08	4.93
CaO	10.77	6.81	12.76	10.67	6.37	6.40	9.19
Na_2O	4.28	5.28	3.76	3.74	4.42	4.33	4.09
K_2O	1.30	2.41	1.03	1.07	2.85	2.97	3.52
TiO_2	2.58	2.96	1.78	2.31	2.12	2.25	1.89
P_2O_5	1.29	1.71	1.40	1.46	n.d.	n.d.	n.d.
MnO	1.38	1.23	0.61	0.12	0.24	0.20	none
H_2O+ }	0.46	1.01	0.45	0.56	0.40	0.64	0.04
H_2O- }					0.06	n.d.	0.04
SO_2	0.03	n.d.	n.d.	n.d.	n.d.		n.d.
Total	99.98	100.67	100.16	100.51	99.78	100.50	100.64
Anal.	Haraguchi	Haraguchi	Haraguchi	Haraguchi	Seto	Haraguchi	Seto
Norms							
or	7.78	14.46	6.12	6.12	16.68	17.79	20.57
ab	12.58	23.58	22.79	27.77	30.39	29.87	17.29
an	19.18	13.90	20.29	24.19	13.34	13.07	13.62
ne	12.78	11.36	4.97	1.99	3.69	3.41	9.37
wo	10.79	3.60	14.15	11.60	7.66	7.77	13.34
en	6.10	2.50	7.00	6.90	5.40	5.20	7.00
fs	4.22	0.79	6.86	4.09	1.58	1.98	5.94
fo	7.56	5.67	3.22	2.38	4.18	5.25	3.71
fa	5.71	2.24	3.57	3.57	1.53	2.14	3.37
mt	5.80	8.82	4.18	6.73	9.98	9.28	2.55
il	3.04	5.17	3.34	4.41	3.95	3.95	3.65
ap	3.02	4.03	3.36	0.34	—	—	—
or	20	28	13	11	28	29	40
ab	32	45	46	48	50	49	34
an	48	27	41	41	22	22	26
Q	12	8	18	20	15	14	17
fo	50	66	39	48	65	61	43
fa	38	26	43	32	20	25	40

198. Basanitoid (Kŭmnyŏng basalt); Kŭmnyŏng, Kucha-myŏn, Cheju-do, (Haraguchi, K., 1931, *Bull. Geol. Surv. Chōsen,* v. 10, part 1, p. 10).
199. Plagioclase-augite-olivine basalt; Cheju, Cheju-myŏn, Cheju-do (Haraguchi, K., *ibid*).
200. Microporphyritic plagioclase basalt; east wall of the crater of Halla-san, Cheju-do (Haraguchi, K., *ibid.*).
201. Augite basalt (Yongdam lava); Yongdam, Cheju-do (Haraguchi, K., *ibid.*).
202. Trachybasalt; Sŏ-myŏn, Cheju-do (Kōzu, S., and Seto, K., 1929, Abstract of paper from the 4th Pacific Sci. Cong. Java, v. 2, B, p. 1067).
203. Olivine-trachybasalt (Saektal lava); Saektal, Cheju-do (Haraguchi, K., 1931).
204. Olivine-basalt (Hallasan basalt); same locality as 200 (Kōzu, S., and Seto, K., 1929).

Table 19. Chemical Composition of the Lung-wan Volcanic Rocks.

No.	178	179	180	181	182	183	184	185	186	187
SiO_2	45.54	45.54	46.16	46.67	46.70	46.93	47.03	47.36	47.36	47.54
Al_2O_3	13.13	17.87	15.41	16.86	16.81	17.95	16.01	12.98	17.45	17.59
Fe_2O_3	1.25	3.02	5.84	3.22	2.39	1.20	3.52	2.66	1.71	7.50
FeO	9.13	9.08	5.15	9.14	9.48	10.83	7.88	10.90	8.51	4.07
MgO	12.11	7.07	13.51	8.04	8.15	6.76	11.03	8.21	8.73	6.58
CaO	8.73	8.48	5.73	7.58	8.01	7.83	6.85	7.91	7.21	6.45
Na_2O	4.31	3.66	2.33	3.53	3.69	2.88	2.84	4.48	4.09	2.50
K_2O	1.91	2.17	1.88	2.17	2.31	2.33	2.26	2.38	2.44	2.22
TiO_2	0.83	2.74	2.10	2.36	1.92	2.53	2.13	1.04	2.31	2.10
P_2O_5	0.43	0.44	0.57	0.29	0.50	0.58	0.27	0.57	0.24	0.68
MnO	0.29	0.20	0.23	0.25	0.22	0.24	0.33	0.33	0.25	0.26
H_2O+	0.45	0.06	0.41	0.55	0.49	n.d.	0.29	0.31	0.24	2.23
H_2O-	1.27	0.16	0.11	0.04		0.11	0.03	0.74	0.03	0.12
Total	99.38	100.49	99.39	100.50	100.67	100.46	100.47	99.87	100.57	99.84
Anal.	Geol. Sur. of S. M. Ry.	Murata	Murata	Murata	Sawayama	Murata	Murata	Geol. Sur. of S. M. Ry.	Murata	Murata
Norms										
Q	—	—	—	—	—	—	—	—	—	3.18
C	—	—	0.31	—	—	—	—	—	—	1.22
or	11.12	12.79	11.12	12.79	13.34	13.90	13.34	14.46	14.46	12.79
ab	7.34	14.67	19.91	19.39	10.48	20.44	20.96	15.72	16.77	20.96
an	10.84	25.85	25.02	23.91	22.52	28.91	24.19	7.78	22.24	27.24
ne	15.62	8.80	—	5.68	11.36	2.27	1.70	12.21	9.66	—
wo	12.41	5.68	—	4.99	5.68	2.67	3.25	11.60	4.87	—
en	7.80	3.30	12.60	3.10	2.50	1.40	2.30	6.30	3.10	16.50
fs	3.83	2.11	0.66	1.58	3.17	1.19	0.66	4.88	1.45	—
fo	15.75	10.08	14.84	11.90	12.60	15.81	17.71	9.94	13.09	—
fa	8.57	7.14	0.82	7.04	17.54	10.61	6.22	8.57	7.24	—
mt	1.86	4.41	8.35	4.64	3.48	1.86	5.10	3.94	2.55	8.12
hm	—	—	—	—	—	—	—	—		1.92
il	1.52	5.17	3.95	4.56	3.65	4.86	4.10	1.98	4.41	3.95
ap	1.01	1.01	1.34	0.67	1.34	1.34	0.67	1.34	0.67	1.68
or	38	24	20	23	29	22	23	38	27	21
ab	37	28	35	35	23	32	36	41	31	34
an	25	48	45	42	48	46	41	21	42	45
Q	9	6	12	5	4	2	3	10	5	42
fo	61	55	83	60	38	45	72	48	61	58
fa	30	39	5	35	58	53	25	42	34	0

No.	188	189	190	191	192	193	194	195	196	197
SiO_2	48.10	48.20	48.28	48.56	48.68	48.86	49.66	49.96	50.16	50.16
Al_2O_3	14.54	18.16	18.61	17.54	16.96	13.63	17.29	19.33	16.46	18.49
Fe_2O_3	2.77	1.57	7.29	3.84	6.23	7.74	2.23	9.35	0.74	7.34
FeO	9.26	9.60	3.74	7.80	5.29	3.47	8.32	1.35	9.42	3.43
MgO	5.74	6.88	5.44	7.96	6.60	9.00	6.85	4.16	8.15	5.86
CaO	8.54	7.44	6.97	7.16	7.74	8.22	6.87	6.38	8.58	6.28
Na_2O	5.11	3.18	3.84	3.07	3.24	4.41	3.74	3.53	3.08	3.17
K_2O	2.59	1.81	2.93	1.49	2.58	1.82	2.66	2.70	1.15	2.47
TiO_2	1.01	2.22	1.54	2.09	2.13	1.00	1.80	1.78	1.75	2.10
P_2O_5	0.63	0.61	0.32	0.57	0.39	0.35	0.47	0.71	0.29	0.15
MnO	0.31	0.23	0.10	0.25	0.23	0.31	0.20	0.20	0.19	0.25
H_2O+	0.05	0.34	1.51	n.d.	0.33	0.07	0.27	0.64	0.36	0.46
H_2O-	1.36	0.28		0.12	0.12	0.18	0.18	0.41	0.19	0.05
Total	100.01	100.53	100.57	100.45	100.57	99.06	100.54	100.50	100.52	100.21
Anal.	Geol. Sur. of S. M. Ry.	Murata	Sawayama	Murata	Murata	Geol. Sur. of S. M. Ry.	Murata	Murata	Murata	Murata
Norms										
Q	—	—	—	—	—	—	—	1.50	—	0.84
C	—	—	—	—	—	—	—	0.71	—	—
or	15.57	10.56	17.24	8.90	15.57	10.56	16.12	16.12	6.67	14.46
ab	15.72	26.72	27.25	25.68	27.25	28.82	26.20	29.34	26.20	26.72
an	8.90	30.02	24.74	29.75	24.19	11.95	22.52	26.97	27.80	28.91
ne	14.77	—	2.84	—	—	4.54	2.84	—	—	—
wo	12.53	1.39	3.25	0.93	4.76	10.79	3.60	—	5.45	0.58
en	6.30	2.60	2.80	8.80	3.80	9.30	2.10	10.40	8.00	14.70
fs	5.94	1.85	—	4.36	0.66	—	1.32	—	5.54	—
fo	5.67	10.22	9.52	7.77	8.89	9.24	10.57	—	8.68	—
fa	5.81	8.57	—	4.18	1.94	—	8.24	—	6.73	—
mt	4.18	2.32	7.89	5.57	9.05	9.05	3.25	—	0.93	5.80
hm	—	—	1.92	—	—	1.44	—	9.34	—	3.36
il	1.98	4.26	2.98	2.13	2.13	1.98	3.50	3.34	3.34	3.95
ap	1.34	1.34	0.67	1.34	1.01	1.01	1.01	1.68	0.67	0.34
or	39	16	25	14	23	21	25	22	12	21
ab	39	40	39	40	41	56	40	41	43	38
an	22	44	36	46	36	23	35	37	45	41
Q	14	5	8	14	7	15	4	39	13	34
fo	42	52	92	56	58	85	54	61	49	66
fa	44	43	0	30	35	0	42	0	38	0

178. Olivine-trachyandesitic basalt, crust of volcanic bomb; Ta-i Shan, Lung-wan Volcano (Ogura, T., 1951, *Chemical composition of igneous rocks of Manchuria, in* Geology and Mineral Resources of the Far East, no. 150).
179. Olivine trachybasalt, lava flow; south of Ta-lung-wan (Ogura, T., *ibid.*, no. 149).
180. Olivine trachybasalt, reddish scoria; Ta-i Shan, Lung-wan Volcano (Ogura, T., *ibid.*, no. 145).
181. Olivine trachybasalt, lava flow; Shuang-yang-tung Ho, Lung-wan Volcano (Ogura, T., *ibid.*, no. 143).
182. Olivine trachybasalt, lava flow; west of Ta-i Shan, Lung-wan Volcano (Ogura, T., *ibid.*, no. 141).
183. Olivine trachybasalt, lava flow; Ha-ma-t'ang, Lung-wan Volcano (Ogura, T., *ibid.*, no. 140).
184. Olivine trachybasalt, scoria; Ta-i Shan, Lung-wan Volcano (Ogura, T., *ibid.*, no. 139).
185. Olivine-trachyandesitic basalt, scoria; Hsi Shan, Hsien-shui-ting-tzu, Lung-wan Volcano (Ogura, T., *ibid.*, 134).
186. Olivine trachybasalt, lava flow; Chen-chia-p'u, Lung-wan Volcano (Ogura, T., *ibid.*, no. 135).
187. Olivine trachybasalt, black scoria; Ta-ku Shan, Lung-wan Volcano (Ogura, T., *ibid.*, no. 131).
188. Olivine-trachyandesitic basalt, lava flow; west of Huang-ni-kang-hsi, Lung-wan Volcano (Ogura, T., *ibid.*, no. 128).
189. Olivine trachybasalt, black scoria; Hu-lu-lung-wan, Lung-wan Volcano (Ogura, T., *ibid.*, no. 125).
190. Olivine trachybasalt, lava flow; east shore of Hu-lu-lung-wan, Lung-wan Volcano (Ogura, T., *ibid.*, no. 124).
191. Glassy basalt, lava flow; Ta-lung-wan, Lung-wan Volcano (Ogura, T., *ibid.*, no. 122).
192. Olivine trachybasalt, scoria; Hsiao-i Shan, Lung-wan Volcano (Ogura, T., *ibid.*, no. 121).
193. Olivine-trachyandesitic basalt, scoria; Ta-lung-wan Volcano (Ogura, T., *ibid.*, no. 119).
194. Olivine trachybasalt, compact lava; Hsiao-weng-ch'uan crater, Lung-wan Volcano (Ogura, T., *ibid.*, no. 114).
195. Olivine trachybasalt, brown scoria; Kuan-ts'o Ling, Lung-wan Volcano (Ogura, T., *ibid.*, no. 112).
196. Olivine trachybasalt, lava flow; north of Hsi-heng-tao Shan, Lung-wan Volcano (Ogura, T., *ibid.*, no. 111).
197. Olivine trachybasalt, brown scoria; north of Hsi-heng-tao Shan, Lung-wan Volcano (Ogura, T., *ibid.*, no. 110).

Table 21. Chemical Composition of Basalts From Western Japan.

No.	205	206	207
SiO_2	47.56	48.33	55.90
Al_2O_3	14.13	16.29	16.00
Fe_2O_3	1.89	3.24	0.92
FeO	10.00	8.73	6.10
MgO	8.37	5.70	4.89
CaO	8.43	8.50	7.32
Na_2O	2.95	3.59	3.56
K_2O	1.38	1.49	1.52
TiO_2	2.77	2.40	1.56
P_2O_5	0.66	0.79	0.37
MnO	0.13	0.11	0.12
H_2O+	1.92	0.82	0.98
H_2O-			0.14
Total	100.19	99.99	99.33
Anal.	Yokoyama	Yokoyama	Taguchi
Norms			
Q	—	—	6.48
or	8.34	8.90	8.90
ab	25.15	30.39	29.87
an	21.13	22.80	23.35
wo	6.73	4.64	4.18
en	7.90	9.20	12.10
fs	3.96	9.10	8.05
fo	9.10	0.21	—
fa	6.53	0.31	—
mt	2.78	4.64	1.39
il	5.32	4.56	3.04
ap	1.68	2.02	1.01
or	15	14	14
ab	46	49	48
an	39	37	38
Q	12	26	45
fo	53	35	32
fa	35	39	23

205. Olivine-titanaugite-labradolite trachydolerite; top of Daimanjiyama, Dōgo, Oki Islands (Kōzu, S., 1913, *Sci. Rep. Tōhoku Imp. Univ.*, 2nd ser., v. 1, p. 50).
206. Trachydolerite; On-dake, Fukue-jima, Gotō Islands (Kōzu, S., 1911, *Jour. Geol*, v. 19, p. 574).
207. Quartz basalt, in the upper part of lava; Kasa-yama, Nagato Province (Sugi, K., 1942, Mem. Fac. Sci., *Kyūshū Imp. Univ.*, ser., D, v. 1, no. 3, p. 82).

Table 22. Chemical Composition of Rocks at Otsurumizu and Hyŏnam.

No.	a	b	c	d	e	f	g
SiO_2	45.58	53.91	54.64	55.31	55.54	60.27	61.52
Al_2O_3	11.60	15.65	17.11	16.96	17.31	17.38	17.53
Fe_2O_3	3.12	3.75	3.07	2.16	2.09	4.45	1.72
FeO	7.31	2.82	5.38	5.18	4.73	1.83	0.91
MgO	8.71	4.81	4.04	4.17	3.70	1.03	0.24
CaO	7.98	7.09	5.35	5.70	5.46	3.01	2.46
Na_2O	4.02	4.12	5.85	5.88	3.96	6.27	6.54
K_2O	2.67	2.47	2.84	2.73	3.53	4.77	6.40
TiO_2	2.97	2.00	0.27	0.15	1.10	0.26	0.17
P_2O_5	1.98	1.28	0.08	0.12	0.38	tr.	0.12
MnO	0.04	tr.	0.41	0.68	0.12	0.15	0.15
H_2O+	} 4.39	} 2.05	1.26	1.02	0.99	0.72	1.32
H_2O-			0.45	0.41	1.14	0.67	0.51
CO_2	n.d.	n.d.	n.d.	n.d.	0.12	n.d.	n.d.
Total	100.37	99.95	100.75	100.47	100.17	100.81	99.59
Anal.	Yokoyama	Yokoyama	Koike	Koike	Raoult	Koike	Koike
Norms							
Q	—	3.06	—	—	5.22	—	—
or	15.57	15.01	16.68	16.12	20.57	28.36	37.81
ab	32.49	34.58	39.30	39.82	34.06	52.40	46.63
an	5.84	16.96	11.95	11.95	18.90	5.00	—
ne	0.85	—	5.68	5.40	—	0.28	4.26
ac	—	—	—	—	—	—	0.46
wo	3.02	4.18	5.80	6.50	2.20	4.18	4.76
en	2.20	12.00	3.10	3.40	9.30	2.60	0.60
fs	0.53	1.59	2.51	2.90	5.15	—	0.40
fo	11.37	—	4.90	4.90	—	—	—
fa	4.18	—	4.08	4.49	—	—	—
mt	4.41	5.57	4.41	3.25	3.02	5.57	2.32
hm	—	—	—	—	—	0.64	—
il	5.78	0.46	0.46	0.30	2.13	0.46	0.30
ap	4.70	3.02	0.34	0.34	1.01	—	0.34
or	29	23	24	24	28	33	45
ab	60	52	58	59	46	61	55
an	11	25	18	17	26	6	0
Q	4	42	10	11	47	30	27
fo	71	50	52	46	33	70	42
fa	25	8	38	43	20	0	31

a. Glassy monchiquitic rock; Otsurumizu, Kanzaki, Bungo Province (Kōzu, S., 1914, *Sci. Rep. Tōhoku Imp. Univ.*, 2nd ser., 1, p. 80).
b. Soretite trachyandesite; same locality as above (Kōzu, S., *ibid.*, p. 79).
c,d. Syenodolerite; Hyŏnam, Kuk-tong, Tong-myŏn, Myŏngch'ŏn-gun, Hamgyŏng-pukto, Korea (Itō, T., 1937, *Beiträge zur Mineralogie von Japan*, Neue Folge, 2 (Tōkyō), p. 152).
e. Dolerite; same locality as above (Lacroix, A., 1928, *Bull Geol. Soc. China*, v. 7, p. 58).
f. Syenite; same locality as above (Itō, T., 1937, p. 151).
g. Syenite-aplite; same locality as above (Itō, T., 1937, p. 153).

Table 9. Chemical Composition of Paektu-san Lavas.

No.	47	48	49	50	51	52	53	54	55	56	57	58	59
SiO_2	61.30	61.68	61.83	62.98	64.42	64.76	64.78	64.89	65.04	65.68	65.84	66.24	66.27
Al_2O_3	16.47	17.36	18.27	16.53	16.26	15.08	15.00	15.42	16.66	15.93	15.39	14.64	14.57
Fe_2O_3	2.76	1.79	1.48	1.94	2.26	4.63	3.73	2.94	2.36	3.02	1.45	1.45	1.87
FeO	3.75	4.03	3.47	4.00	3.77	1.85	2.55	3.68	2.93	3.44	3.55	3.52	3.08
MgO	0.25	0.37	0.37	0.55	0.17	0.35	0.13	0.12	0.02	0.03	0.03	0.79	0.59
CaO	1.69	1.53	1.63	2.17	1.24	1.34	1.21	1.23	0.99	0.72	1.50	0.49	0.94
Na_2O	5.38	4.68	4.92	4.73	5.44	4.85	6.28	5.46	6.08	4.76	5.96	7.46	7.70
K_2O	5.10	5.10	5.98	5.66	4.74	5.23	4.90	4.74	4.88	5.06	5.27	4.44	4.41
TiO_2	0.55	0.65	0.60	0.69	0.55	0.53	0.50	0.40	0.40	0.42	0.66	0.15	0.28
P_2O_5	0.02	0.03	0.03	0.23	0.02	0.12	tr.	tr.	tr.	tr.	0.12	n.d.	n.d.
MnO	0.14	0.13	0.06	0.13	0.12	0.20	0.07	0.12	0.09	0.07	0.17	0.39	0.37
H_2O+	0.73	0.27	0.28	none	0.10	0.47	none	none	none	0.05	0.21	} 0.27	} 0.13
H_2O-	0.57	0.39	0.52	0.10	0.22	0.37	0.20	0.12	0.14	0.02	0.08		
CO_2	1.23	1.80	0.45	0.20	0.28	0.12	0.40	0.58	0.16	0.31	n.d.	n.d.	n.d.
Total	99.94	99.81	99.89	99.91	99.59	99.90	99.75	99.70	99.75	99.71	100.23	99.84	100.21
Anal.	MURATA	MURATA	MURATA	MURATA	MURATA	MURATA	MURATA	MURATA	MURATA	MURATA	RAOULT	KIN'NARI	KIN'NARI
Norms													
Q	5.40	7.50	4.44	4.20	9.90	14.16	7.80	11.22	7.80	15.42	7.56	6.84	6.42
C	—	1.43	0.71	—	—	—	—	—	—	1.22	—	—	—
or	30.02	30.02	35.58	33.92	27.80	30.58	28.91	27.80	28.91	30.02	31.14	26.13	26.13
ab	45.59	39.82	41.39	39.82	46.11	40.87	50.30	46.11	51.35	40.35	50.30	50.30	50.30
an	5.84	7.51	8.06	6.95	6.12	4.17	—	3.61	3.89	3.61	—	—	—
ac	—	—	—	—	—	—	2.77	—	—	—	—	4.16	5.54
ns	—	—	—	—	—	—	—	—	—	—	—	1.83	1.95
wo	1.04	—	—	0.81	—	0.70	2.44	0.93	0.46	—	2.78	1.04	1.97
en	0.60	0.90	0.90	1.40	0.40	0.90	0.30	0.30	0.10	0.10	0.10	2.00	1.50
fs	3.83	5.02	4.22	4.88	4.36	—	1.85	3.96	2.77	3.30	4.49	6.86	5.81
mt	4.18	2.55	2.09	2.78	3.26	5.34	3.94	4.18	3.48	4.41	2.09	—	—
mh	—	—	—	—	—	0.96	—	—	—	—	—	—	—
il	1.06	1.22	1.22	1.37	1.06	0.91	0.91	0.76	0.76	0.76	1.22	0.30	0.61
ap	—	—	—	0.67	—	0.34	—	—	—	—	0.34	—	—
or	37	39	42	42	35	40	36	36	34	41	38	34	34
ab	56	51	49	49	57	54	64	59	61	54	62	66	66
an	7	10	9	9	8	6	0	5	5	5	0	0	0
Q	66	66	59	55	75	96	84	79	79	86	71	58	59
fo	4	5	7	9	2	4	2	1	1	0	1	9	8
fa	30	29	34	36	23	0	14	20	20	14	28	33	33

No.	60	61	62	63	64	65	66	67	68	69	70	71	72
SiO_2	67.42	67.68	67.84	68.98	70.81	70.95	71.76	72.76	72.86	54.64	66.28	71.67	73.20
Al_2O_3	15.07	12.55	15.27	13.18	10.63	12.23	11.65	11.06	10.64	16.95	14.86	13.05	9.31
Fe_2O_3	0.44	3.00	2.22	0.44	2.60	1.22	2.51	2.94	3.42	2.11	2.26	1.00	3.25
FeO	2.79	2.85	2.38	3.49	4.01	4.13	3.23	2.46	2.77	6.63	2.92	2.80	3.10
MgO	0.25	0.24	0.04	0.69	0.23	0.05		0.10	tr.	3.17	0.34	none	0.04
CaO	1.42	1.25	0.82	1.60	0.75	0.47	0.62	0.59	0.64	6.14	1.66	3.32	0.38
Na_2O	6.11	6.31	5.32	6.02	5.97	5.46	4.68	4.55	4.73	3.77	6.34	4.83	5.25
K_2O	5.01	4.71	5.02	5.08	3.47	4.60	4.51	4.33	4.30	3.17	4.73	4.02	4.43
TiO_2	0.72	0.31	0.35	0.40	0.11	0.30	0.38	0.29	0.32	1.81	0.40	0.21	0.60
P_2O_5	0.07	0.19	none	—	0.05	tr.	0.05	0.08	tr.	0.42	0.10	—	0.10
MnO	0.14	0.06	0.05	0.62	0.10	0.09	0.10	0.05	0.12	0.16	0.10	none	0.19
H_2O+	0.36	0.51	none	0.14	0.93	none	0.59	0.71	0.36	none	0.13	0.11	0.28
H_2O-	0.05	0.08	0.14	0.12	0.40	0.04	0.22	0.33	0.21	0.25	0.09	0.02	0.12
CO_2	n.d.	n.d.	0.22	n.d.	n.d.	0.36	n.d.	n.d.	n.d.	0.57	n.d.	n.d.	n.d.
Total	99.85	99.74	99.67	100.76	100.06	99.90	100.30	100.25	100.37	99.79	100.21	100.94	100.25
Anal.	RAOULT	NEMOTO	MURATA	SETO	SETO	MURATA	RAOULT	NEMOTO	RAOULT	MURATA	NEMOTO	SETO	RAOULT
Norms													
Q	9.84	14.22	15.60	14.94	24.24	21.54	25.56	30.42	28.50	2.04	7.86	21.78	31.62
C	—	—	—	—	—	—	—	—	—	—	—	—	—
or	29.47	27.80	29.47	30.02	20.57	27.24	26.69	25.58	25.58	18.90	27.80	23.91	26.13
ab	49.78	38.77	44.54	39.30	35.11	37.20	35.11	27.77	30.39	31.96	50.30	40.35	23.06
an	—	—	3.34	—	—	—	—	—	—	20.02	—	2.22	—
ac	1.39	8.78	—	1.39	7.39	3.70	4.16	8.32	8.32	—	2.77	—	9.70
ns	—	1.10	—	2.32	1.59	1.10	—	0.37	—	—	—	—	2.44
wo	2.55	2.20	0.23	3.36	1.51	0.93	1.28	0.35	1.28	3.25	3.13	5.68	0.81
en	0.60	0.60	0.10	1.50	0.60	0.10	—	0.30	—	7.90	0.90	—	0.10
fs	4.22	4.88	2.11	6.86	7.39	7.13	4.36	4.09	4.36	7.39	3.70	3.96	4.62
mt	—	—	3.25	0.76	—	—	1.62	—	0.70	3.02	1.86	1.39	—
mh	—	—	—	—	—	—	—	—	—	—	—	—	—
il	1.37	0.61	0.61	—	0.15	0.61	0.76	0.61	0.61	3.50	0.76	0.46	1.22
ap	0.34	0.34	—	—	—	—	—	0.34	—	1.01	0.34	—	0.34
or	37	42	38	43	37	42	43	48	46	27	36	36	53
ab	63	58	58	57	63	58	57	52	54	45	64	61	47
an	0	0	4	0	0	0	0	0	0	28	0	3	0
Q	75	79	91	73	81	81	89	90	90	35	72	79	90
fo	3	2	0	4	1	0	0	1	0	32	5	11	0
fa	22	19	9	23	18	19	11	9	10	33	23	10	10

47. Soda-diopside-anorthoclase trachyte; P'aektu-san (Ogura, T., 1951, Chemical composition of igneous rocks of Manchuria no. 63, *in* Geology and Mineral Res. Far East).
48. Yellow augite-anorthoclase trachyte; Maan-san, P'aektu-san (same as above, no. 62).
49. Fayalite-augite-anorthoclase-trachyte; (same as above, no. 61).
50. Yellow augite-olivine-anorthoclase-potash oligoclase trachyte; Mach'ŏnmol, P'aektu-san (same as above, no. 60).
51. Fayalite-soda diopside-anorthoclase trachyte; Mach'ŏnmol, P'aektu-san (same as above, no. 59).
52. Fayalite-augite-anorthoclase trachyte; (same as above, no. 58).
53. Fayalite-soda diopside-anorthoclase trachyte; in the vicinity of Changbaek hot spring, P'aektu-san (same as above, no. 57).
54. Alkali hornblende-fayalite-soda diopside anorthoclase pantellerite; P'aektu-san formation (same as above, no. 40).
55. Anorthoclase-soda diopside trachyte; south of P'aektu-san formation (same as above, no. 56).
56. Anorthoclase trachyte; in the valley of Mach'ŏnmol, P'aektu-san (same as above, no. 55).
57. Alkali-trachyte obsidian; Pyŏngsiam, P'aektu-san (Lacroix, A., 1927, Les rhyolites et les trachyte hyperalcalines quartziferes, à propos de la Corée: *Comptes Rendus*, Tome 185, p.1414).
58. Fayalite-bearing soda diopsidic-aegirine-augite-anorthoclase trachyte; at the foot of the east wall of Talmun, P'aektu-san (Watanabe, T., 1934, *Volcanol. Soc. Japan, Bull.*, v. 2, p. 65).
59. Fayalite-soda diopside-anorthoclase trachyte; at the foot of Taejong-bong, P'aektu-san (Watanabe, T., *ibid.*).
60. Trachyte à silice libre (2e facies) (hakutoite); (Lacroix, A., 1927).
61. Hyalo-pantelleritic trachyte; top of P'aeg-am, P'aektu-san (Nemoto, T., 1935, *Japan. Assoc. Mineralogists, Petrologists and Econ. Geologists Jour.*, v. 14, p. 157).
62. Aegirine-soda diopside-anorthoclase pantellerite; Mach'ŏnmol, P'aektu-san (Ogura, T., 1951, no. 37).
63. Aegirine-riebeckite trachyte (pantelleritic); at the top of P'aektu-san (Kōzu, S., and Seto, K., 1929, Abstract of paper from the 4th Pacific Sci. Congress Java, v. 2, B, p. 1067).
64. Hyalopantellerite; P'aektu-san (Kōzu, S., and Seto, K., 1922, *Geol. Soc. Japan Jour.*, v. 29, p. 215).
65. Quartz-glassy pantellerite; on the side of P'aektu-san, P'aeg-am (Ogura, T., same as 62, no. 34).
66. Comendite (facies à lithophyses); P'aektu-san (Lacroix, A., 1927 [item 57], p. 1413).
67. Comenditic pantellerite; entrance of Taejong-bong trail, P'aektu-san (Nemoto, S., 1935, cited under sample 61).
68. Pantellerite (facies à lithophyses); P'aektu-san (Lacroix, A., 1927 [item 57], p. 1413).
69. Olivine labradorite-soda anorthoclase-trachybasalt; gravels scattered at the top of Taejong-bong, P'aektu-san (Ogura, T., 1951, no. 92).
70. Nordmarkitic ejecta; at the top of P'aektu-san (Suzuki, J., 1938, *Hokkaidō Imp. Univ., Fac. Sci. Jour.*, ser. IV, v. 4, p. 180).
71. Pumice (comendite type); at the top of P'aektu-san (Kōzu, S., and Seto, K., 1929. [item 63], p. 1067).
72. Pantellerite (facies vitreux); P'aektu-san (Lacroix, A., loc. cit. [item 57], p. 1413).

Note: 69–72, eruptive material of the Pleistocene age.

Table 23. Chemical Composition of Rocks From Hoeryŏng and Chongsŏng.

No.	h	i	j	k	l	m	n	o
SiO_2	46.22	47.08	49.27	50.26	58.43	47.82	50.75	59.74
Al_2O_3	16.33	13.41	20.30	19.23	21.73	17.98	18.07	20.59
Fe_2O_3	1.24	2.85	0.41	1.00	1.56	2.88	2.91	2.21
FeO	7.40	7.19	7.82	3.89	1.75	6.74	6.39	1.35
MgO	7.88	3.97	6.43	3.21	0.88	3.86	0.07	0.17
CaO	8.46	12.38	10.84	7.70	2.53	8.96	8.85	2.44
Na_2O	4.33	4.83	1.78	7.69	6.03	2.66	3.00	7.88
K_2O	2.25	4.91	0.51	4.39	5.24	5.88	6.33	4.09
TiO_2	2.78	0.57	1.62	1.93	none	0.62	0.72	0.23
P_2O_5	0.54	0.10	0.14	—	none	0.37	0.91	none
MnO	0.17	0.14	0.33	0.08	0.03	—	0.04	none
$H_2O\pm$	1.74	0.39	0.60	0.93	1.23	1.72	1.67	1.38
H_2O-	0.13	1.81	0.13	0.29	0.34	0.67	0.54	0.02
CO_2	0.41	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Cl	n.d.	n.d.	tr.	n.d.	0.49	0.31	0.27	0.58
Total	99.88	99.59	100.18	100.60	100.24	100.47	100.52	100.68
Anal.	RAOULT	SETO	SETO	SETO	SETO	SETO	SETO	SETO
Norms								
Q	—	—	0.60	—	—	—	—	—
C	—	—	—	—	1.53	—	—	—
or	13.34	28.91	2.78	26.13	31.14	32.53	37.25	24.46
ab	15.46	6.81	15.20	6.29	44.01	—	11.00	51.87
an	18.63	0.56	45.87	4.73	12.51	19.46	17.24	8.62
lc	—	—	—	—	—	1.96	—	—
ne	10.93	18.18	—	31.81	3.69	12.21	7.67	7.95
wo	8.24	13.46	3.02	14.04	—	9.28	8.82	1.51
en	5.40	6.50	16.10	8.00	—	4.70	0.20	0.40
fs	2.24	6.73	11.88	3.30	—	4.36	8.32	0.26
fo	10.01	2.38	—	—	1.54	3.50	—	—
fa	4.59	2.65	—	—	1.53	3.47	—	—
mt	1.86	4.18	0.70	1.39	2.32	4.18	4.18	3.25
il	5.32	1.06	3.04	3.65	—	1.22	1.37	0.46
ap	1.34	0.34	0.34	—	—	1.01	2.02	—

h. Basanitoid; Undusŏng, P'arŭl-myŏn, Hoeryŏng-gun, Hamgyŏng-pukto, Korea (Lacroix, A., 1928, *Bull. Geol. Soc. China*, v. 7, p. 28).

i. Trachydolerite; same locality as above (Kōzu, S., and Seto, K., 1922, *Jour. Geol. Soc. of Japan*, v. 29, p. 217).

j. Olivine trachybasalt; top of Sansŏng-san, Hoeryŏng-ŭp, Hoeryŏng-gun (Kōzu, S., and Seto, K., 1929, Proc, 4th Pacific Sci, Cong., Java, v. 2, B, p. 1067).

k. Trachydolerite with sodalite and analcite; north side of Sansŏng-san, Hoeryŏng-ŭp, Hoeryŏng-gun (Kōzu, S., and Seto, K., *ibid.*, p. 1067).

l. Sodalite microsyenite; Yŏndae-bong, Pyŏksŏng-myŏn, Hoeryŏng-gun (Kōzu, S., and Seto, K., *ibid.*, p. 1067).

m. Alkali-gabbroid rock (fine-grained); Nanchuri, Shokwamen, Chongsŏng-gun, Hamgyŏng-pukto, Korea (Kōzu, S., and Seto, K., 1926, *Proc. 3rd Pan-Pacific Sci. Cong.* Tōkyō, v. 1, p. 781)

n. Alkali-gabbroid rock (coarse-grained); same locality as above (Kōzu, S., and Seto, K., 1926. ibid.).

o. Sodalite microsyenite; same locality as above (Kōzu, S., and Seto, K., 1926, *ibid.*).

Table 24. Chemical Composition of Rocks From Manchuria, Taiwan and China.

No.	p	q	r	s	t
SiO_2	43.03	47.56	48.10	48.74	48.98
Al_2O_3	14.25	13.21	15.64	15.84	14.12
Fe_2O_3	6.91	6.65	6.80	6.90	2.25
FeO	4.26	2.98	2.78	2.82	7.40
MgO	8.01	3.59	3.80	3.85	7.98
CaO	11.55	5.04	7.77	7.88	10.30
Na_2O	3.73	4.20	2.61	2.65	2.61
K_2O	2.61	4.64	3.49	3.54	1.61
TiO_2	1.76	4.23	2.26	2.29	2.88
P_2O_5	0.28	2.21	1.66	1.68	0.30
MnO	0.41	—	tr.	—	0.15
H_2O+ } H_2O-	2.34	5.11	4.40	4.46	1.03
H_2O-			1.32		0.32
CO_2	1.55	n.d.	n.d.	n.d.	n.d.
Total	100.72	99.42	100.63	100.68	99.93
Anal.	MURATA	KŌNO	KŌNO	KŌNO	YAGI
Norms					
Q	—	—	3.60	3.36	—
or	15.57	27.74	20.57	21.13	9.45
ab	7.34	35.11	22.01	22.53	22.01
an	14.46	3.34	20.57	20.85	21.96
ne	13.06	0.28	—	—	—
wo	12.99	1.97	2.90	3.02	11.37
en	11.20	1.70	9.50	9.60	12.30
fs	—	—	—	—	4.49
fo	6.16	5.11	—	—	5.39
fa	—	—	—	—	2.14
mt	9.98	—	2.55	2.32	3.25
hm	—	6.72	5.12	5.28	—
il	3.34	6.38	4.26	4.41	5.47
pf	—	1.50	—	—	—
ap	0.67	5.04	4.03	4.03	0.67
cc	3.50	—	—	—	—
or	42	42	32.5	33	17
ab	19	53	35	35	42
an	39	5	32.5	32	41
Q	23	7	49	48	19
fo	77	93	51	52	58
fa	0	0	0	0	23

p. Barkevikite monchiquite; P'i-tzu-wo, Kuan-tung Province (Ogura, T., 1933, *Mem. Ryojun Coll. Eng.*, v. 6, no. 9).

q,r,s. Teschenite; near Lu-k'u, T'ai-pei Province, Taiwan (Ichimura, T., 1932, *Geol. Mag.*, v. 69, p. 72).

t. Olivine trachybasalt; Wei-chou Tao, Kuang-tung Province, China (Yagi, K., 1949, *Kagaku* [Science], v. 19, p. 331).

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On the Cenozoic Vertebrates in Korea

Fuyuji Takai

Fossils of Cenozoic vertebrates of Korea are in poorer condition than those of China and are also inferior to those of Japan, which have been considered rather poor. To summarize the present knowledge of these fossils may be significant for future studies on Cenozoic formations, so their specific names, the fossil-bearing formations, and their localities are given below in the order of their geological succession. Their palaeontological descriptions are omitted, but references to periodicals which include descriptions are given at the end of this article.

Eocene

The following seven mammalian species occur in the coal seams of the Pongsan and Sariwŏn coal mines of the Pongsan coal field in Pongsan-gun, Hwanghae-do, and the geological age of the seven is presumed to be latest Eocene from their relationships with the Shara Murun and Irdin Manha formations of Mongolia.

Carnivora	*Harpagolestes koreanicus* Shikama
Perissodactyla	*Cristidentinus* sp.
	Desmatotherium grangeri Tokunaga
	Lophialetes tokunagai Takai
	Colodon hodosimai Takai
	Caenolophus makii Takai
	Protitanotherium koreanicum Takai

Occurrences of mammalian remains in the Pongsan coal field were first reported by Tokunaga (1926), and although lacking sufficient data, he considered their geological age to be Miocene. Later, Mori (1929) and Tokunaga (1929 b) stated that their age was Miocene, but Tokunaga (1932, 1933a-c) concluded that they were late Eocene from the occurrences of late Eocene species which had close relationships with the Mongolian Eocene species collected by the Asiatic Expedition of the American Museum of Natural History. The results of the research on fresh-water mollusc and plant remains by Matsushita, Onoyama and Maejima (1935) also confirmed their age as late Eocene. Further study by the writer (1938, 1939a, 1945) and Shikama (1943) revealed that the Pongsan formation consisted of the above-mentioned seven species.

Through a comparison of mammalian assemblages, the writer (1950) concluded that the Pongsan formation may be correlated with the Ube coal-bearing formation and the Sōshu sandstone in the upper part of the Tachibetsu formation in Japan.[1)] Other equivalent beds which are assigned to latest Eocene are the Kuanchuang series of Shansi Province, the lower Yuanch'u series of Shansi and Honan Provinces, the Lushih series and the Fanchuang series of Honan Province, the Lunan series of Yunnan Province, all of China; the Irdin Manha formation and the Shara Murun formation, Inner Mongolia; the Pondaung formation, Burma; and the Melawi group, Borneo.

Miocene

The Miocene series occurs in several limited areas, but among them the Myŏngch'ŏn and Kilchu districts of North Hamgyŏng-do in North Korea and the Yongil, Changgi, and Yŏnil districts of North Kyŏngsang-do in South Korea are comparatively wide.

The Myŏngch'ŏn series in North Korea is divided into two parts, the lower P'yŏngnyuk stage and the upper Hamjin stage. The latter contains some mollusc remains which are characteristic of the Miocene, and the following four vertebrates. From these remains its geological age is presumed to be middle Miocene.

Pisces	Teleostei	*Clupea* sp.
Mammalia	Cetacea	*Cetacea* gen. and sp. indet.
	Proboscidea	*Bunolophodon annectens* (MATSUMOTO)
	Perissodactyla	*"Rhinoceros"* sp.

From the Yŏnil series in South Korea a shark of *Carcharodon megalodon* AGASSIZ and several bones and scales of unidentifiable bony fishes were collected, together with molluscs and other fossils, plants and animals. Their age is considered to be somewhat later than the Hamjin stage and from the middle to late Miocene.

Among the fossil fishes the occurrences of *Clupea* sp. and other bones and scales were reported for the first time by TATEIWA (1924, 1925), and KANEHARA later (1936) added the occurrence of *Carcharodon megalodon* AGASSIZ. But precise palaeontological studies of these have never been undertaken.

The first fragments of mammalian remains, unidentifiable cetacean bones, were reported by MORI (1926, 1929A) but were never studied palaeontologically. The second, mastodon, was first reported by MAKIYAMA (1935, 1936A) under the name *Trilophodon* cfr. *angustidens* (CUVIER), but later (1936B, 1938) he described it under the new specific name *Bunolophodon yokotii* Makiyama. The writer, however, (1938, 1939B, C) considered that it might be synonymous with the Japanese mastodon,

[1)] As the Gonosawa sandstone member, the lower part of the Tachibetsu formation, was erroneously mentioned in the previous report, here the writer corrects it to the Soshu sandstone member, the upper part of the Tachibetsu formation.

I correct my 1950 report in which I correlated the Pongsan formation with Gonosawa sandstone, the lower part of the Tachibetsu formation.

Bunolophodon annectens (MATSUMOTO). The third, rhinoceros, was also reported by MORI (1929A), but the writer (1938, 1939B) supposed it to be related to the Japanese Miocene rhinoceros, *Chilotherium pugnator* (MATSUMOTO), judging from its site of occurrence.

Pleistocene

The mammal-bearing Pleistocene series is also not well developed. Remains were found at several localities, such as Kaesŏng-bu, Kyŏnggi-do; Changyŏn-gun, Hwangju-gun, and Kŭmch'ŏn-gun, Hwanghae-do; Sŏngch'ŏn-gun, South P'yŏngan-do; and Kilchu-gun and Chongsŏng-gun, North Hamgyŏng-do. Some of the remains were derived from fissure-filling or terrace deposits, little is known of the other localities. From the above-mentioned localities the following nineteen mammalian species were recorded by several geologists. Judging from the species of the terrace deposits at Chongsŏng-gun, North Hamgyong-do (marked by an asterisk), the geological age of the deposit is evidently very late Pleistocene and all other remains are perhaps late Pleistocene.

Rodentia	* *Citellus tomanensis* TOKUNAGA and MORI
	* *Myospalax* cfr. *epsilanus* THOMAS
	* *Microtus maekawai* TOKUNAGA and MORI
	* *Ochotona* sp.
Carnivora	* *Hyaena ultima dokantinensis* TOKUNAGA and MORI
	Megantereon nihowanensis (TEILHARD and PIVETEAU)
Proboscidea	*Palaeoloxodon naumanni* MAKIYAMA
	* *Mammonteus primigenius* BLUMENBACH
Perissodactyla	* *Equus przewalskii* POLIAKOFF
	E. caballus fossilis LINN.
	* *Rhinoceros antiquitatis* BLUMENBACH
	R. shindoi TOKUNAGA
Artiodactyla	* *Capreolus* cfr. *pygargus ochracea* BARCLAY
	* *Cervus elaphus elaphus* LINN.
	* *C. elaphus canadensis* ERXLEBEN
	* *Megaceros* sp.
	* *Ovis* cfr. *ammon* LINN.
	* *Bos primigenius* BOJANUS
	* *Bison exguus* MATSUMOTO

Of these nineteen species, the fifteen marked by an asterisk were excavated on two occasions by MORI (1935), and TOKUNAGA and MORI (1939) from the terrace deposit at Tonggwan-jin, Chonggwan-myon, Chongsŏnggun, North Hamgyong-do, and they closely resemble the materials being excavated at Ho-chia-kou, Ku-hsiang-tung in the vicinity of Harbin, but seem to be younger than the Manchurian ones. The writer considers them to be very late Pleistocene.

A saber-toothed tiger, collected from the residual clay at the Hwan-san limestone quarry at Kyomip'o-up, Hwangju-gun, Hwanghae-do, was identified by SHIKAMA (1934) as *Machairodus* cfr. *cultridens* (CUVIER) and he concluded its geological age to be Pliocene, but the writer (1938) had some doubt about SHIKAMA's conclusion and supposed its age to be late Pleistocene. TEILHARD DE CHARDIN and LEROY (1945) later identified it with the Villafranchian species *Megantereon nihowanensis* (TEILHARD and PIVETEAU), originally described from the Nihowan formation, Hopeh Province in North China, and presumed it to be early Pleistocene. Therefore, the Early Pleistocene mammalian faunule is expected to be confirmed in Korea some day.

MORI (1929A) reported the occurrence of an elephantine tooth, related to the Indian species of *Palaeoloxodon namadicus* (FALCONER and CAUTLEY) from near Kilchu-up, Kilchu-gun, North Hamgyong-do; but he gave no data about its precise location or formation. The writer has indentified it with a Japanese Pleistocene species of *Palaeoloxodon naumanni* MAKIYAMA because of its resemblance to the Indian *Palaeoloxodon*. The occurrence may be the most northern in the distribution of *Palaeoloxodon* in Japan, Korea and China. Another occurrence of this species was reported by TAKAI (1937, 1938) from the sea floor near the island of Paengnyŏng, Changyŏn-gun, Hwanghae-do; this is the only reliable example of this species from Korea. As *Palaeoloxodon naumanni* MAKIYAMA flourished in the Pleistocene of Japan, it may also belong to the late Pleistocene of Korea.

JIMBO (1915) reported the first occurrences of mammalian remains from a limestone cave near Kyejŏng, Kodong-myŏn, Kŭmch'ŏn-gun, Hwanghae-do. Afterwards TOKUNAGA (1929A, B, 1930) clarified that they were horse and rhinoceros remains, and he (1933C) altered the previously mentioned locality to Kyŏnggi-do. On the other hand, MORI (1929A) gave an account of some fossil horse and rhinoceros from a limestone cave near Che-sok-san, Kaesŏng-gun, Kyŏnggi-do. These two localities are very near each other, and, therefore, these fossils reported by TOKUNAGA and MORI probably occurred in the same locality and possibly belonged to the same specimens. The horses were named *Equus caballus fossilis* LINN. TOKUNAGA (1929B, 1930) gave a new specific name, *Rhinoceros koreanicus* TOKUNAGA to the rhinoceros but included no description or illustrations. TAKAI (1938) suggested that it might be identified with the Japanese Pleistocene species *Rhinoceros shindoi* TOKUNAGA. The geological age of these two fossils may be Pleistocene; a more exact age determination is impossible.

TOKUNAGA (1929A) and MORI (1929A) each reported a red deer from a limestone cave at Majŏn-ni, Sŏngch'ŏn-myŏn, Sŏngch'ŏn-gun, South P'yŏngan-do, but gave no description of it. Its geological age may also be Pleistocene.

Holocene

MORI (1929B, 1930) reported a Korean bear, *Ursus ussuricus* HEUDE, and a Korean boar, *Sus coreanus* HEUDE, from a well-known limestone cave, Tŭngryong-gul, at Unhakch'am, Yongsan-myŏn, Yŏnghyŏn-gun, North P'yŏngan-do. As their occurrence in the Pleistocene has not been established, it cannot be determined whether the bones are Pleistocene or of a recent species which entered the cave to hibernate. Therefore, they may not be called fossils in a strict sense.

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The Yŏnch'ŏn System Containing Cyanite and Andalusite Deposits

Takao YAMAGUCHI

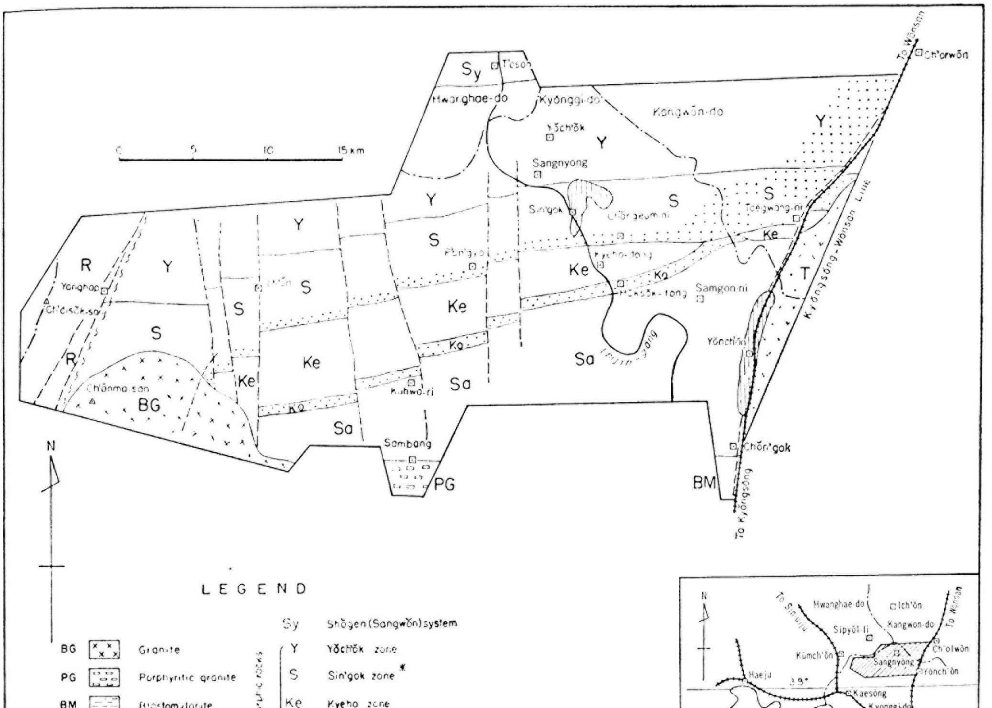


Fig. 1. Geological Map of the Sangnyŏng-Yŏnch'ŏn District, Kyŏnggi-do, South Korea. Note: S zone is divided into three subzones (see figs. 15 and 16). The author sometimes refers to these subzones by using the symbols SI, SII, and SIII.

1. Introduction

Several localities of cyanite, andalusite, and sillimanite deposits have been found in Korea. The rocks of these localities are generally considered to be Archean or Proterozoic: the Yŏnch'ŏn, Okch'ŏn, and Sangwŏn systems (YAMAGUCHI, 1941, 1952) and the gneisses in Ŭiju-gun, P'yŏngan-pukdo (TAKAHASHI, 1940) and in Kangsŏ-gun, P'yŏngan-namdo (MIYAZAWA, 1940).

The deposits generally consist of cyanite, andalusite and sillimanite concentrated in veins or pockets with smaller amounts of other minerals or other easily separable minerals.

The fact that the deposits are distributed in remarkably metamorphosed regions indicates that they are closely related genetically to the metamorphism of their country rocks.

It has not been proved that these country rocks geologically and petrologically belong to the Archean or Proterozoic system; we have the old unsolved problems:

1. What are the kinds and ages of the original rocks?
2. What are the nature and ages of the metamorphism?

The same questions also apply to the so-called Yŏnch'ŏn system.[1)]

The area covered in this paper is the type locality of the Yŏnch'ŏn system, which Shigetaro KAWASAKI (1918) reported upon earlier.

After 1939[2)] the deposits in this region became known to the miners in Korea: Y. KINOSAKI (1938) had surveyed them for the mineral resources and I later surveyed the area (1941).

2. Geology

A. The Relation of the Yŏnch'ŏn Metamorphic Group to Other Geological Members

No evidence has been found in this region to prove that this metamorphic group belongs to the Archean system. As shown in Fig. 1, this group is in contact with the Sangwŏn system in the north, probably without faulting, and is in contact with granite and gneiss in the south where the relation is that of intrusions and injections. In the east and west the geological extensions of the group are such that they cannot be described clearly.

The members clearly overlying this metamorphic group are the tuff-breccia (near Yŏnch'ŏn), the plateau basalts (near Yŏnch'ŏn and Sin'gok), and the alluvial sediments.

Relations to the blasto-mylonite (BM), *the porphyritic granite* (PG), *and granite* (BG)

(i) Western side of the southern margin (of the area of this report)—near Chung'-bang.

The porphyritic granite (PG) is injected in the Samgot granulite zone. Near the plane of contact, the rock distributions are from north to south as follows:

1) I prefer the name Yŏnch'ŏn metamorphic group to the Yŏnch'ŏn system, because no evidence suggesting that this "system" is Archean has been found.

2) The mining of these cyanite deposits increased from 1937 to 1943; many amateur prospectors and miners actively worked these deposits.

the Yŏnch'ŏn metamorphic group
Granulite[3] (Samgot zone)
Alternation of granulite and melanocratic gneiss[4], approx. 150 m thick
Injection of aplite veins in melanocratic gneiss, approx. 150 m thick
Augen-gneiss, grading southward into PG
Porphyritic granite (PG)

The rocks have a similar orientation of schistosity and show gradual transition from one to another. The forming of PG (injection of basic magma in the earlier stage and injection of aplite veins in the later stage), therefore, is considered to have occurred simultaneously with the dynamometamorphism of the Samgot granulite.

(ii) Eastern side of the southern margin—near Chon'gok.

The blasto-mylonite[5] BM, named according to petrographic textures and structures, has an almost parallel schistosity orientation to the Samgot granulite. The contact relation is not that of a fault. Sheet-like melanocratic gneisses are also distributed in that part of the granulite near the contact. The blasto-mylonitization, therefore, is considered to have occurred simultaneously with the dynamometamorphism of the Samgot granulite.

(iii) The granite BG[6] in the southwest.

This granite undoubtedly intruded the metamorphic group.

(iv) The relation between PG, BM, and BG.

The field relations between them have not been clarified, but the succession of their intrusions is considered to be as follows:

(Intrusion or injection of the original rock of BM)—(injection of PG—simultaneous with the dynamometamorphism of the Yŏnch'on metamorphic groups)—(intrusion of BG).

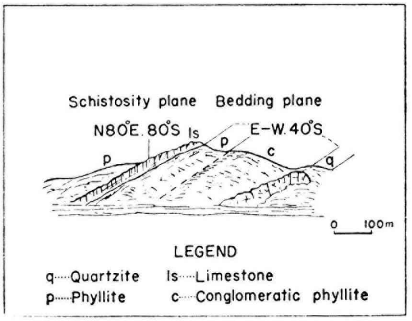


Fig. 2. Difference between the Schistosity Plane and the Bedding Plane in the Sangwŏn System Near To'san.

3) According to Harker's definition.
4) Granoblastic gabbro under the microscope.
5) According to Sander's nomenclature.
6) The Pulguksa granite?

The relation to the so-called Sangwŏn system, in the northern side.

The Yŏch'ŏk mica schist zone of the metamorphic group is in contact with the Proterozoic Sangwŏn system in the northern side. The contact relation is not considered a fault, as they alternate on a small scale near the contact and show an almost similar orientation of schistosity.

Conglomeratic phyllite, the characteristic key bed of the upper formation of the Sang'wŏn system in Middle Korea, is found near the contact (T'osan). The striking fact is that the plane of stratification and the plane of schistosity differ distinctively[7] (see Fig. 2).

The stratigraphic succession of the Sang'wŏn system (T'osan—Ich'ŏn) is as follows[8]:

Kuhyŏn Series	Phyllite P_5
	Limestone L_2
	Conglomeratic phyllite P_4
	Quartzite Q_3[9]
Sadangmol Series	Phyllite P_3
	Limestone L_1
	Ottrelite slate P_2
Chikhyŏn Series	Quartzite Q_2
	Phyllite P_1
	Quartzite Q_1

..........Unconformity..........
Gneiss (Blasto-mylonite)

The thickness of the quartzites and the limestones varies from place to place along those horizons.

B. The Internal Construction of The Yŏnch'ŏn Metamorphic Group

The zone distribution of the several rock types

Every rock type occupies an area extending almost E-W, with zone-to-zone changes from north to south. All rock types are easily distinguishable by eye in the field.

The orientations of their schistosity planes and the existence of cyanite-andalusite deposits are shown in the following table.

7) Such facts are also often observed in the Yŏnch'ŏn metamorphic group (see Figs. 4, 7).

8) The correlation of the Sang'won system of several localities has been shown in: YAMAGUCHI (1943), *Min. Journ. of Korea*, vol. XXVI, no. 4, p. 209.

9) Near Namjŏng-ni (a village between Kumch'on and Sibyon), I found one species each of *Monograptus* and *Cypridea* in the sandy slate and limestone correlated to P_3 and L_1 respectively. These fossils are well-known index fossils of Gotlandian Period.

The upper formation of the so-called Sang'won system in Middle Korea is therefore considered to be Silurian.

Zone (symbol)	Strike and dip of schistosity plane	Cyanite-andalusite deposits
Yŏch'ŏk mica schist zone (Y)	N70–90°W, 60–90°N	Few in the eastern area
Sin'gok ,, zone I (SI)	N70–90°W, 70–80°Q	None
,, ,, zone II (SII)[10]	N70–90°W, 70–80°N	None
,, ,, zone III (SIII)	N70–90°W, 60–70°N	Many
Kyeho biotite-hornfels zone (Ke)	N-E, 80–90°N (Schistosity planes generally less developed)	None
Hŭksŏk mica schist zone (Ko)	N50–70°E, 50–70°S	Some
Samgot granulite zone (Sa)	N50–70°E, 50–70°N	None
Yanghap chlorite-schist zone (R)	N50°E, 60–70°N	None

Boundaries of the zones

Excluding the Yanghap zone, every zone shows transition from one to the other, without any fault and within a short distance. In fact such a transition from the highly metamorphosed zone SIII to the low metamorphosed zone Ke can be observed on the road cut between Sin'gok and Kyeho-dong.

The boundary planes (between the zones) differ genetically from the schistosity planes, although the two seem generally to be parallel. As seen in the occurrence of the Ke zone in the eastern part, the boundary is serrate (see Fig. 3).

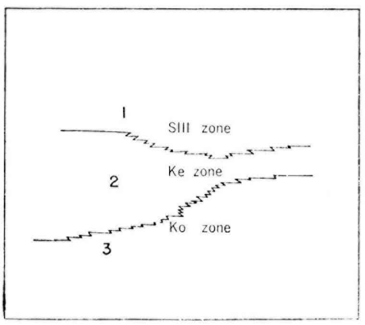


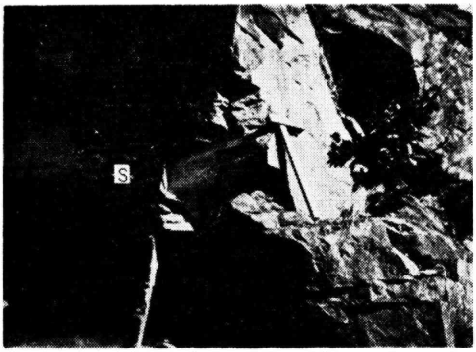
Fig. 3. Schematic Representation of the Serrate Countering of Zones.

The plane of stratification of the original formation and the plane of schistosity

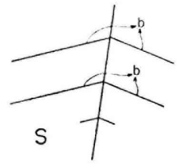
The fact that the two planes generally differ from each other in the metamorphic region is often evident in the zones Ke and Y (see Figs. 4, 7).

[10] See Fig. 16.

A



B



On B, the two kinds of plane, Sand b, are shown in geometrical form extracted from A. The plane b inclines gently as seen near the hammer on A.

Fig. 4.

The thickness of the zones

The common stratigraphic conception of thickness has no significance for the metamorphic group because of the difference between the plane of schistosity and that of stratification[11]. However, since each zone has its own nature of metamorphism, the "thickness of each kind of metamorphic zone" is shown in the following table:

	Thickness in meters	
Zone	Eastern part	Western part
Y	About 10,000	15,000
SI, SII, SIII	4,000	4,000
Ke	0 to 4,000	4,000
Ko	0 to 4,000	1,000
Sa	8,000	4,000
Total	28,000	28,000

Cyanite-andalusite deposits

These deposits are generally distributed only in the SIII and Ko zones, which have well-developed schistosity. The main deposits of large quantity and good quality are found in the SIII zone. They surely have some close relation to the remarkable metamorphism of the country rock.

[11] The stratigraphic succession and thickness of the Yŏnch'ŏn system has been shown by KAWASAKI (1918) as follows:

Upper	Mica schist, phyllite	12,290 m
	Cyanite-bearing mica schist	2,260 m
Lower	Amphibolite, hornfels	12,990 m
	Quartzite, amphibolite	
	Total	27,540 m

But, in the writer's opinion, these are the thicknesses of metamorphic zones.

Green schist and gabbro

Near T'osan, the gabbroic intrusive rocks change to green schist similar to the Mikabu green schist of Japan. Gabbroic rocks containing garnets are injected in the form of sheets of tongues into the Samgot zone.

Faults

There are some parallel step faults striking almost N-S in the metamorphic region; these faults do not cut the granite BG. A few faults striking northeast cut BG. The former are considered to have occurred simultaneously with the metamorphism, and the latter, after the metamorphism.

3. Petrology of Rocks and Ore Deposits

A. Development of Schistosity Petrofabrics or Gefügekunde

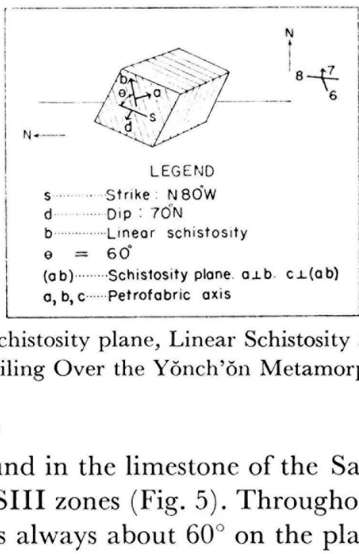


Fig. 5. The Schistosity plane, Linear Schistosity and Petrofabric Axis Prevailing Over the Yŏnch'ŏn Metamorphic Group.

(i) Linear schistosity[12]

Linear schistosity is found in the limestone of the Sangwŏn system, and in the rocks of the SI, SII, and SIII zones (Fig. 5). Throughout these zones, the inclination of linear schistosity is always about 60° on the plane of schistosity.

(ii) The system

The phyllite and the conglomeratic phyllite have phyllitic cleavage; the quartzite Q_3 was disturbed and became angular blocks; and the limestone L_2 shows ptygmatic folding and linear schistosity.

The *Gefügeregelung* of the calcites in L_2 is shown in Fig. 6.

(iii) The Yŏch'ŏk zone

The foliation is generally slaty or shaly, and no phyllitic cleavage is seen. The term granulite[13] may be preferable to schist as a name for the rocks in this zone.

Some rock has three kinds of cleavage and traces of the schistosity of the former stage and of the original stratification (see Fig. 7).

[12] The linear schistosity is indicated by symbol "b", one of the petrofabric axes which are used as the co-ordinate axis in petrofabric analysis (Fig. 5).

[13] According to Harker's definition.

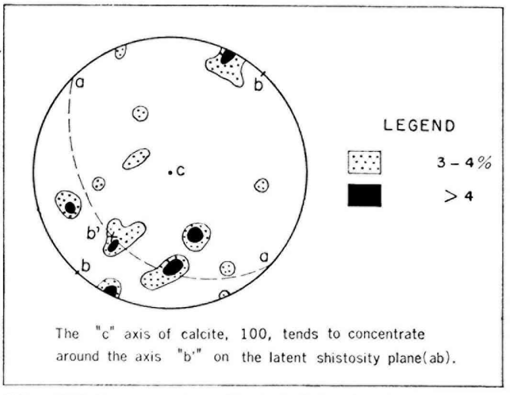
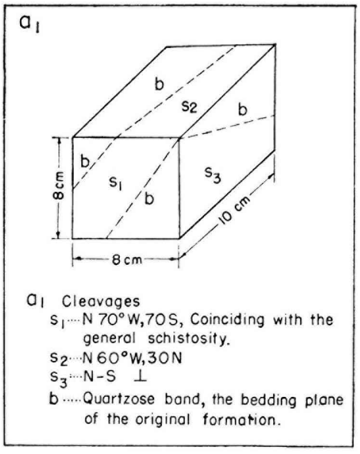


Fig. 6. The "Gefügeregelung" of Calcite in the Limestone of the Shōgen System (South of Tosan).



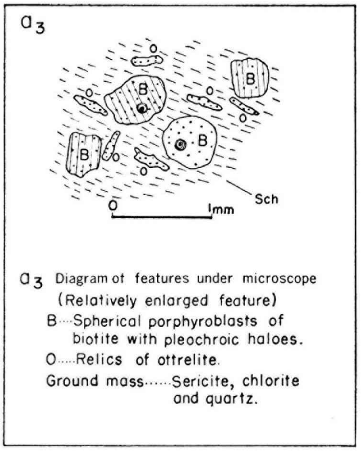


Fig. 7. a_1, a_3 Rock in the Yŏch'ŏk Zone (Specimen No. 106).

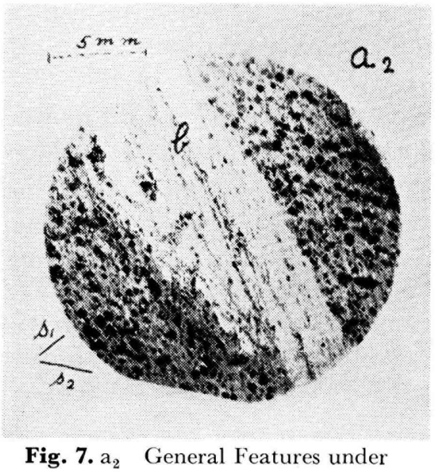


Fig. 7. a_2 General Features under Microscope.

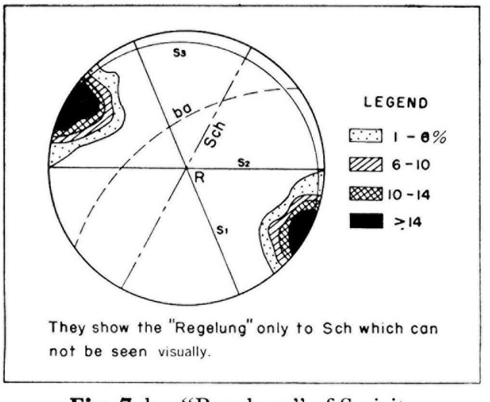


Fig. 7. b "Regelung" of Sericite 50 Poles of the Flakes.

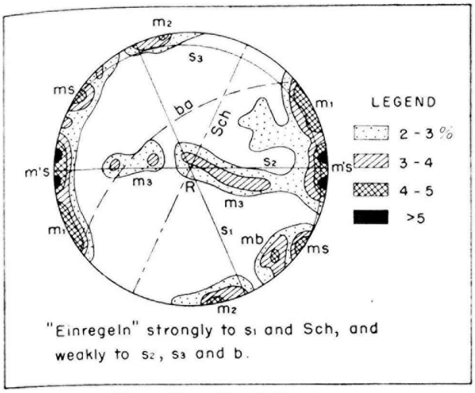


Fig. 7.c "Regelung" of Biotite 100 c-Axis.

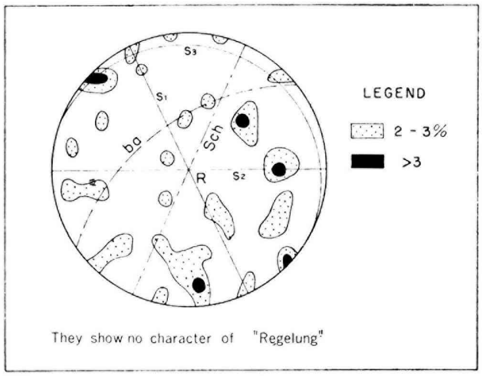


Fig. 7.d "Regelung" of Quartz 150 c-Axis.

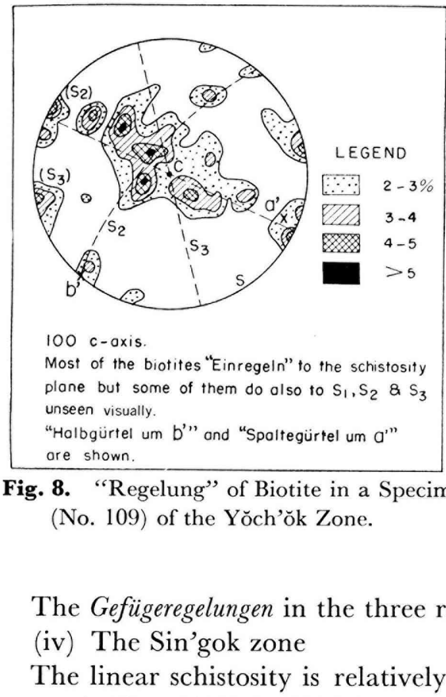


Fig. 8. "Regelung" of Biotite in a Specimen (No. 109) of the Yŏch'ŏk Zone.

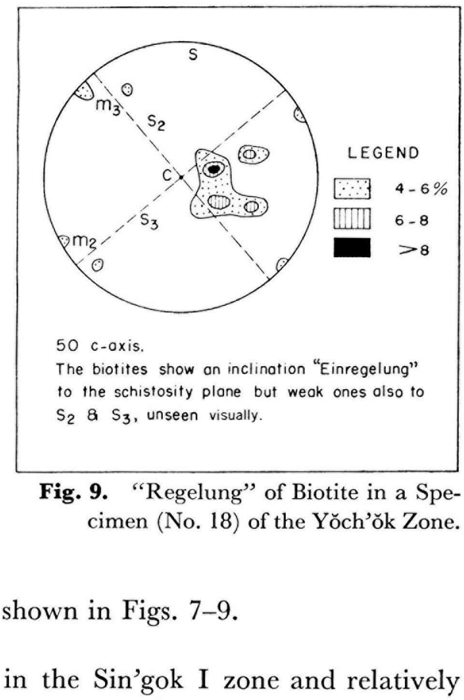


Fig. 9. "Regelung" of Biotite in a Specimen (No. 18) of the Yŏch'ŏk Zone.

The *Gefügeregelungen* in the three rocks is shown in Figs. 7–9.

(iv) The Sin'gok zone

The linear schistosity is relatively weak in the Sin'gok I zone and relatively strong in II and III; in III, it becomes weaker when cyanite and andalusite appear as constituent minerals.

The *Gefügeregelungen* in I, II, and III are shown in Figs. 10–13.

(v) The Kyeho zone

In this zone the schistosity is not generally clear, but traces of the original stratification are often found (see Fig. 4). Mica schists are sometimes intercalated.

(vi) The Hŭksŏk zone

The schistose cleavage is perfect but the plane of schistosity is often bent, and the linear schistosity is not seen.

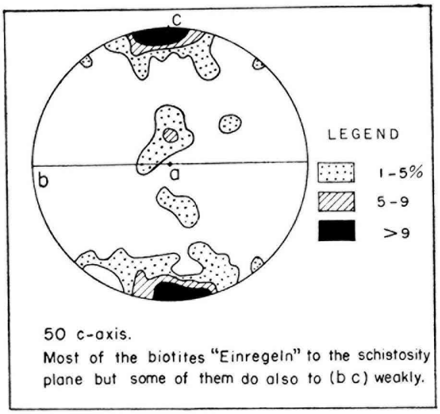
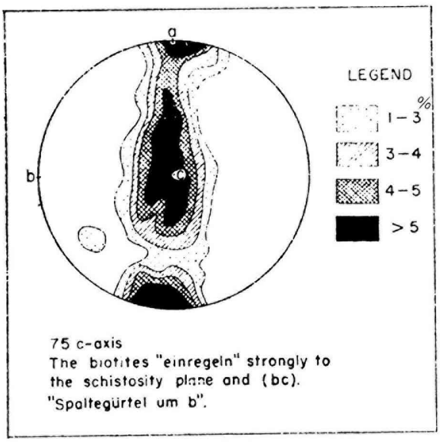
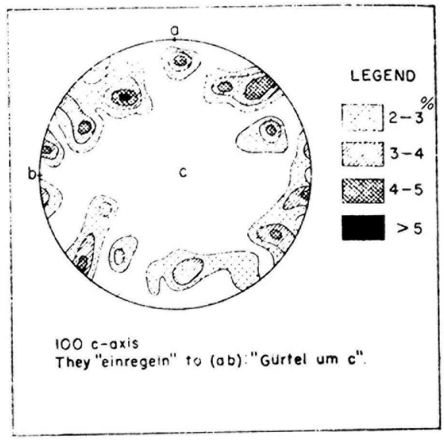


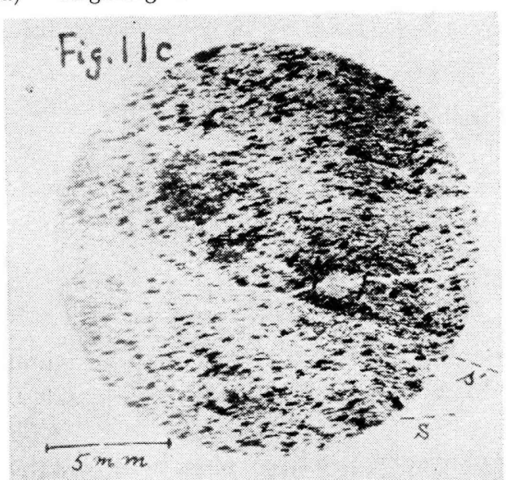
Fig. 10. "Regelung" of Biotite in a Specimen (No. 48) of the Sin'gok Zone I.



a) "Regelung" of Biotite

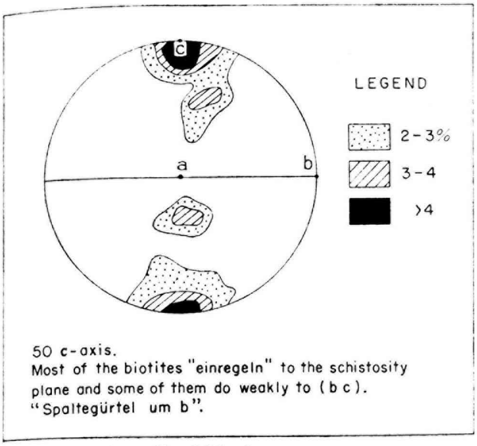


b) "Regelung" of Quartz

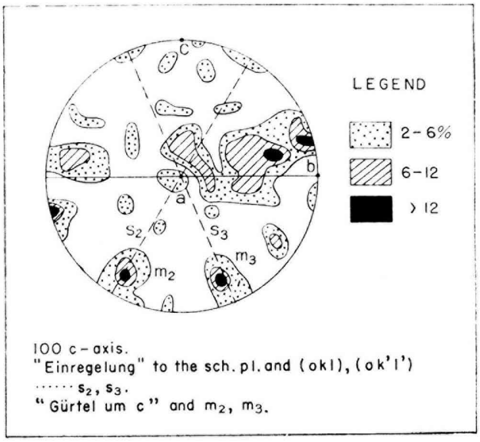


c)
The Texture Under the Microscope
S′ ......Bedding plane of the original rook
S ....Schistosity plane
In the broken circle........garnet
The porphyroblasts are garnet and biotite, and the groundmass consists of chlorite, sericite and quartz.

Fig. 11. Examples of "Gefügeregelung" from the Sin'gok II Zone.



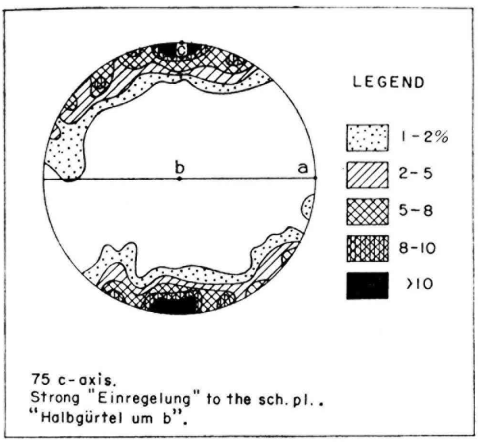
50 c-axis.
Most of the biotites "einregeln" to the schistosity plane and some of them do weakly to (b c).
"Spaltegürtel um b".



100 c-axis.
"Einregelung" to the sch. pl. and (okl), (ok'l')
...... s2, s3.
"Gürtel um c" and m2, m3.

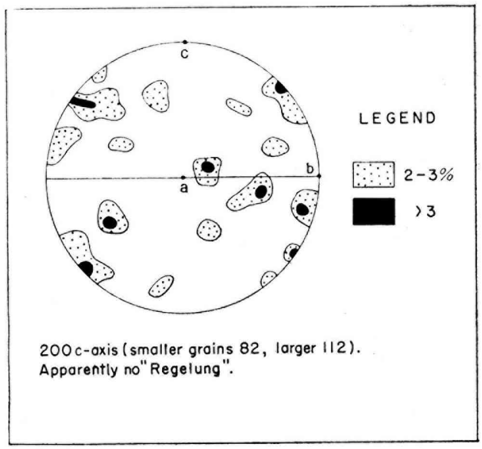
a) "Regelung" of Biotite b) "Regelung" of Quartz

Fig. 12. G-schist in the Sin'gok III Zone (Specimen No. 32).



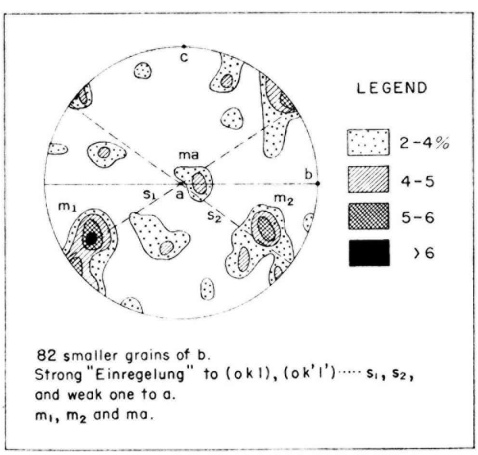
75 c-axis.
Strong "Einregelung" to the sch. pl..
"Halbgürtel um b".

a) "Regelung" of Biotite in the First Part



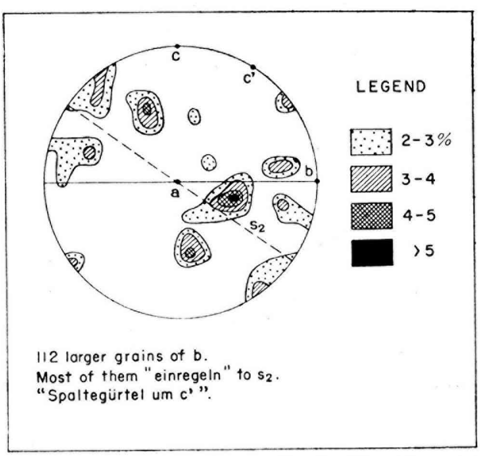
200 c-axis (smaller grains 82, larger 112).
Apparently no "Regelung".

b) "Regelung" of Quartz in the First Part (1)



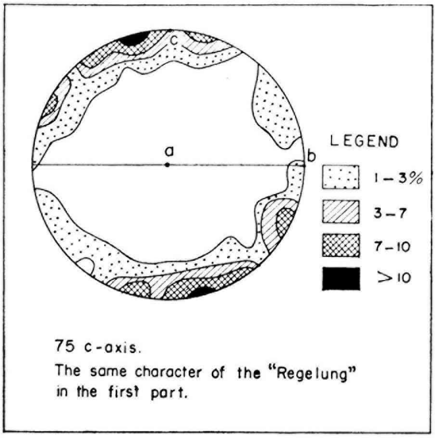
82 smaller grains of b.
Strong "Einregelung" to (ok l), (ok'l') s1, s2,
and weak one to a.
m1, m2 and ma.

c) "Regelung" of Quartz in the First Part (2)

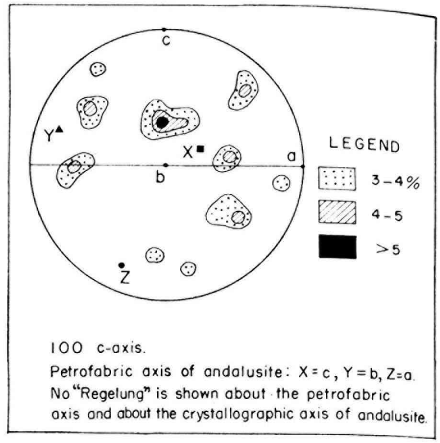


112 larger grains of b.
Most of them "einregeln" to s2.
"Spaltegürtel um c'".

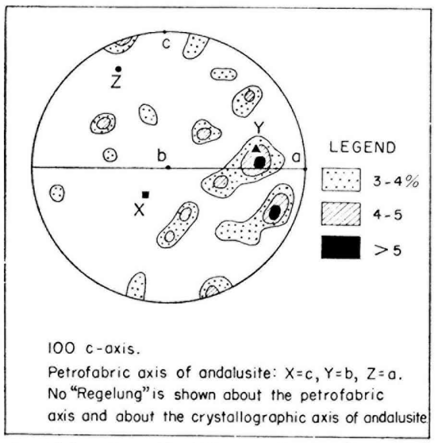
d) "Regelung" of Quartz in the First Part (3)



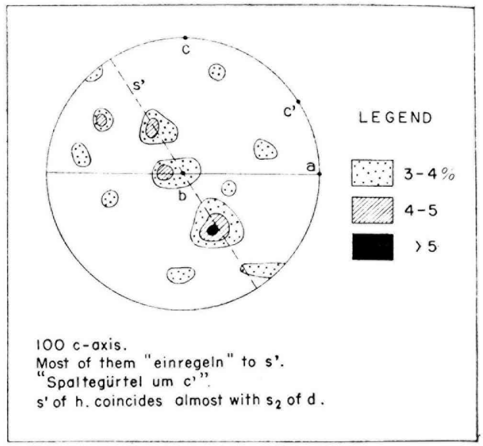
e) "Regelung" of Biotite in the Second Part



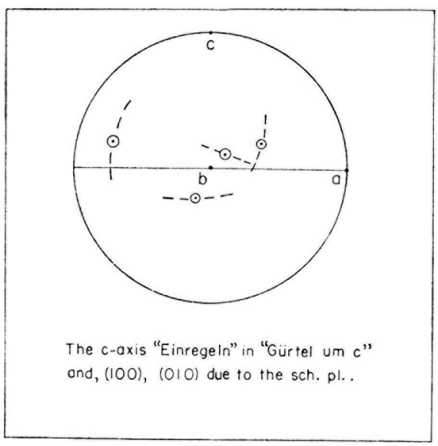
f) "Regelung" of Quartz in the Second Part



g) "Regelung" of Quartz in the Second Part



h) "Regelung" of Quartz in the Third Part



i) "Regelung" of Andalusite

Fig. 13. A-Schist in the Sin'gok III Zone (Specimen No. 43).

(vii) The Samgot zone

The cleavage is shaly and the schistosity plane is very platy, but no linear schistosity is seen. The *Gefügeregelungen* is shown in Fig. 14.

(viii) The Yanghap zone

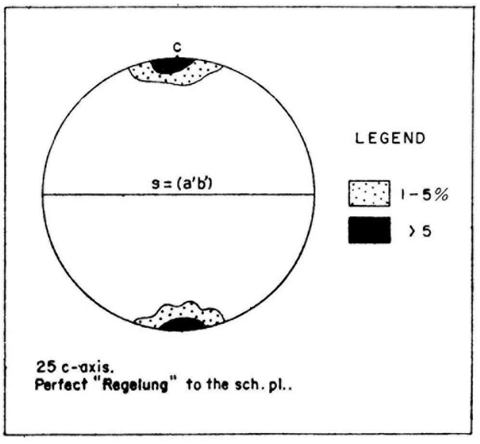
The cleavage is phyllitic. No linear schistosity is seen.

(ix) The blasto-mylonite and the *Augen*-gneiss

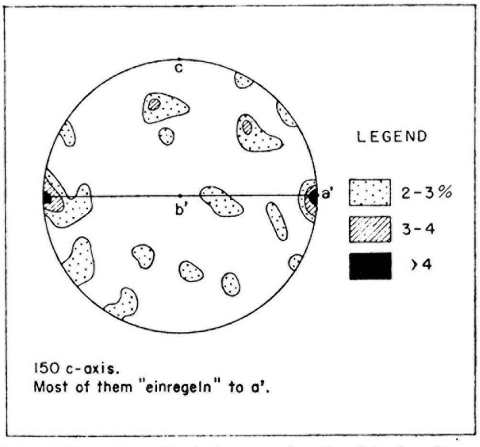
The gneissic schistosity is not developed so clearly.

(x) The nature of the dynamometamorphism as interpreted from the *Gefügeregelungen* of the minerals.

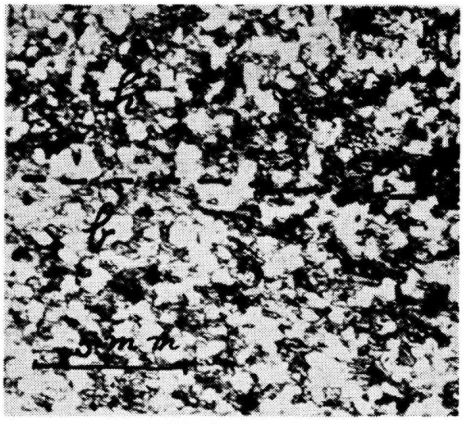
Interpreting the *Gefügeregelungen* shown in Figs. 8–14, the nature of the internal movements in the rocks is summarized in Table 1.



a) "Regelung" of Biotite in the Biotite-Granulite Layer



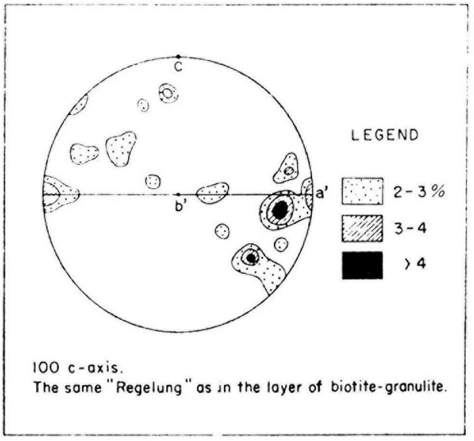
Hornblend layer



b) "Regelung" of Quartz in the Biotite-Granulite Layer

Biotite layer

Fig. 14. Examples of "Gefügereglung" from the Samgot Zone (Specimen).



c) "Regelung" of Quartz in the Hornblende-Granulite Layer

Table 1. Internal Movements Caused by the Dynamometamorphism.

	Conspicuous kinds of internal movement					
Zone	Gliding of schistosity plane in the earlier stage	Rotation around b axis	*Plättung nach* c axis	Gliding of plane (bc)	Shearing of (okl) & (ok'l')	Differential movement to a axis
Y	Sericite ((+++)) Biotite ((++))	Biotite ((++)) (±)	Biotite (++)	Biotite (±)	Biotite (±)	
SI			Biotite (++)	Biotite (±)		
SII		Biotite (+)	Biotite (++) Quartz (++)	Biotite (++)		
SIIIg		Biotite (±)	Biotite (++) Quartz (+)		Quartz (+)	
SIIIa		Biotite (+)	Biotite (++) Andalusite (+)		Quartz (+)	Quartz (±)
Sa			Biotite (+++)			Quartz (+)

(+++)....Very strongly, (++)....Strongly, (+)....Considerably, (±)....Weakly *geregelte*.
Plättung nach c:——c—— (( ))....Some cases.

The characters of the internal movements in each zone may be summarized as follows:

Y zone: The principal movement of *Plättung* in direction c is not so strong and the movements of several planes have some influence upon the *Regelung* of biotite. Sometimes, planes (okl) and (ok'l') actually appear.

SI zone: The *Plättung nach* c appears to have moved strongly and plane (bc) has glided weakly.

SII zone: The types of *Regelung* of biotite show proof of the following movements: rotation around axis b, *Plättung nach* c and gliding of plane (bc) which by hammering can be made to appear. For quartz, the *Plättung nach* c is much stronger than the other movements.

Table 2. Mineral Assemblage.

Zone	Specimen no. \ Minerals	Sericite	Chlorite	Biotite	Muscovite	Ottrelite	Garnet	Staurolite	Cyanite	Andalusite	Anorthite	Diopside	Green hornblende	Zoisite	Apatite
Y	109	+	+	+°		(+)	±								
,,	106	+	+	+°		(+)									
,,	85	+	+	+											
,,	88	+	+	+°											
,,	92	+	+	+											
,,	18	+	+	+°		±	±								
SI	15	+	+	+°			+°							[+]	[±]
,,	48	+	+	+°										[+]	[±]
SII	53	±	+	+°			+°							[±]	[+]
,,	54	±	+	+°			+°							[+]	[±]
SIII	26		±	+	+		±°								[+]
,,	32		±	+	+		+°								[+]
,,	39			+	+		+°	+°							[+]
,,	42			+	+		+°	+°	+°						[+]
,,	43			+	+		+°	+°	+°	+°					[+]
Ke	68	+	+	+											[+]
,,	72	+	+	+											[+]
Ko	145			+			±								[+]
Sa	273			+								+	+		
,,	266			+							±	+	+		[+]
,,	250*			+											
,,	,, **												+		
,,	264			+							±	+	+		[±]
,,	262			+			+				+	+	+	+	

The specimens are arranged according to zones and from north to south.
+ . . . . much,
± . . . . less,
° . . . . porphyroblast.
( ) . . . . relict.
[ ] . . . . accessory.
Quartz is + in specimens other than no. 264 which is [±].
Tourmaline, magnetite or ilmenite, and zircon occur [+] in all the specimens.
* . . . . biotite layer,
** . . . . hornblende layer.

SIII zone: "A-schist" shows very complicated *Regelungen*. The representative *Regelung* of quartz is the one of the smaller grains in the first part: shearing of planes (okl) and (ok'l'), and differential movements in direction a. The *Regelung* of biotite informs us that the *Plättung nach* c accompanied by micro-folding around b is conspicuous.

Sa zone: For biotite, the *Plättung* in direction c and the differential movement in direction a for quartz is conspicuous.

(xi) General view on the internal movement in the metamorphic region.

The behavior of the Y zone shows considerable properties of a solid[14]. One subzone of the S zone has the properties of both a solid and liquid. One subzone of the Sa zone is almost liquid and less viscous.[15] The Ko zone is considered to have behaved in almost the same manner as the S zone while the Ke zone is a solid. The Yŏnch'ŏn metamorphic group, therefore, is considered to have behaved more liquidly toward the south.

B. Mineral Assemblage

In the metamorphic region, several index minerals appear and disappear zone-by-zone and facies-by-facies[16] (see Table. 2, Fig. 15).

In the Samgot zone, Ca0-bearing minerals are common. It is quite possible that these rocks are the products of several kinds of contamination of some basic magma into common argillaceous sediments[17]. No relict of limestone was found.

Cummingtonite rocks[18] are often found in the SIII zone.

C. The Modes of Occurrence of some Characteristic Minerals

(1) Ottrelite and Biotite in the Y Zone

In this zone there commonly exist relicts of ottrelite, whose shapes were generally so severely altered that the original shapes could not be discerned.

The porphyroblasts of biotite show rounded, spheritic forms with rotating or recumbent micro-folded structures. The biotite, therefore, can be considered to have been formed a stage later than the ottrelite and the minerals (sericite and chlorite) in the ground-mass; the metamorphic process forming the biotite may be a combination of two processes as follows:

Ottrelite + $K_2O \rightarrow$ Biotite

Chlorite + Sericite $\rightarrow K_2O \rightarrow$ Biotite.

These formulas of the metamorphic processes are not a perfect representation

14) I assume when shearing by deformation occurs the material behaves as a solid, and when it does not, it behaves as a liquid.

15) When the material is highly viscous, the biotite must show a rotating "Regelung". The word "highly viscous" means that the product of (viscosity) × (velocity gradient), is high. The larger the product is, the greater the influence of the internal movement to the constituent minerals.

16) Barrow-Tilley's classification of "metamorphic" zone is suitable for this metamorphic group.

17) Refer to II. A. (i).

18) Cordierite-anthophyllite-garnet rocks exist in the Okchon system.

but only indicate the succession of transitions. In the above processes, "$+K_2O$" means some addition of K_2O, that is, a positive metasomatism of K_2O.

(2) Several Aluminous Minerals in the SIII Zone[19)]

(garnet, staurolite, cyanite and andalusite)

i. The distribution of schists within zone SIII is as follows (also see Fig. 16):

	Schist	Plane of schistosity
(m)	2M—Q Schist	Silky luster; even
(g)	G—2M—Q ,,	↑
(s)	S—G—2M—Q ,,	Transitional
(c)	C—S—G—2M—Q ,,	↓
(a)	A—C—S—G—2M—Q ,,	Brownish; micro-folded

Legend. Q. . . Quartz, 2M. . . Biotite and muscovite, S. . . Staurolite, C. . . Cyanite, A. . . Andalusite, G. . . Garnet.
From (m) to (a), the amount of muscovite decreases and the amount of biotite increases.

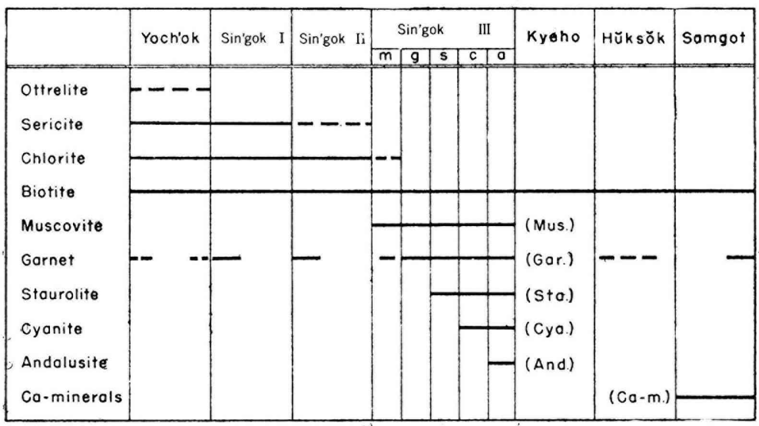


Fig. 15. Zone-distribution of "Index Minerals".

ii. The modes of occurrence of the minerals are observed representatively in a-schist. Two kinds of layers are found: in one mica is concentrated and in the other quartz. These layers were perhaps separated by metamorphic differentiation. Each layer is 0.3 to 1.0 mm thick, and folds around petrofabric axis b and is sometimes flexed along axis a. The garnet, staurolite, and cyanite often exist at the flexure along axis a (Fig. 17).

The aluminous minerals occupy their own spaces in a very regular manner as schematically shown in Fig. 18, with garnet and andalusite in the quartzose layer, and staurolite and cyanite in the micaceous layer.

19) Subzone number III of the Sin'gok zone.

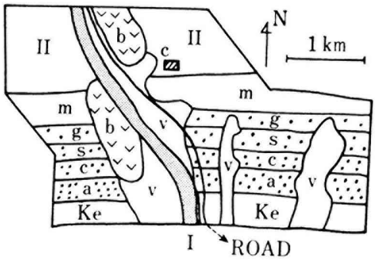


Fig. 16. The Zone-distribution of Schists near Chin'gok-ni.

II......S-II Garnet-biotite-sericite-chlorite-quartz schist

m, g, s, c, a......S-II

m. Two mica-quartz schist

g. Garnet-two mica-quartz schist

s. Staurolite-garnet-two mica-quartz schist

c. Cyanite-staurolite-garnet-two mica-quartz schist

a. Andalusite-cyanite-staurolite-garnet-two mica-quartz schist

Dots show distribution of cyanite-andalusite-bearing veins.

b. Basalt flow v. Alluvial

c. Chingok-ni I. Imjing-gang

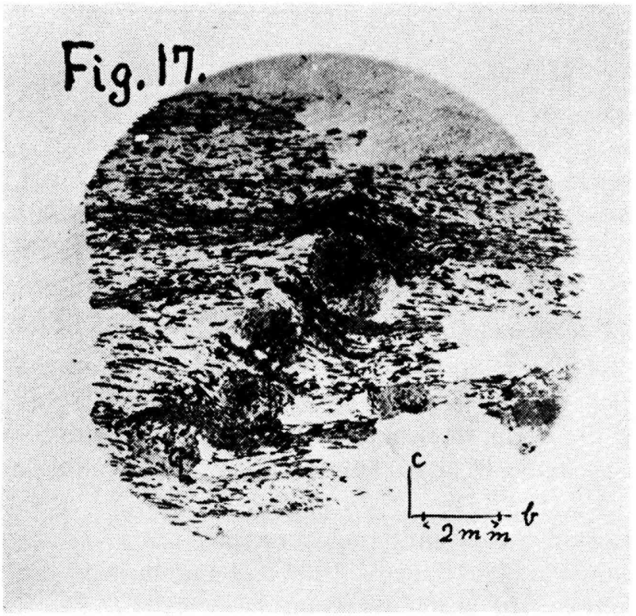


Fig. 17.

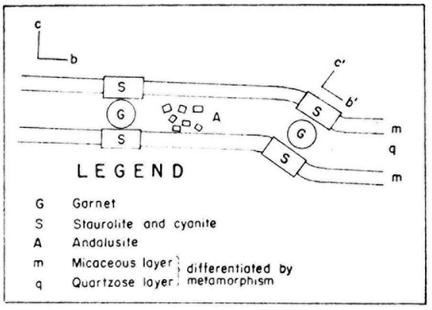


Fig. 18. Schematic Diagram of the Mode of Occurrence of Minerals in a-schist.

The interior of a-schist must be divided petrographically into three parts: (1) a representative part which consists of cyanite, staurolite, garnet, micas, and quartz; (2) the quartzose layer which consists of andalusite, cyanite, staurolite, garnet, micas and quartz and (3) the micaceous layer, in which micas are abnormally chloritized[20).

Each part is a 2–3 cm irregular mass.

iii. Microscopic structures of the minerals

Garnet In thin section the garnet shows rounded hexahedrons, and is therefore, considered to be a dodecahedron crystal. In general, it is accompanied by abnormal chlorite[20) (Fig. 19). Its formative process, therefore, may be as follows:

Micas→abnormal chlorite→garnet

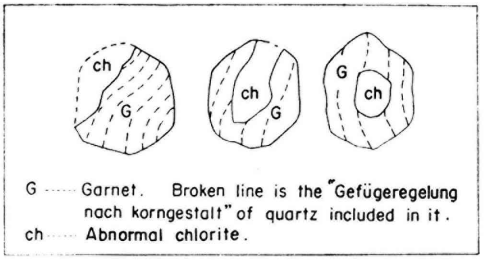


Fig. 19. Garnet in a-schist.

It contains a considerable amount of small grains of quartz *geregelt nach Korngestalt*[21). This fact shows that the formation of garnet was accompanied by some kind of movement[22).

20) It has the relicts of cleavages of micas, is severely flexed, and is dirty yellowish-green. The amount of optical retardation γ-α is about 0.02.

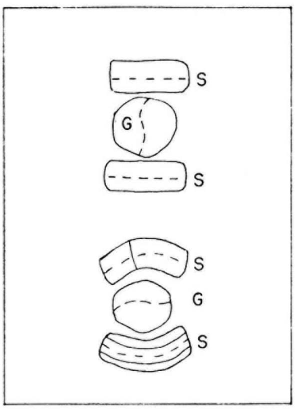
21) The more or less elongated grains of quartz are ranged in the form of S-shaped "inclusion-vortex."

22) The movements can be considered to be rotation by differential movement (the writer, 1947) or recumbent folding by compression (the writer, 1952).

Staurolite It exists generally in contact with garnet. Staurolite is found in the space of the micaceous layer while garnet is found in the space of the quartzose layer (Figs. 17, 18). It shows twin-like intergrowths which is not the characteristic twinning of staurolite. Its shape is irregular. It contains a considerable amount of quartz *geregelt nach Korngestalt* in the schistosity plane and is sometimes continuous to the inclusive-vortex in the neighboring garnet. Its modes of occurrence are shown in Fig. 20.

Cyanite Its mode of occurrence is almost similar to staurolite (Fig. 21).

A. Staurolite (S) and Garnet (G) in a-schist



B.

Fig. 20.

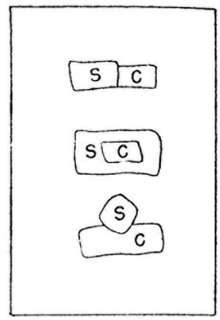
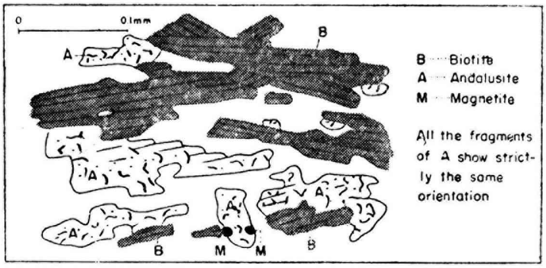


Fig. 21. The Equal Relation between Cyanite (C) and Staurolite (S).

Andalusite It exists as fragments in the quartzose layer. Sizes and shapes are almost the same as the fragments of biotite. All the fragments in the area of about 200 grains of quartz in a thin section show an identical orientation. This fact may show that the fragments of andalusite in this area are really from one crystal and that the quartz and micas in this area are its inclusions, the amount of which is so large that the one crystal of andalusite was separated into many fragments. The *Gefügeregelung* of the biotite in the area is almost the same as in the first part (Fig. 13E). The *Gefügeregelung* of the quartz in the area shows no regularity (Fig. 13G, H).

The andalusite has a tendency for its prismatic plane to lie on the plane of schistosity (Fig. 13I). It sometimes seems to have behaved in a way similar to the staurolite (Fig. 22B). The andalusite is therefore considered to have been formed simultaneously with staurolite and cyanite; the genetic difference seems to be the field of recrystallization; the material, $SiO_2+Al_2O_3$ $(+Fe_2O_3)$, recrystallizes to andalusite if in the quartzose layer, or recrystallizes to cyanite or staurolite if in the micaceous layer. The modes of occurrence of the andalusite are shown in Fig. 22.

A. Mode of Occurrence of Andalusite in a-schist



B. Mode of Occurrence of Andalusite in a-schist

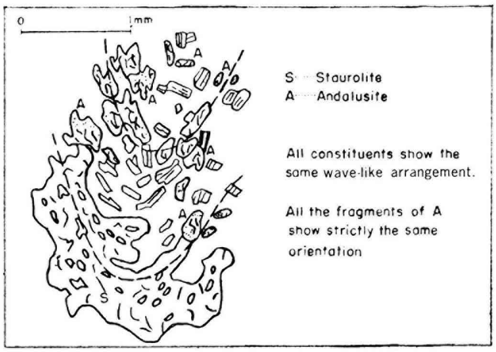


Fig. 22.

D. Sequence of Mineral Formation, Progressive Metamorphism and Metasomatism

(1) Metamorphic Progressions

As previously mentioned in C, the following metamorphic process can be viewed as the most probable.

Micas→abnormal chlorite→garnet

The chemical relations of those processes are as follows:

i. For the process, micas→abnormal chlorite, subtraction of K_2O is necessary.

ii. The measured data of the chemical composition of micas, abnormal chlorite, and garnet are shown in Table 3 and Fig. 23 (in molecular ratio).

Fig. 23 shows us the following five informative items:

The ratio of Al_2O_3 to ($FeO+MgO$) of the micas is larger than that of the soluble component of the abnormal chlorite.

In Fig. 23a BCK is on a line.

The ratio of FeO to MgO in the micas and in the soluble component of the abnormal chlorite is almost equal.

The ratio of Al_2O_3 to ($FeO+MgO$) in the garnet and the soluble component of the abnormal chlorite is almost equal.

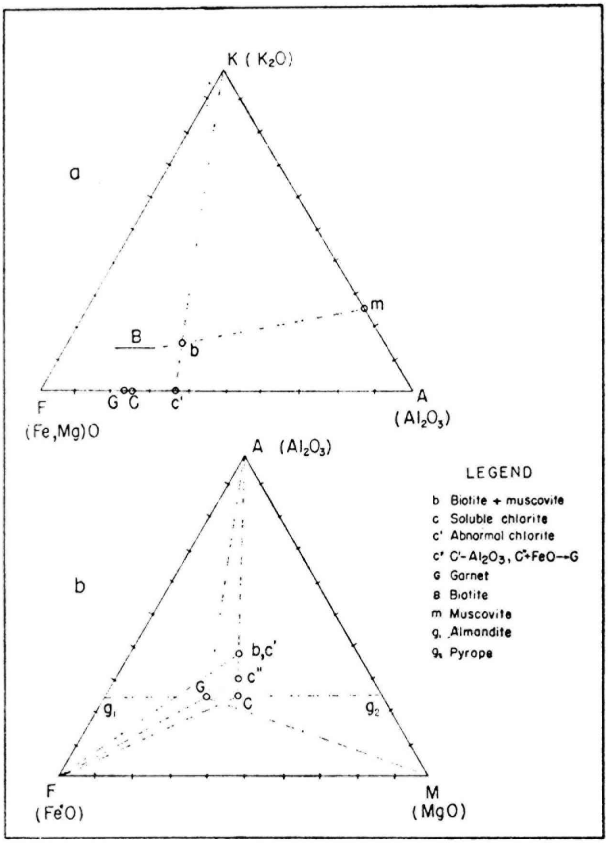


Fig. 23. Chemical Relations between the Minerals.

Table 3. Chemical Relation between Mica, Abnormal Chlorite and Garnet.

	Micas biotite+muscovite +quartz			Soluble component of abnormal chlorite		Garnet
	Wt. %	mol. ratio		Wt. gm	mol. ratio	mol. ratio
SiO_2	63.4					
Al_2O_3	14.4	37.8	32.8	0.30088	25.8	25
FeO	7.9	31.4		0.2554	38.3	47
MgO	4.3	30.8	52.1	0.1342	35.9	28
K_2O	6.2		15.1			
Total	95.2	100.0	100.0	0.6984	100.0	100

Analyzed by the writer

1. In FeO, Fe_2O_3 is included.
2. In K_2O, Na_2O is included. CaO is negligible.
3. Refractive index of the garnet is n=1.793; almandine: Pyrope=68:32 (mol. ratio).
4. The soluble component of abnormal chlorite was obtained by using dil. HCl to dissolve the abnormal chlorite out of the powder from which magnetite had been previously taken out by means of a magnet.
5. After 4, mica-quartz was separated by means of flotation in a heavy liquid (sp. gr. 3.0) from the heavier minerals (garnet, staurolite, cyanite and andalusite).

The ratio of FeO to MgO in the soluble component of the abnormal chlorite is smaller than the one in the garnet. SiO_2 and H_2O were not considered.

From the first three, $2M-K_2O \rightarrow ch+Al_2O_3$ .....

From the last two, $ch+FeO \rightarrow G-MgO$ .....

or, $ch+Al_2O_3+FeO \rightarrow G$ .....

From the first, $ch' = ch+Al_2O_3$ .....

The symbols used above are as follows:

2M .... Micas, ch' .... Abnormal chlorite,
ch .... Its soluble component, G .... Garnet.

From these, the following conclusions were made: by means of the subtraction of K_2O, the micas change to a supermicroscopic aggregation of chlorite and perhaps sillimanite[23]. These supermicroscopic needles of sillimanite may migrate, recrystallize, and form several aluminous minerals. The garnet is considered to be formed under the process 6. It is clear in Fig. 23B that Al_2O_3 derived from the micas is present in larger amounts than are necessary for the formation of the garnet:

$$2M-K_2O+FeO \rightarrow G+Al_2O_3$$

(FGC" in Fig. 23B)

The source of $+FeO$ may be magnetite in the schist. Al_2O_3 may have recrystallized as staurolite, cyanite, and andalusite. The process is summarized as follows:

Micas + Magnetite $-K_2O \rightarrow$ Garnet + Staurolite,
Cyanite,
Andalusite.

The K_2O migrates into the outer part of the parent schist bodies.

Table 4. Migrating Materials and Products of Recrystallization.

			Excess of	SiO_2......C + Q......(1)
			some	SiO_2......C ....(2)
			very little	SiO_2......C + R ......(3)
			no	SiO_2......R ....(4)
recrystallization of muscovite	(SiO_2, Al_2O_3, K_2O)	no excess of K_2O		
		no excess of Al_2O_3		......Q + K_2O...(5)
		no excess of SiO		......R + K_2O...(6)

Final mineral assemblages (Products of Recristallization):

(1)	(2)	(3)	(4)	(5)	(6)
M+C+Q	M+C	M+C+R	M+R	M+Q	M+R

K_2O in (5) and (6) migrates out far-away.

C......Cyanite and andalusite Q......Quartz
R......Corundum M......Muscovite

[23] This interpretation agrees with the fact that retardation γ-α of the abnormal chlorite and sillimanite is almost equal. This can be observed in several rocks in Korea.

(2) Metamorphic Differentiation

As mentioned above, K_2O must and Al_2O_3 may migrate. SiO_2 and H_2O are the materials most likely to migrate[24]. In the case where these materials migrate into the fissures or cavities and recrystallize, the mineral assemblages are as shown in Table 4.

All the final mineral assemblages are observed in veins or pockets in the schist zone of SIII as stated in III, E.

(3) Other Examples of Metamorphic Differentiation

A rare example is cummingtonite-quartz rock found in zone SIII. This rock is like a sheet or tongue, several centimeters thick, parallel to the schistosity of the country rock, and is therefore considered to have been formed by dynamo-metamorphism. It is primarily composed of SiO_2, FeO, and MgO. It is therefore possible that this rock was derived from the mica schist by the following process[25]:

$$\text{Micas} - K_2O - Al_2O_3 \rightarrow \text{cummingtonite} \quad \ldots\ldots \quad 10$$

(4) Progressive Metamorphism Accompanied by Metasomatism and Metamorphic Differentiation

It can be summarized that two kinds of processes of progressive metamorphism accompanied by metasomatism occurred in the two zones:

One was in zone Y,

$$\text{ottrelite} + K_2O \rightarrow \text{biotite},$$
$$\text{chlorite} + \text{sericite} + K_2O \rightarrow \text{biotite},$$

The other was in zone SIII,

$$\text{micas} + \text{magnetite} - K_2O \rightarrow \text{garnet} + \text{staurolite}, \text{cyanite}, \text{andalusite}.$$

It is quite possible that K_2O migrates from zone SIII into zone Y as one of metamorphic differentiation.

(5) Some Properties of Biotite

The quantitative relation between biotite and muscovite and the quality of the biotite seem to be related to the grade of metamorphism. The quantitative ratio of the biotite to muscovite increases from m-schist to a-schist (III.C. (2). i.), The refractive indices ($\beta \doteqdot \gamma$) of the biotites are as follows:

m-	g-	s-	c-	a-schist
1.625	1.625	1.625	1.627	1.629

The refractive index ($\beta \doteqdot \gamma$) of the biotites in each zone varies zone by zone:

zone	Y	SI	SII	Ke	Sa
average →	1.628 →	1.625 →	1.633 →	1.625 →	1.630

The relation between the value $\beta \doteqdot \gamma$ and the chemical composition has not been clarified.

24) "Kieselsaure ist das mobilste Material bei der Metamorphose." (Eskola: Entstehung der Gesteine, p. 407).

25) In this process, subtraction of K_2O and Al_2O_3 occurred. In the zone of mica schist of the Okch'ŏn system, (garnet)-anthophyllite-cordierite rocks are found. In such a rock, subtraction of Al_2O_3 is considered to have occurred imperfectly.

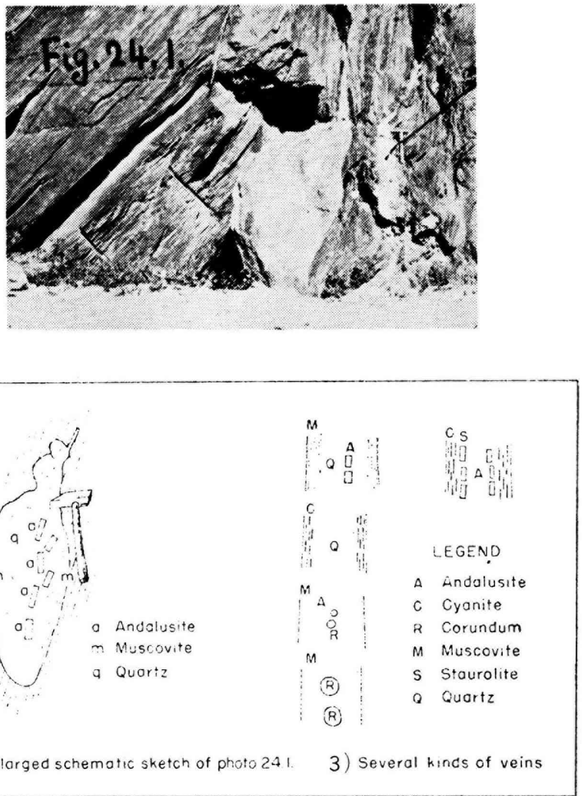


Fig. 24. Modes of Occurrence of the Ore Deposits.

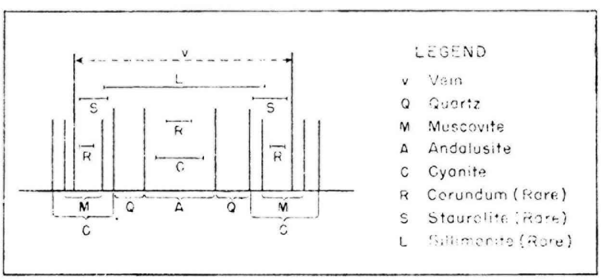


Fig. 25. Synoptic Representation of the Situations of Minerals in Veins.

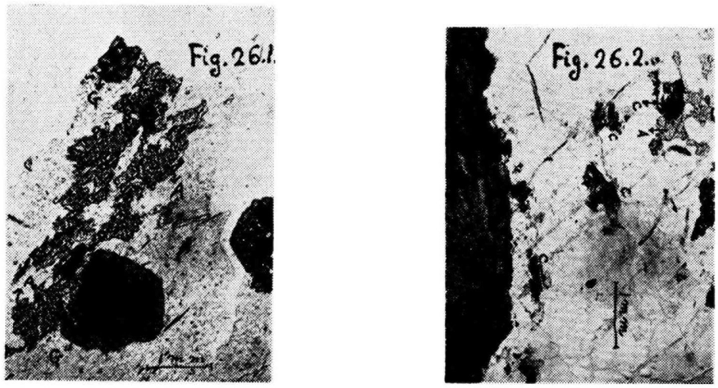


Fig. 26. Some Minerals in a Small Quartz Vein.
G......Garnet A......Andalusite C......Cyanite

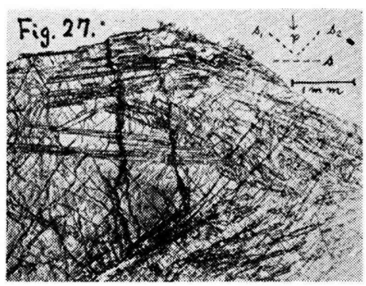


Fig. 27. Cracks and Cyanite Flakes in a Crystal of Andalusite.

E. Cyanite-andalusite Deposits

(1) Deposits which are in the form of veins or pockets containing cyanite and andalusite are one of the proofs of metamorphic differentiation (III. D. (2)).

The modes of occurrence of the minerals in the veins or pockets show some regularity as shown in Fig. 24. This regularity can be diagrammed as in Fig. 25.

Sometimes small quartz veins containing garnet, cyanite, and andalusite are found parallel to the plane of schistosity of the schist. In the schist in contact with the small veins, almost no quartz exists (Fig. 26). This may be one positive example of segregation by means of metamorphic differentiation. Cyanites are regularly found in the relatively large crystals of andalusite (Fig. 27). This informs us that the cyanites were formed regularly under a *Plättung* accompanied by shearing.

(2) The deposits are more concentrated in the eastern area of the Imjin-gang, where the reserve of cyanite and andalusite was estimated to be about 300,000–500,000 metric tons.

As mentioned in the introduction, the residual blocks from the veins or the pockets were collected during the first stage of mining; in the next stage, the veins or the pockets were prospected and mined. During World War II, the residual blocks seem to have been exhausted[26].

4. Summary

1. In the region covered by my study, I found no evidence supporting the proposal that the Yŏnch'ŏn system is Archean. The original formations of this "system" may be the formations succeeding the uppermost member of the Shōgen (Sangwŏn) system in Middle Korea. The dynamometamorphism occurred simultaneously with the injection of the porphyritic granite in the southern region. The plane of schistosity differs distinctively from the plane of stratification of the original formation. I consider the name Yŏnch'ŏn metamorphic group to be preferable to Rensen (Yŏnch'ŏn) system.

2. The Yŏnch'ŏn metamorphic group shows a well-developed zonal structure. Each zone has its own characteristic metamorphism.

3. The metamorphism is a typical progressive metamorphism accompanied by metamorphic differentiations (migrations of some materials) and metasomatism. The principal dynamic factor of the metamorphism is *Plättung*.

4. The cyanite-andalusite deposits are one proof of metamorphic differentiation.

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[26] After the Mining Law of Korea was revised (1941) until August, 1945, the mining and the sale of cyanite (including andalusite, sillimanite, and corundum) was controlled by Chōsen Kōgyō Shinkō Co. (Mining Promotion Company of Korea), but the actual working of the mines was generally assigned to small-scale civilian miners. Because of the simple mining (requiring only the collection of the residual blocks), the low cost of mining (5–10 yen/ton in 1941), and the high selling price (100–150 yen/ton in 1941), large profits were obtained in a relatively short period. Accordingly, many civilian miners or brokers crowded to the cyanite mines to profit from this boom.

On "Kotoite" and "Suanite"

Takeo WATANABE

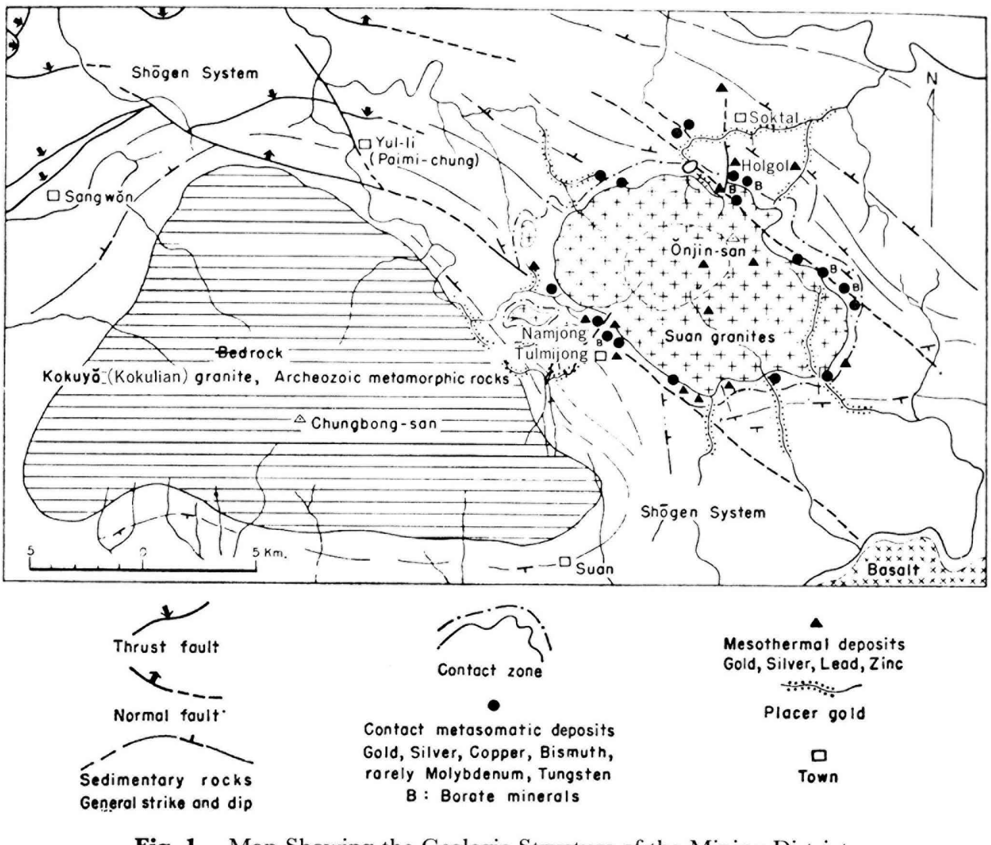

Fig. 1. Map Showing the Geologic Structure of the Mining District.
Holgol = Holkol, Tulmijong = Tul Mi Chung

Introduction

Kotoite is a magnesium borate, $Mg_3\ (BO_3)_2$ which occurs in abundance in the country rock of the contact-type gold-bearing copper bismuth deposit in the Holkol (Hol-gol) mine, Suan district, Korea. Since 1930 the writer has been studying the geology and ore deposits of the Suan district, and in 1932 he noticed that the properties of the mineral did not correspond to those of any known mineral. In 1938, after further study of the ore of the Holkol mine, the writer determined the mineral to be one which had never been found before in nature. He named the mineral "kotoite" after the late Bunjirō Kotō, Professor Emeritus of the University of Tokyo.

The mode of occurrence of this mineral is interesting and important, not only in studying the genesis of the Holkol deposit, but also for prospecting the deposit. As Japan lacked boron resources in those days, the rock containing kotoite, a kind of metasomatized rock called "kotoite marble," came to be regarded as a boron ore. The process of manufacturing borax from the ore was studied by members of the Research Institute of the Hitachi Manufactory, and the attempt proved successful, not only experimentally, but also industrially. Thus, the deposit came to be mined more actively for boron.

Although the studies reported in this paper were first published in the "Kato Commemoration Volume," the writer has added some recent findings to bring the study up to date.

The geology and mineralogy in the district were first studied by Kotō (1910) and later by Tamura and Tsurumaru (1915), Higgins (1918), Maclaren (1915), and Shannon (1921 a, b) and many important facts were brought to light by them. The writer has continued his study of the remaining details of the problem. He is greatly indebted to the late Professor T. Kato for his constant encouragement and guidance in the course of the work. He is also indebted to Professors K. Uwatoko, J. Suzuki, and Z. Harada of Hokkaidō University for their valuable suggestions and help during the time when he was on the staff of that university; fortunately, with their support, the writer had many opportunities to visit the type locality and was able to continue his study for a number of years. The study on kotoite was accomplished under the direction of Prof. P. Ramdohr, director of the Institute of Mineralogy and Petrology, Berlin University, while the writer was in Berlin as a student sent abroad by the Ministry of Education in 1937–1938. The writer is indebted to Prof. P. Ramdohr and Prof. H. Strunz for their great help and he is also indebted to Prof. W. Eitel for his kindness while a part of the experiment was being carried out under his direction. In later years, when kotoite came to be regarded as a boron ore, the writer was aided by grants from the Fifty-seventh Special Committee of the Association for the Promotion of Science, Japan, to make a more detailed study on the Holkol deposit, than he had been able to do in the past.

During the field studies, the writer was afforded many facilities by the mine. Thanks are due especially to Mr. J. Nakamura of the Holkol Mining Office, Hōkō Mining Co., Ltd., as well as to the men and officials of the mine for their kindness. The writer also wishes to thank Mr. T. Yoshioka and Mr. S. Miyagi of the Research Institute of the Hitachi Manufactory, Mr. Y. Tamura of the Osaka Industiral Laboratory, Prof. S. Nagai of the Engineering Department of Tokyo University, Mr. H. Inuzuka of the Institute of the Tokyo Shibaura Electric Co., Ltd., Mr. T. ASAYAMA of Kyoto University, and Mr. E. ASHIDA, chief of the Kanagawa factory of the Takeda Chōbei Shōten, for their kindness in supplying data for analysis of the kotoite-marble.

The study of the X-ray analysis of kotoite was completed by Mr. R. SADANAGA at the Mineralogical Institute, the University of Tokyo, by courtesy of Prof. ITO. As their fndings are cited in this paper, the writer wishes to express his grateful thanks to Prof. ITO and Mr. SADANAGA.

1. Progress on the Study of Kotoite

Early in the summer of 1930, the writer spent about two and one-half months in the Suan district, making a general survey of the area. The ore body, which was actively being worked in Holkol at that time, is a large ore pipe and was called the "new body," *i.e.* the present "north body." As the mineral association of the ore is both complex and interesting, the writer reported on it in the *Journal of the Geological Society of Japan* in 1933. In this report, the writer described an altered magnesian limestone which composes the country rock of the deposit and noted the existence of a fine-grained mineral which bears some resemblance to forsterite, showing a very small 2 V. This mineral is the kotoite described below.

The kotoite, as described on a later page, occurs as very fine crystals, and its optical properties are very close to those of olivine and diopside, so that they can hardly be distinguished from one another when the section is observed under an ordinary microscope; The mineral might be recognized as nearly uniaxial or biaxial with a very small 2 V if it could be observed successfully at a high magnification. As the writer did not obtain the conoscopic figure at the beginning of the study, he considered the mineral a fine-grained forsterite which occurs usually as relatively coarser crystals in the same rock. After the writer observed the interference figure under the high-powered microscope, he noticed that this mineral was different from the coexisting forsterite. Upon further study, its refractive indices were measured by using the immersion method. No known minerals corresponded to it, however, and judging from the mineral association, he assumed it to be a silicate mineral rich in magnesia, probably either clinoenstatite or pigeonite, which were being discussed at that time. He had many doubts about this assumption, because such an occurrence of these pyroxene had rarely been reported from the contact metamorphic rocks which contain forsterite; in addition, the mineral was observed to be so unstable, compared with forsterite, that it had completely decomposed by secondary alteration while the forsterite remained unaltered.

The writer again visited the Suan district in 1931, and consulted with his professors and seniors, but final determination of the mineral was impeded by the difficulty of isolating a pure sample of the fine-grained crystals.

While the writer was studying in Berlin in 1937–38, he studied the ore from the Suan district and attempted to describe it. He also intended to study the as yet undetermined mineral. At that time, Dr. Hugo STRUNZ, assistant at the Institute, was engaged in an X-ray study of silicate minerals. He was especially interested in clinoenstatite-enstatite relationships, namely, the structural problems of both the rhombic and monoclinic pyroxene, and had collected various specimens. The writer considered this convenient for judging the undetermined mineral from Suan and attempted to separate a pure sample of the mineral from the ore by using the heavy-solution method. He obtained a large amount of Clerici solution, and a considerable amount of the pure sample was obtained. Using the powder method, an X-ray photograph of the mineral was prepared. By comparing it with the photographs of pyroxeses, the writer determined that the mineral was entirely different from the pyroxene group. Almost simultaneously with this examination, the writer attempted a preliminary quantitative analysis of the mineral in order to determine what chemical composition it would have if it were a member of the pyroxene group. As a result of repeated analyses, the writer recognized that the silica content of this mineral was very low, which was quite unexpected. Until that time, the writer had supposed it to be a kind of silicate mineral, so he was afraid that he had erred in preparing the sample and examined the separated material under the microscope. In addition, he observed the flame reaction of a dissolved solution of the sample. Upon testing the flame coloration of the product resulting from the quantitative analysis for silica, he found a remarkable green color. This unexpected fact attracted the writer's attention, so he investigated the cause. He first tested a part of the sample to see whether it showed a green flame reaction or not. In order to accomplish this he tried to wash out completely the Clerici solution from the sample, because the heavy solution contains Tl which produces a green flame coloration. But strangely enough, the green color could not be removed, no matter how many times the sample was washed. Therefore, the writer could not deny the existence of another material which produces a green flame reaction.

From that time the writer considered the possibility of the presence of boron; judging from the existence of ludwigite in the same rock, he should consider that the mineral was a borate mineral.

He resolved to complete the entire analysis of the separated material. The optical constants and specific gravity were measured, and the presence of boron and magnesium was confirmed. Thus, optically, the mineral came to be recognized as having no known corresponding boron minerals, and the writer decided to compare it with artificial borate.

In March of the same year he found, through GROTH's "Chemische Kristallographie," mineral properties which almost coincide with those of magnesium ortho-borate, which were measured previously by MALLARD. Thus, the mineral was postulated to be a new mineral whose occurrence in nature had not yet been noted.

Accordingly, in addition to carrying on the complete quantitative analysis of the mineral, the writer decided to synthesize magnesium borate, as EBELMAN had done, in order to identify it by X-ray with the mineral.

After succeeding in synthesizing the artificial crystal, an X-ray photograph of its powder was compared with that of the mineral from the Suan district, which had been phtographed in February. In April 1938 the writer confirmed the coincidence of the two X-ray photographs. Soon after that, the chemical analysis was also completed, and, based on its chemical composition, the mineral was confirmed as magnesium ortho-borate.

From these data, the writer identified it as a new mineral and named it "kotoite" after Prof. Bunjirō Kotō, the "father of Japanese geology," who was the first to publish detailed descriptions of the rocks and minerals from the Suan district, especially those of the Holkol deposit.

In the summer of 1938 the name kotoite was made public before the meeting of the Mineralogical Society of Germany held at Graz, Austria (Watanabe, 1939 a,b).

Though the writer endeavored with Dr. Strunz to continue X-ray studies of the artificial crystal, they were not completed during his stay in Germany. However, the study was continued by Sadanaga of the Institute of Mineralogy, University of Tokyo, who recently reported their results.

In addition, the writer recognized the existence of kotoite in a rock specimen from Rézbánya, Romania, during his study on kotoite. The writer received a magnesium borate mineral and in the course of the study compared it with a fibrous borate mineral contained in a rock from Holkol in order to confirm whether the latter is szaibelyite or not. He noticed the presence of many crystals within the section of the former which correspond to those of kotoite. Immediately after that, the writer separated it from the sample and examined it by X-ray, using the powder method, and found that the X-ray photograph of this mineral coincides with that of kotoite.

The mineral szaibelyite was first reported by Peters in 1861, and specimens were distributed among the museums in Europe and America. Nevertheless, the presence of kotoite had not been noticed, probably due to the fineness of kotoite in the rock and to the close resemblance of the optical properties of this mineral to those of forsterite or pyroxene. The old photomicrographs in Prof. Kotō's paper (1910) indicate that he regarded the kotoite from Holkol as diopside. Both Higgins (1918) and Shannon (1921a,b) seem to have overlooked this mineral, describing it only as diopside. Though kotoite is now known to occur at only two localities. Holkol and Rézbánya, it is highly possible that it may be found in other regions which have geologic conditions similar to those of the two localities.

In the summer of 1939 and the spring of 1941, after the discovery of kotoite, the writer visited the Suan district and made a detailed investigation of both the surface and subsurface of the Holkol mine. Upon examining the distribution and mode of occurrence of kotoite, the writer found that there is a large reserve of the mineral, and that the genesis of the Holkol deposit is closely related to the formation of kotoite.

The writer took up the consideration of industrial uses of kotoite because of its abundance and its relatively simple, homogeneous chemical composition. In 1938 these views were sent from Berlin to Dr. Benzō KATSURA, adviser to the Holkol mine, but the opportunity for industrial utilization of kotoite did not present itself. Later, in July 1949, Mr. Tōsaku YOSHIOKA of the Hitachi Institute read the writer's paper to the late Prof. Shintarō NAKAMURA, who perceived the possibility of utilizing kotoite in the glass industry, which was then running short of raw materials. At that time, Japan imported all her boron materials, especially from the United States, Chile, and Argentina. Most Japanese were little concerned with the boron resources, but the Hitachi group began to study this problem almost two years before World War II.

When the writer reported the existence of kotoite before the meeting of the Mineralogical Society held in Graz, the petrographer, Dr. H. STÜTZEL, who was present at the meeting, stated his views as follows: when magnesia bricks or magnesia clinkers are used for flooring and wallboard in the steel industry, boric acid is often mixed into them, and as a result, their tendency to decompose, a defect of magnesia firebrick as flooring and wallboard material, can more or less be rectified; this suggests the possibility of the production of a high temperature compound which might have a chemical composition similar to that of kotoite.

2. Mode of Occurrence

A. Holkol mine,[1] Suan Hwanghae-do, Korea (WATANABE, 1943)

1. History of the mine; general views on the geology and ore deposits:
The mine has long been known as the Suan gold mine, the oldest gold mine in Korea. It was opened on a large scale by the Americans and the English about 40 years ago. The name "Suan gold mine" is a name which, in early days, included several mines around Onjin-san. The present Holkol mine was also called Suan mine because it is located in the center of the claim. The principal area of development was the Namjŏng-ni deposit, a branch of the old Suan mine, and in about 1928 the claim was divided into two areas, the Holkol mine in the north and the Namjŏng (Tul-Mi-Chung) gold mine in the south. The historic name of the Suan gold mine was assumed by the newly-developed Namjŏng (Tul-Mi-Chung) mine, which was being operated by the Japan (Nippon) Mining Co., and the Holkol mine was given a name of its own. In 1928 the Holkol mine belonged to Chong-un Chong and three others, but after 1932 it was managed by the Japanese. More recently, the mine was worked by the Hōkō Mining Co., Ltd., and gold, silver, copper, tungsten, and boron were mined.

The office and ore-dressing plant of this mine were located at Soktal-li in the upper reaches of the U-gang, a branch of the South Taedong-gang. The principal mining area is Pogwang-ni, which is also known as Holkol, about 2 km south of Soktal-li. This region can be reached by truck in five to six hours by way of Sang-

[1] The mine is called "Kotsudo" in Japanese and "Holgol" in Korean.

won and Yul-li from P'yongyang or Chunghwa stations on the railroad between Seoul and Sinuiju. Locally, the road runs across an abrupt area.

The geology of the area near the mine will be briefly described. As shown in the sketch map of the geologic structure (Fig. 1), Pre-Cambrian formations are widely distributed in the Suan district; especially in the Holkol region where Holkol dolomite, which consists chiefly of dolomite of the Shidōgu series, the middle Sangwon system, and Suan shale, which corresponds to the Kuken series, is found. These sedimentary rocks are intruded by Suan granite, which is considered to be representative of the Pulguk-sa igneous activity which took place during the Late Mesozoic. The rocks of the Sangwon system have been intensely metamorphosed, and various kinds of thermal metamorphic rocks were formed around the contact. In addition to the Namsan gold-copper-tungsten deposit northwest of Sŏktal-li, the important ore bodies of the main working deposits in the Holkol mine are the pyrometasomatic gold-copper deposits. There are three important ore bodies, in the east, west and north.

The East ore body is vertical and extends from east to west along the contact between the Suan granite and the Holkol dolomite, forming skarn composed chiefly of diopside, tremolite, phlogopite, and minerals of the chondrodite group. It also contains native gold, bornite, chalcopyrite, pyrrhotite, bismuthinite, and several other minerals. In the thermally metamorphosed crystalline dolomite surrounding the skarn, we can find such borate minerals as ludwigite and kotoite.

The West ore body comprises two types of deposits; one is the skarn type, similar to the east ore body, and the other is the mesothermal metasomatic type. The west ore body is 60–100 m west of the east body. The deposit along the contact with the Suan granite is of the skarn type, similar to that of the East ore body. The deposit along the Holkol fault west of the Holkol valley and that contained in its crush zone show a dip and strike similar to the fault which strikes north to south and dips 55–60° east and contain two types of deposits, the skarn type and the mesothermal type, both of which occur in the metamorphosed dolomite. Ludwigite and kotoite have been found in the country rock of the skarn deposit, though only on rare occasions. The mineral association in the skarn ore is nearly the same as that of the East ore body. The mesothermal-type ore, on the other hand, has no skarn minerals, but some traces of replaced dolomite of the crush zone remain. Metallic minerals, other than chalcopyrite, contained in the ore are tetrahedrite, sphalerite, and galena, and the silver content of the ore is somewhat higher than that of the skarn ore.

The north ore body is located about 30–60 m north of the other two ore bodies, and it occurs as an ore pipe completely surrounded by dolomite.

Both the east and west ore bodies were found in the early days of the development of the mine, and mining began with the outcrops. The discovery of the North ore body, on the other hand, took place relatively late; that is, it was found by a Korean in the tunnel after the time of the foreign management and was for a time called "new ore body," or Pae-kum-kaeng (white metal tunnel) ore body, because of the large occurrence of white minerals, native bismuth etc., in the ore. It has become the most important ore body of the Holkol mine. The country rocks widely distributed around the ore body are dolomite-marble (crystalline dolomite) and brucite-marble. A marble-like metamorphic rock which contains kotoite and calcite as the principal mineral constituents is always found near the ore body, and the skarn consisting of diopside, phlogopite, clinohumite, etc., which may be regarded as a gold-copper ore, is completely surrounded by it.

Thus, the metamorphic rock which consists of kotoite and calcite, has been formed by replacing dolomite by the B_2O_3 in a pneumatolytic process whereby the deposit was formed. As the rock resembles ordinary marble, it will be called "kotoite-marble." In other words, the North ore body is a composite ore pipe of kotoite-marble which includes diopside skarn. This pipe stands like an inverted funnel, somewhat thick in the lower part and thinning out in the upper (see Fig. 2).

The relationship between the diopside skarn and the kotoite-marble is quite complicated and shows irregular boundaries, as seen in Fig. 3. However, the skarn is found almost in the center of the ore pipe, though it branches in three directions in the lower part. Specimens which exhibit the relationship of the three zones, that is, the dolomitic marble, kotoite-marble, and diopside skarn, are rarely found, but they can be collected from the margin of the ore body (see Fig. 4).

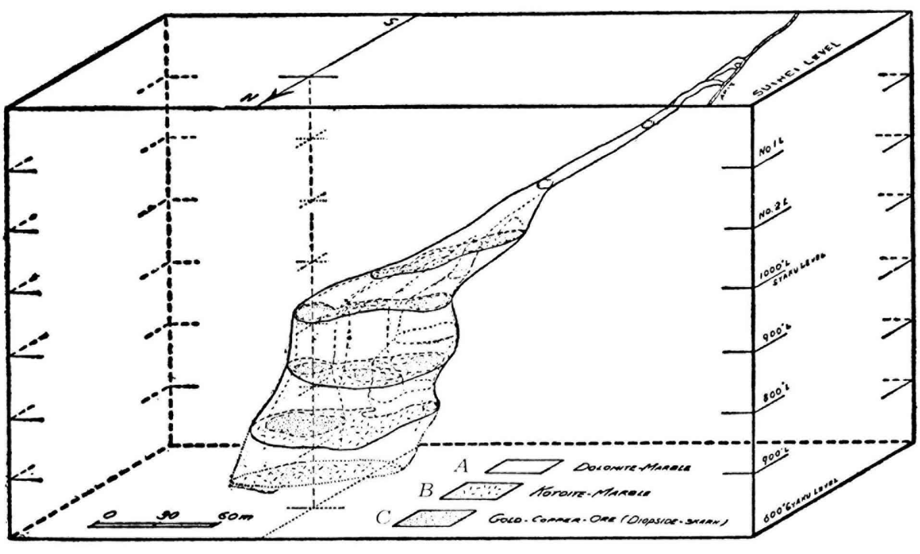

Fig. 2. Block Diagram of the North Ore Body of the Holkol Mine, Suan.

A. Dolomite-marble
B. Kotoite-marble
C. Gold-copper-bismuth ore (Diopside Skarn)

K: Kotoite-marble
L: Ludwigite
R: Reaction zone between diopside skarn and kotoite-marble
D: Diopside-clinohumite-skarn containing gold and copper

Fig. 3. Underground Photograph Showing the Relation between Gold Copper-bearing Diopside Skarn and Kotoite-marble.

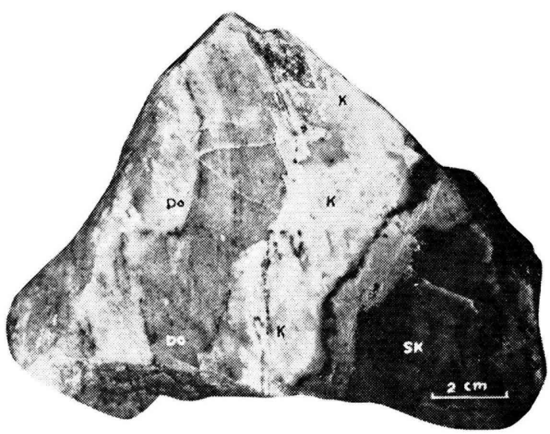

Fig. 4. Zonal Arrangement of Diopside Skarn (SK) Kotoite-marble (K) and Dolomite (Do).

Small branches of diopside skarn, round masses, or small lenticular bodies of skarn, as shown in Fig. 6, are irregularly distributed within the kotoite-marble, and almost all of the metallic minerals are contained in the skarn. Therefore, the gold-copper mine is being worked by following the diopside skarn.

The metallic minerals of the north ore body are native gold, native bismuth, bismuthinite, pyrrhotite, cubanite, chalcopyrite, bornite, and other sulfides of bismuth or copper. As this mineral association was considered very interesting, it has already been partly reported in detail (WATANABE; 1933, 1943) and needs no further description here. In the upper part of the ore body, the associated minerals are usually poor in iron, and the ores contained in white diopside skarn are chiefly bornite and chalcopyrite; the ludwigite content of the kotoite-marble around the ore body is relatively small. In the lower part, on and below the 300 m level, the associated minerals gradually become rich in iron, and the association of such minerals as pyrrhotite, cubanite, chalcopyrite, and valleriite can be seen in many places; at the 210 m level, the ore becomes chiefly cubanite and the bornite content decreases. At the 180 m level the kotoite-marble contains a large amount of ludwigite, the diopside skarn is tinged with green, and the iron content increases slightly.

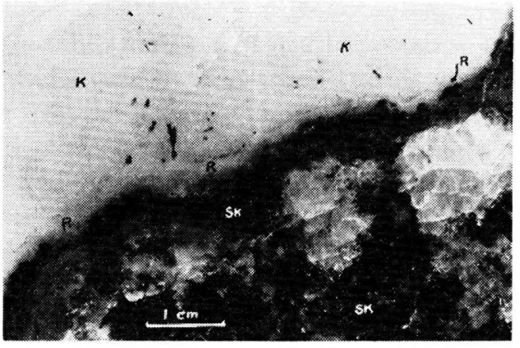

Fig. 5. Reaction Zone (R) between Diopside Skarn (SK) and Kotoite-marble (K). (In this zone occur fluoborite, ludwigite and clinohumite.)

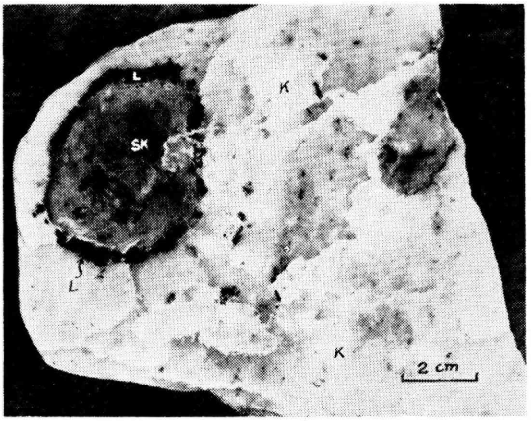

Fig. 6. Nodular Masses of Diopside Skarn (SK) with Ludwigite (L)-zone in the Kotoite-marble (K).

The relationship between the kotoite-marble and the diopside skarn, as already mentioned, is generally distinct; however, as seen in Figs. 5 and 6, a transition zone several millimeters wide occurs between them as if it were a kind of reaction zone. The mineral association in this zone differs from that of the kotoite-marble. It consists of fluoborite, szaibelyite, clinohumite, ludwigite, calcite, etc. The kotoite near this zone has been decomposed showing that the mineral was unstable at the time the zone was formed.

Judging from these relations, the writer thinks the kotoite-marble was formed earlier than the reaction zone and the formation of the skarn continued for some time after the formation of the kotoite-marble, because the diopside skarn has some branches which extend into the kotoite-marble. However, as the skarn body is always found within the kotoite-marble, they are closely related, and were possibly formed in succession, even though the stages during their formation may differ somewhat.

2. Kotoite-marble:

The kotoite-marble as described before, does not differ greatly in appearance from ordinary dolomite-marbles; however, it is somewhat hard and compact, and is difficult to crush even with a hammer. Because this rock appeared to be harder than ordinary dolomite, it was often said that the Holkol dolomite had been silicified around the ore bodies. The rock is generally white to pale yellowish brown, and sporadic black specks of ludwigite are often observed. In proportion as the clinohumite content of the rock increases, the yellowish brown color of the rock becomes progressively deeper, and brown to dark brown thin bands, com-

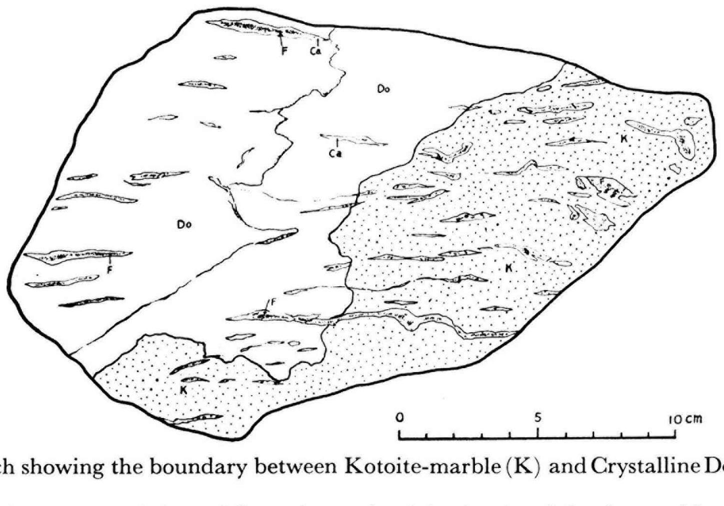

Fig. 7. Sketch showing the boundary between Kotoite-marble (K) and Crystalline Dolomite (Do).

Streaks and lenses consisting of forsterite and calcite in the dolomite-marble and kotoite-marble, corresponding to the original siliceous layers of the dolomite.

The forsterite has been formed by thermal metamorphism due to the reaction between impure silica and magnesia originally found in dolomite.

Near the forsterite is usually well developed newly formed calcite.

The kotoitization took place in the later stage of thermal metamorphism.

posed chiefly of forsterite, clinohumite, warwickite, and spinel are often found in the rock.

If the kotoite-marble is polished for a considerable length of time, the calcite of relatively low hardness may be rubbed off and the harder materials, such as grains of kotoite and tabular crystals of forsterite, will exhibit a distinct relief. From the polished specimen, one can perceive as shown in Fig. 7, that the forsterite of the kotoite-marble is distributed in the silica-rich impure zone of dolomite and, therefore, this mineral must have been formed during the recrystallization of the rock.

The boundary between kotoite-marble and the surrounding crystalline dolomite is often so indistinct that it is generally not traceable at underground; but it can clearly be observed on polished sections. Also observable is the boundary that cuts across the bedding planes, along which the forsterite is arranged. This suggests that the formation of forsterite was completed before the kotoite-marble was formed by pneumatolysis.

To distinguish between kotoite and calcite in kotoite-marble is almost impossible with the naked eye; however, if the rock had been exposed for a long time, the kotoite would be weathered and would change into a secondary mineral which is white and powdery, and could be recognized by careful observation, as innumerable fine spotty minerals (szaibelyite). Therefore, in order to confirm the presence of kotoite in kotoite-marble, it is necessary to observe a thin section under the microscope.

Under the microscope, the kotoite-marble exhibits a texture like that of pencatite or predazzite (WATANABE, 1935), which are known to be formed by the thermal metamorphism of dolomite or of periclase marble. But instead of periclase or brucite one finds a granular mineral which is about 0.1–0.15 mm in diameter, is highly birefringent, and is surrounded by a somewhat coarser mosaic of calcite.

This fine crystal, as mentioned previously, bears some resemblance to olivine or pyroxene, but a detailed investigation will disclose many differences between them. When the crystal is very fine, the cleavages are not distinct, but when somewhat coarse, it shows distinct cleavages on fairly thin sections, and extinction is straight and parallel to the c-axis. When the section is perpendicular to the c-axis, the cleavages (110) are clearly seen to cross each other at an angle of about 60° and the extinction is not parallel (Fig. 8).

Kotoite crystals are usually somewhat rounded, but hypidiomorphic crystals with developed faces are common. The arrangement of kotoite in kotoite-marble is shown in Figs. 8, 10, 11, and 12; a few dozen neighboring fine crystals are distributed with the same orientation and extinction, as can be seen almost simultaneously under crossed nicols. The space between the kotoite crystals is filled with calcite mosaic which is somewhat coarser than kotoite. The composing ratio of the two minerals measured on thin sections is not very different in any portion, *i.e.* the volumetric ratio of kotoite to calcite is nearly 2:7. This ratio shows a genetically restricted value, so the occurrence of a rock consisting completely of kotoite cannot be expected in the dolomite-contact zone. For the same reason, the

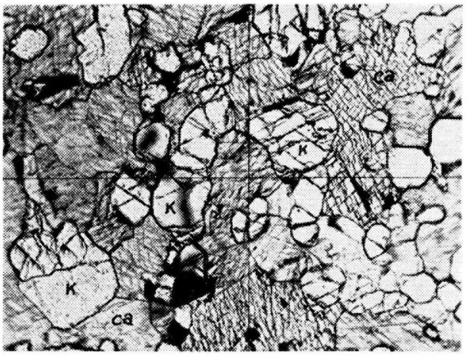

Fig. 8. Photomicrograph of the Kotoite-marble (Notice the cleavage in kotoite grains.) $\times 60$.
K: Kotoite Ca: Calcite

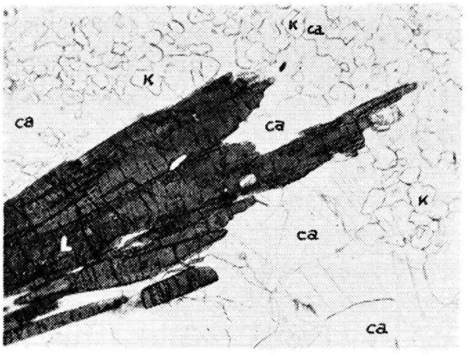

Fig. 9. Ludwigite in Kotoite-marble $\times 30$.
(In the area of calcite surrounding the ludwigite granular kotoite is not usually found.)

Fig. 10. Clinohumite in Kotoite-marble ($\times 90$, crossed nicols).
K: Kotoite Ca: Calcite h: Clinohumite

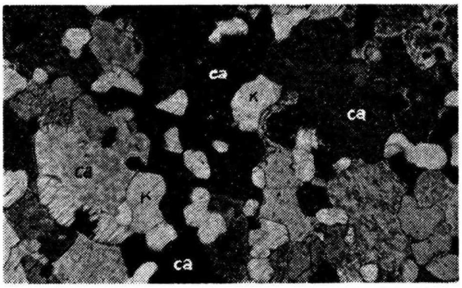

Fig. 11. Photomicrograph of Kotoite-marble from Holkol
($\times$ 90, crossed nicols).
K: Kotoite Ca: Calcite

Fig. 12. Photomicrograph of Kotoite-marble from Rézbanya, Romania
($\times$ 90, crossed nicols).
K: Kotoite Ca: Calcite Sz: Szaibelyite

volumetric ratio of periclase to calcite in periclase marble and that of brucite to calcite in pencatite or predazzite exhibit similar conditions. These ratios are also within the limits of 2:7 to 3:7.

In addition to the above-mentioned two minerals, several accessory minerals are contained in kotoite-marble. The important ones are forsterite, clinohumite, spinel, such borate minerals as ludwigite, suanite, warwickite, and a few other sulphide minerals. In order to study the composing ratios of minerals in kotoite-marble, two typical thin sections were selected, and the results of study by using the Rosiwal micrometric method are presented as (17) and (18) in Table 1. The results of the chemical analyses of kotoite-marble are also given in Table 1. These results, especially when comparing the values of (19) with those of the chemical analyses, show that the value for the kotoite-marble cannot be more than 14.19 per cent.

Each component mineral of the rock will be described briefly as follows:

Kotoite: This mineral is usually found as fine-grained and allotriomorphic crystals about 0.1 to 0.15 mm in diameter; attaining a maximum diameter of 0.5 mm. Occasionally it occurs as hypidiomorphic crystals with well-developed faces. Other properties of this mineral will be described later in detail.

Table 1. (a) Chemical Analyses of Kotoite-marble from Holkol.

No.	1	2	3	4	5	6	7	8	9
d	—	—	—	—	—	—	—	—	—
SiO_2	3.56	3.38	2.56	14.24	3.60	2.46	3.64	2.71	2.24
TiO_2	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.03	n.d.
Al_2O_3	0.21	0.21	0.09	0.31	0.32	0.07	—	0.67	0.48
Fe_2O_3	0.31	0.29	0.23	0.37	0.46	0.29	0.26	0.27	0.62
MnO	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.05	n.d.
CaO	34.10	34.72	33.50	34.02	34.24	34.42	33.94	33.23	33.43
MgO	21.28	20.30	21.62	14.52	21.20	22.68	21.14	22.66	24.32
B_2O_3	11.98	10.59	14.63	7.36	12.02	12.71	12.39	12.49	12.28
K_2O	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.05	n.d.
Na_2O	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.63	n.d.
F	tr.	tr.	tr.	tr.	tr.	—	tr.	n.d.	n.d.
Ig. loss	27.82	29.78	27.10	28.38	27.42	27.90	27.54	27.41	26.76
Total	99.26	99.27	99.73	99.20	99.26	100.53	98.91	100.20	100.13

No.	10	11	12	13	14	15	16	17	18	19
d	—	—	—	—	—	—	2.86	2.87	2.86	2.85 (cal.)
SiO_2	7.64	5.11	1.98	2.96	2.98	2.39	3.63	2.0	2.2	—
TiO_2	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	—	—	—
Al_2O_3	1.55	0.14	0.22	0.61	0.68	1.10	0.82	0.4	0.4	—
Fe_2O_3	0.25	1.08	0.65		0.80	0.25	0.33	2.8	1.1	—
MnO	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	—	—	—
CaO	34.73	29.26	34.01	33.70	32.03	34.90	34.43	39.2	38.4	34.28
MgO	23.93	28.01	25.00	15.75	21.58	22.18	22.75	17.3	18.8	24.64
B_2O_3	9.83	9.60	11.34	11.26	15.12	9.50	9.39	8.3	9.0	14.19
K_2O	n.d.	n.d.	n.d.	2.06	n.d.	0.42	n.d.	—	—	—
Na_2O	n.d.	n.d.	n.d.		n.d.		n.d.	—	—	—
F	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	—	—	—
Ig. loss	21.76	26.89	26.69	34.21	26.86	29.23	28.71	30.0	30.1	26.89
Total	99.69	100.09	99.89	100.55	100.05	99.97	100.06	100.00	100.00	100.00

(b) Mineral Composition of Kotoite-marble (Percentage by weight; calculated values)

No.	1	2	3	4	5	6	7	8	9
Calcite	60.7	61.9	59.8	—	61.1	61.4	60.6	59.3	59.7
Kotoite	32.5	28.8	33.8?	—	32.5	34.5	33.7	34.1	33.2
Ludwigite	0.5	0.5	0.6	—	0.8	0.5	0.5	0.5	1.1
Forsterite	8.3	7.9	6.0	—	8.4	5.8	8.5	6.3	5.3
Spinel	0.3	0.3	0.2	—	0.4	0.1	—	0.9	0.7
Total	102.3	99.4	100.4	—	103.2	102.3	103.3	101.1	100.0
$\frac{CaO}{MgO}$ (Mol. rat.)	1.15	1.23	1.11	1.68	1.16	1.09	1.15	1.05	1.00

No.	10	11	12	13	14	15	16	17	18	19
Calcite	49.5	61.2?	60.7	60.1	57.2	62.2	61.4	69.5	68.5	61.17
Kotoite	26.7	25.6	30.5	30.8	40.8	25.8	25.4	21.4	23.9	38.83
Ludwigite	0.4	1.9	1.2	—	1.4	0.4	0.5	3.2	1.9	—
Forsterite	17.9	12.0	4.6	6.9	7.0	5.6	8.6	5.3	5.1	—
Spinel	2.2	0.2	0.3	—	1.0	1.5	1.1	0.6	0.6	—
Total	96.7	100.9	97.3	97.8	107.4	95.5	97.0	100.0	100.0	100.0
$\frac{CaO}{MgO}$ (Mol. rat.)	1.04	0.75	0.98	1.55	1.06	1.13	1.09	1.63	1.46	1.00

(1) Kotoite-marble 182-m level, north ore body
(2) Kotoite-marble Do.
(3) Kotoite-marble North drift on 212-m level north ore body
(4) Kotoite-marble (Contains impurities) 212-m level, north ore body
(5) Kotoite-marble No. 4 breast, 303-m level, north ore body
(1)–(5) According to Yamazaki and Yamada
(6) Kotoite-marble No. 4 breast, 242-m level, north ore body
(7) Kotoite-marble No. 4 breast, 273-m level, north ore body
(8) Kotoite-marble North ore body; analyzed by the Ceramic Inst. of the Dept. of Commerce and Industry (According to Mr. Tetsuji Asayama)
(9), (10), (11), (12) Kotoite-marble North ore body; according to Prof. Shōichiro Nagai of the Engineering Dept., Tokyo Univ.
(13) Kotoite-marble 1,000-shaku level, north ore body. (Analyzed by the Takeda Chōbei Shoten)
(14) Kotoite-marble North ore body; analyzed by the Inst. of the Hitachi Manufactory.
(15) Kotoite-marble (S. 1563); 1,000-shaku level, north ore body. (Analyzed by the Industrial Inst. of Osaka)
(16) Kotoite-marble (S. 260); north ore body; analyzed by the Matsuda Inst.
(17) Kotoite-marble (S. 260); north ore body; computed value by Rosiwal method. (10 shaku = 3.03m)
(18) Kotoite-marble (S. 839); north ore body; computated value by Rosiwal method
(19) Theoretical value for kotoite marble ($Mg_3B_2O_6 + 3CaCO_3$) derived from pure dolomite ($Mg, Ca(CO_3)_2$)

Calcite: This mineral composes the largest part of the rock. When it fills the space around the kotoite crystals, it occurs as mosaic crystals about 0.2 mm in diameter, i.e. about twice the size of the kotoite crystal. Around the crystals of such minerals as ludwigite and forsterite, the calcite tends to form a somewhat coarser mosaic, and in many cases no kotoite crystals are found among them.

Forsterite: This mineral usually occurs as fine-grained idiomorphic crystals flattened parallel to (100). Specific gravity=3.22. Under the microcope it shows straight extinction, and the refractive indices, measured by the immersion method, are: $\alpha=1.638$, $\beta=1.651$, $\gamma=1.669$; $\gamma-\alpha=0.031$; $(+)2V=84°$. These values indicate that the mineral almost belongs to the forsterite endmember. It is distributed within kotoite-marble, assuming such forms as lenses, fine bands, and layers. It is also often found in association with clinohumite.

Clinohumite Minerals: The minerals of the chondrodite group are irregularly distributed in the rock; however, they may occur as veinlets in association with forsterite, spinel, and calcite. When the rock is relatively rich in these minerals, it is pale yellow or pale yellowish brown. Study of the optical and other properties of most of the minerals of this group shows that it corresponds to clinohumite ($4\,Mg_2SiO_2 \cdot Mg\,(F, OH)_2$). The clinohumite occurs as somewhat coarser crystals than the kotoite and forms idiomorphic crystals, most of which are about 0.2 to 1.0 mm in diameter. Specific gravity=3.20. Optical properties are: $\alpha=1.625$, $\beta=1.631$, $\gamma=1.655$; $\gamma-\alpha=0.030$; $(+)2V=71°$; extinction angle (angle between the twinning plane and X')$=9$–$10°$; more or less pleochroic, changing from colorless to pale yellow; however, colorless crystals may also be found among the thin sections. The minerals of this group are characterized by their lamellar twinning, as shown in Fig. 10.

Spinel: This mineral is found in only a few places in kotoite-marble. Since it is fine-grained and sporadically distributed, it may be overlooked. The crystals are generally idiomorphic and occur mostly in octahedral form. However, a spinel twinning is also frequently found.

The spinel, in some cases, forms irregular brown layers several millimeters to several centimeters wide. It is associated with forsterite, clinohumite, ludwigite, etc. in kotoite-marble. The spinel found in the kotoite-marble composing the upper part of the North ore body, where little ludwigite is found associated with it, is colorless in thin section; when concentrated by using heavy solution the crystals are pale pink. The spinel in the lower part of the North ore body, where much iron-rich ludwigite is associated with it, is somewhat greenish, even in thin section.

The crystals are optically isotropic, and the refractive index of the colorless ones is $n=1.718$; the measured specific gravity is 3.54.

Ludwigite ($(Mg, Fe^{+2})_2\,Fe^{+3}BO_5$) : This mineral is a borate mineral which has long been a subject of discussion. Prof. Kōtō described it as lievrite (ilvaite), because its optical properties in thin section bear a close resemblance to those of lievrite. After that, D. F. Higgins (1918) regarded it as an iron-rich pyroxene, and gave it a new name, "collbranite." Still later, E. V. SHANNON (1921, A,B) confirmed it to be ludwigite.

The mineral appears black, and often occurs as a radial aggregation of acicular crystals several millimeters, occasionally 2–3 cm, in length. It is scarcely contained in the kotoite-marble of the upper part of the north ore body. As shown in Fig. 2 it forms black minutely striated zones which appear as if they were the bedding planes of the original rock.

This mineral also occurs sporadically in kotoite-marble, and is especially concentrated on and near the 182 m level in the lower part of the North ore body. It is also found in abundance in the kotoite-marble of both the East and the West ore bodies.

Under the microscope, the thickest part of the thin section of this mineral is opaque but the thinnest part is semi-transparent and distinctly pleochroic, being deep brown parallel to the elongation of the crystal (z′), and deep grass green perpendicular to it (x′); absorption z′>x′; straight extinction. As shown clearly in Fig. 9, the ludwigite crystals in kotoite-marble are usually surrounded by calcite that is not associated with kotoite.

Suanite ($2MgO \cdot B_2O_3$ or $Mg_2B_2O_5$): This, a new mineral, (WATANABE, 1953) is a magnesium borate mineral which occurs extensively in the kotoite-marble of the North ore body. As the mineral appears white, it can barely be seen with the naked eye, but it can clearly be recognized by its silky luster when it occurs as an aggregate of fibrous bundles several millimeters long. In a part of the east ore body, this mineral occurs as somewhat large crystals in kotoite-marble which contains ludwigite. Some of them attain 2–3 cm in length, but the mineral has long been undetected due to its lack of color.

Under the microscope, this mineral is observed to be coarser than the nearby kotoite, and aggregates radially exhibiting very high birefringence. The direction of x′ is parallel to the elongation of the crystal; $\alpha=1.596$, $\beta=1.639$, $\gamma=1.670$; (−) $2V=70°$; $r>v$; specific gravity=2.91. Chemical tests have clearly indicated the presence of Mg and B and X-rays method has confirmed that this mineral differs from similar known borate minerals such as camsellite and szaibelyite has already been confirmed by X-ray.

The sample from the east ore body was analyzed by Mr. Kiyoshi ISONO through the kindness of Dr. YAMANE, the former director of the Geological Survey of Japan. The results of the analysis are given in Table 2.

Since the analyzed sample clearly contained small quantities of calcite and forsterite as impurities, the chemical composition of the mineral must be considered by removing CaO, CO_2, SiO_2, etc. from the results of the chemical analysis. The value for H_2O is obtained by deducting the value for CO_2 from that for ignition loss, so the mineral must be examined to find out whether this was part of its original content of the mineral or not. However, this mineral can be thought to have a composition of almost $2MgO \cdot B_2O_3$, as shown in Table 2.

Warwickite ($3(Mg, Fe)O \cdot TiO_2 \cdot B_2O_3$): (WATANABE, 1954) A brown, very fine-grained mineral, this occurs as spots in the kotoite-marble. When these "spots" were observed under the microscope, they were found to be an aggregate of fine acicular crystals 0.2–0.5 mm in length. x′ is parallel to the elongation of the crystal; pleochroism is more or less observable as x′=pale yellow and z′=light brown; the index of refraction is very high.

Table 2. Chemical Analysis of Suanite From Holkol.
(Analysed by K. Isono, Geol. Survey, Dept. of Commerce and Industry)

	I	II	III
SiO_2	0.70%	-%	-%
Al_2O_3	0.97	-	-
Fe_2O_3	0.33	-	-
MgO	46.48	54.89	53.66
CaO	3.70	-	-
Na_2O	0.90	-	-
K_2O	0.00	-	-
B_2O_3	38.20	45.11	46.34
CO_2	5.70	-	-
$H_2O\pm$	3.50	-	-
	100.48	100.00	100.00

I: Chemical analysis of suanite; the sample contains a few impurities of calcite, spinel, and forsterite.
II: Calculated values for $MgO+B_2O_3$ in the chemical analysis of suanite reduced to 100.
III: Theoretical values for 2 $MgO \cdot B_2O_3$ (by weight percentage)

Though this mineral is widely distributed in the kotoite-marble, its properties were hard to confirm because of the fineness of the crystal and the difficulty in separation.

Since warwickite occurs only in kotoite-marble and not in the surrounding dolomite, it was also assumed to be a kind of borate mineral. An X-ray photograph of the powder was prepared by using a minute amount of the sample separated from the rock, and this was identified as warwickite. This was only the second occurrence of warwickite which had been found in the world.

Associated sulfide minerals: Large amounts of opaque metallic minerals are generally contained in the diopside skarn, although very fine spotty sulfides are also found in kotoite-marble. Under the reflecting microscope, two types of mineral association can be seen. When there is little iron bornite, chalcopyrite, sulphosalts of copper and bismuth, and native bismuth are observed; when there is much iron, such minerals as pyrrhotite, chalcopyrite, cubanite, valleriite, bismuthinite, native bismuth, and native gold are present.

Chemical composition: Since kotoite-marble first attracted attention as a boron ore, many chemical analyses of it have been completed. The data which the writer received are listed in Table 1, and the mineral composition computed with them is given as (2) in Table 1.

The table shows that the rock has a remarkably well-defined chemical composition. Kotoite-marble is very narrowly defined in composition, samples were collected from various parts of the ore body, because the rock is derived from relatively pure dolomite supplied with boron; its outstanding characteristic of the rock. By considering the constituent minerals detected under the microscope, one should be able to compute the composing ratio of the minerals. According to these results, the ratio is almost constant in all specimens.

3. Reaction zone between kotoite-marble and diopside skarn: The boundary between the skarn, which is mined as gold and copper ore, and the surrounding kotoite-marble is generally very distinct. Although a narrow reaction zone occurs between them, the mineral association in this zone differs somewhat from those of the other parts. Microscopic examination of the rock of this zone

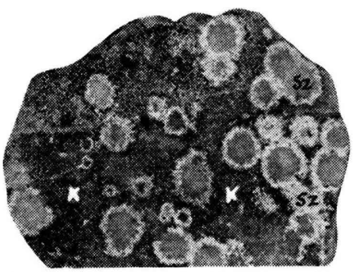

Fig. 13. Polished Surface of Kotoite-marble Containing Spherical Masses of Szaibelyite from Rézbánya, Romania $\times 1.6$.

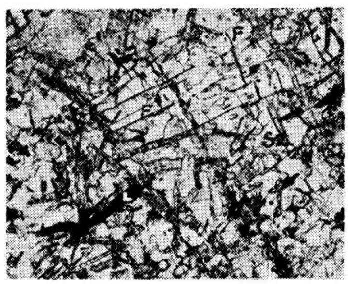

Fig. 14. Photomicrograph of the Reaction Zone between Kotoite-marble and Diopside Skarn, Holkol $\times 30$.

F: Fluoborite
L: Ludwigite
Sz: Szaibelyite

shows that it retains the original texture of kotoite-marble; but the kotoite has already decomposed and faded away, and, as shown in Fig. 14, other borate minerals—fluoborite, szaibelyite, and ludwigite—come out in place of it and the silicate minerals, especially those of the chondrodite group increase. This obviously suggests that the formation of the kotoite-marble preceded that of the diopside skarn and the special association of such minerals may have been established by obtaining a supply of F, OH, etc. which makes the kotoite unstable on the surface of the diopside skarn. Each of these minerals are described briefly below.

Fluoborite ($Mg_3 B_2O_6 \cdot 3Mg (OH, F)_2$): This mineral occurs as prismatic crystals 0.5–1 mm long. The section perpendicular to the axis is clearly hexagonal. The crystal is optically uniaxial and negative; $\omega=1.550$, $\varepsilon=1.522$, $\omega-\varepsilon=0.028$; that *i.e.* it shows almost the same properties as the fluoborite which was discovered by Geijer (1926) in the ludwigite-bearing rock from Sweden.

Szaibelyite ($HMgBO_3$): This mineral also occurs as colorless and very fine acicular crystals rarely larger than 0.2 mm long. The birefringence measures as high as 0.074, and $x'=1.650$, $z'=1.576$; x' is parallel to the direction of the elongation of the crystal.

Other minerals: Other minerals, e.g. ludwigite, clinohumite, and calcite which occur in the same reaction zone, are nearly equal to those already described, so detailed descriptions of them have been omitted.

B. Kotoite from Rézbánya, Romania (KOCH, 1888, PETERS, 1861)

Various kinds of ore deposits are known from Transylvania, or Siebenbürgen, in the Balkans. Rézbánya, especially, has long been known for the occurrence of various kinds of minerals, as well as copper and zinc deposits. These minerals and copper-zinc deposits are found where the Mesozoic limestone is in contact with diorite and green dikes. A kind of marble of special appearance, which was collected by SZAIBLYI, a mining engineer, has long been known to mineralogists, and has been studied extensively by PETERS and others. PETERS found a fibrous mineral in the rock and named it szaibelyite, and by chemical analysis STROMEYER showed it to be a kind of borate.

While he was studying borate minerals in Berlin, the writer found a mineral corresponding to szaibelyite among the component minerals of the rock from Holkol. In order to compare it with the szaibelyite from Rézbánya, he obtained a piece of the Rézbánya specimen through the kindness of J. SCHROETER who was at the Berlin Technical University at the time. This specimen, as shown in Fig. 13, was a marble containing spherulites about 3–4 mm in diameter, corresponding to PETERS' old description, that is, the specimen was judged to be similar to that studied by PETERS.

Under the microscope, the spherulites are seen to be chiefly of szaibelyite; the outer part of the spherulites consists of a somewhat longer fibrous mineral than the inner part, and the former crystals radiate from the surface of the latter and are cemented by calcite.

Both the fibrous minerals constituting the outer and the inner parts of the spherulites are obviously of the same kind, that is, the two have the same refractive indices: $\gamma'=1.651$, $\alpha'=1.578$, and x' is found equally in the direction of elongation. Needless to say, this is the same mineral that was studied and called szaibelyite by PETERS and investigators after him.

However, the marble-like part surrounding the spherulite was microscopically seen to contain a granular mineral which is associated with szaibelyite and a few opaque minerals. This granular mineral, as shown in Fig. 12, has distinct cleavage and straight extinction, small 2V, and is characterized by the simultaneous extinction of several crystals. Since its properties are quite similar to those of the Holkol kotoite, the mineral was studied in detail optically; then it was also separated from calcite with dilute hydrochloric acid and studied by chemical and X-ray methods. The results of these studies proved this mineral to be kotoite.

The mineral composition of the marble-like part containing kotoite in the Rézbánya specimen was studied by using the ROSIWAL method. The results are shown in Table 3.

Table 3. Mineral Composition of the Marble like Part Containing Kotoite in the Rézbánya Specimen.

	Sp. gr.	Volume, %	Weight, %
Calcite	2.71	81.0	79.1
Kotoite	3.06	16.7	18.5
Szaibelyite	2.70	2.0	2.1
Sulfides (Chiefly sphalerite)	4.0	0.3	0.3

The lower kotoite content of this rock, as compared with that of the kotoite-marble from Holkol, may be attributed to the decomposition and change into szaibelyite of some kotoite.

Thus, kotoite was discovered almost simultaneously in specimens from both Holkol and Rézbánya. The confirmation of this mineral enables us to solve various problems which were not fully clarified earlier when PETERS and STROMEYER (1863) studied szaibelyite. For instance, the values reported for the chemical analysis of szaibelyite should have aroused suspicion if they were a mixture of szaibelyite and kotoite, because STROMEYER did not recognize the existence of kotoite in his specimen, though it certainly contained it. The meaning of previous chemical analyses may be understood if they are examined again from such a point of view.

In short, the kotoite of Rézbánya is found in the country rock of a contact deposit as it is in Holkol and similarly forms kotoite-marble which contains szaibelyite. Similar conditions probably generated both cases.

3. Properties of Kotoite

A. Chemical Composition

As already described in the section on mode of occurrence, collection of a pure sample of kotoite is difficult. However, as kotoite is not very soluble in cold hydrochloric acid, it will be left in the residue when the kotoite-marble is treated with cold dilute hydrochloric acid, while the calcite is dissolved. If 100 gm of kotoite-marble are treated, about 30 gm of residue will be obtained, and many fine grains of kotoite will be found in it, though it may be mixed with many other insoluble minerals.

In treating the sample with acid, the original specimen should not be finely crushed; little pieces should be used. When such pieces are dissolved, the forms of the relatively coarser minerals—forsterite, clinohumite, ludwigite, and suanite—will remain unchanged.

During the first step, the writer used a 0.15 mm sieve to separate the coarser minerals from the fine colorless sandy grains. Under the microscope, this sandy material was observed to consist mainly of kotoite grains, though mixed with a few fine crystals of forsterite, spinel, and other borate minerals. During the second step, in order to reject these fine impurities, he prepared Clerici heavy solutions, specific gravity 2.95 and 3.2 and attempted to collect pure kotoite by using a centrifugal separator. The sample remaining within the limit of specific gravity between 2.95 and 3.2, was composed almost entirely of pure kotoite. As further separation was considered quite difficult, this same sample was used for chemical analysis.

The sample was first tested for the presence of boric acid, iron, magnesia, etc., and then was carefully fused with sodium carbonate. During the course of the quantitative analysis, special care was taken to separate the boric acid, and afterwards, the quantity of silica, alumina, iron oxide, lime, and magnesia were measured in the ordinary way. The ferrous oxide and water contents of another sample were measured; the boric acid was separately measured by the Chapin method. The results are shown in Table 4, of which SiO_2, Al_2O_3, and Fe_2O_3 are considered to have been derived from the impurities. They may be divided and distributed between forsterite and spinel. If these are deducted from the molecular ratio, we arrive at the following:

$$(Mg, Fe, Ca)O:B_2O_3=1.5209:0.5055=3:1$$

As the value for $FeO+CaO$ measures only about 1 per cent of the MgO content, the formula for the Holkol kotoite can be stated as $3MgO \cdot B_2O_3$.

Table 4. Chemical Analysis of Holkol Kotoite.

	Anal. value (%)	Mol. ratio	$-0.0220\ Mg_2SiO_4$ $-0.0039\ Mg\ (Al, Fe)_2O_4$	Ratio	$Mg_3B_2O_6$ Theo. value (%)
SiO_2	1.32	0.0220	—	—	—
Al_2O_3	0.26	0.0026	—	—	—
Fe_2O_3	0.20	0.0013	—	—	—
FeO	0.61	0.0085			
CaO	0.18	0.0032	1.5209	3.00	
MgO	62.78	1.5571			63.46
B_2O_3	35.20	0.5055	0.5055	1.00	36.54
$H_2O^{+}110°$	0.05	0.0028	—	—	—
Total	100.60				100.00

B. Form and Physical Properties

Kotoites from both Rézbánya and Holkol occur as very fine grains. The crystal form has not been clarified, though it can usually be recognized as allotriomorphic or hypidiomorphic; the crystal grains are 0.1–0.5 mm in diameter. The hypidiomorphic crystals seem to have well-developed pyramids or domes, and they are occasionally found to be somewhat elongated in the direction of the b axis. Distinct cleavage is found parallel to axis c, and in some cases straight extinction is observable. These characteristics may serve to identify this mineral. In the section perpendicular to the c axis, a pair of cleavages parallel to (110) which cross each other at an angle of about 65° can be seen.

A study on the crystal form of artificial kotoite was prepared by EBELMAN with measurements by MALLARD in 1887. According to MALLARD, the crystal belongs to the orthorhombic system, and crystal planes such as (110), (011), (101), (403), and (100) occur. MALLARD also computed the axial ratio a:b:c=0.6412:1:0.5494 by using the values (110): (110)=65° 20′ and (110):(011)=74° 56′; and he recognized that the cleavages on (110) are distinct. The writer also tried to synthesize artificial kotoite; he obtained a somewhat large crystal, but it did not have good form. By using the cleavage planes of this crystal, the writer determined the value (110):(110)=65° 20′. A native crystal shows almost the same value. A noteworthy property of kotoite is the formation of secondary twinning by shock; that is, when the refractive index of kotoite is measured by the immersion method, the sample is usually crushed and lamellar twinning may often be observed. This property, which is also found in artificial kotoite, comes from the phenomenon of the so-called *Einfache Schiebung*, or slipping in a certain direction within kotoite. In order to study this direction, the writer cemented the mineral particles with bakelite and observed a thin section by using the Leiz universal stage. By studying the various relations between the optical orientation and other properties, he confirmed the angle between C and the direction perpendicular to the twinning plane as about 40°. He also measured the angle between the twinning plane and the cleavage plane and obtained the value 56° for it. On comparing these values with those measured from artificial kotoite, that is (101): (001)=40° 36′, (101):(110)=56° 48′, the former was found to almost correspond with the latter, and, hence, the twinning plane is assumed to be possibly (101). Such a twinning plane can be seen in very thin sections, although only in very rare cases.

The mineral is relatively hard. It was measured by rubbing the fine grains, which were collected from the rock, on the standard test plate; artificial kotoite was also used for this purpose, and its hardness was determined to be almost $6\frac{1}{2}$.

When a polished section of kotoite-marble is observed under a reflecting microscope, the relative hardness of kotoite can be perceived from the relief of the polished surface; it is equal to forsterite, much higher than calcite, and lower than spinel.

The specific gravity of the mineral was determined by placing the fine grains or crystals in Clerici heavy solution and measuring the specific gravity of the Clerici solution at the point in which the suspended mineral grains remained in a state of equilibrium.

Thus, the following values were obtained: 3.106 for the kotoite from Holkol, 3.07=3.10 for that from Rézbánya, and 3.092 for artificial kotoite. The specific gravity of the old artificial kotoite measured by MALLARD was 2.987. This value is somewhat lower than that given above, so it is assumed that the old artificial kotoite may have been mixed with some other crystals.

C. Optical Properties

The pure separated grains of kotoite are colorless and transparent. The crystal is biaxial and optically positive under a conoscope, however, and occasionally appears almost uniaxial because of the smallness of 2V. Therefore, under the microscope it closely resembles pyroxenes of small 2V such as pigeonite and enstatite. Optical measurements of the kotoite from the two districts and of the artificial kotoite are well in accordance with one another, as shown in Table 5.

Table 5. Optical Properties of Kotoite.

Name	WATANABE	WATANABE	WATANABE	WATANABE	MALLARD
Method	Immersion	Immersion	Prism	Immersion	Prism
Specimen	Holkol	Rézbánya	Artificial; cleavage flake	Artificial	Artificial; parallel to C
Color	Colorless	Colorless	Colorless	Colorless	Colorless
α	1.652	1.652	1.6514	1.652	1.6527
β	1.653	1.653	1.6521 (Calc.)	1.652	1.6537
γ	1.673	1.674	1.6725	1.673	1.6748
$\gamma-\alpha$	0.021	0.022	0.0211	0.021	0.0221
2V	21° (+)	small (+)	22° (+)		24°30′(+) (calc.)
2E	36° (calc.)		38° (calc.)		43°18′ (obs.)

Dispersion . . . . $r>v$ Orientation . . . . z=c
Optical plane . . . . (010) Extinction . . . . z′//cleavage plane

D. General Physicochemical Properties

An experiment to determine the melting point of artificial kotoite was made by the writer under Prof. EITEL at the Kaiser Wilhelm Silicate Institute, but no convincing results were obtained, probably because of the volatility of B_2O_3. Judging from the temperature curve obtained during the experiment, the writer determined that the melting point of this mineral was near 1,340°C.

When the Holkol kotoite is highly heated in air, it becomes somewhat yellow. It is easily soluble in warm, concentrated hydrochloric acid, although it is almost insoluble when the acid is dilute. The presence of iron, magnesium, boron, etc. can be detected in this acid solution.

Synthesis of artificial kotoite: EBELMAN (1900) succeeded in synthesizing artificial kotoite as early as 1851. He placed magnesia and boric acid anhydride in a stone crucible and fused them into magnesium orthoborate, or artificial kotoite. Both the crystallographic and optical properties of this crystal were studied by MALLARD in 1887. In 1904, GUERTLER (1904, 1909) synthesized the borates of alkali earth metals and studied them systematically, clarifying the equilibrium relations in the MgO-B_2O_3 system to some extent. In this system, he recognized the formation of such borates as $Mg_3B_2O_6$ ($3MgO \cdot B_2O_3$) and $Mg_2B_2O_5$ ($2MgO \cdot B_2O_3$).

The writer also obtained a good crystal of artificial kotoite during his experiments at the University of Berlin. To do so he placed a mixture of 1.27 gm MgO and 0.73 gm B_2O_3 in a small platinium crucible and heated it at about 1,200° C in a small electric furnace.

A portion of the crystal was quite pure, but the rest contained a few crystal grains of periclase and $Mg_3B_2O_6$. The pure portion was isolated and used for X-ray study and measurement of optical properties.

Kotoite is a relatively stable mineral, but it is unstable under hydrothermal conditions or when it is exposed to the air; it weathers and decomposes easily. In the thin sections of a weathered specimen, one can observe the secondary fibrous minerals which are arranged parallel to the b axis. On weathered surfaces of kotoite-marble a powdery mineral is observed to have formed secondarily from the kotoite. These secondary minerals were collected from the rock and examined under the microscope, and the presence of a mineral corresponding to szaibelyite confirmed. Kotoite alters partly to brucite.

E. Results of the X-ray Study of Kotoite

An X-ray study of the Holkol kotoite was made primarily to compare it with pyroxene. As it was later clarified as a borate, the X-ray photograph was used to determine whether it coincides with that of the artificial borate $Mg_3B_2O_6$. The X-ray photographs were prepared by the powder method, and the three photographs of the carefully purified kotoite from Holkol, the kotoite from Rézbánya and the artificial crystal were found to coincide perfectly, as shown in Fig. 15. The diameter of the camera used for the photographs was 57.3 mm; the X-ray tube was fitted with an iron anticathode; β-ray was not removed. The grain size of the sample was 0.3 to 0.4 mm.

The writer studied the artificial crystal by means of the rotation method under the guidance of Dr. STRUNZ. The same specimen was later studied by SADANAGA, and others of the Mineralogical Institute of the University of Tokyo, who also analyzed the structure of the crystal. The results obtained by the these Institute researchers, together with the writer's, are cited here through the kindness of SADANAGA.

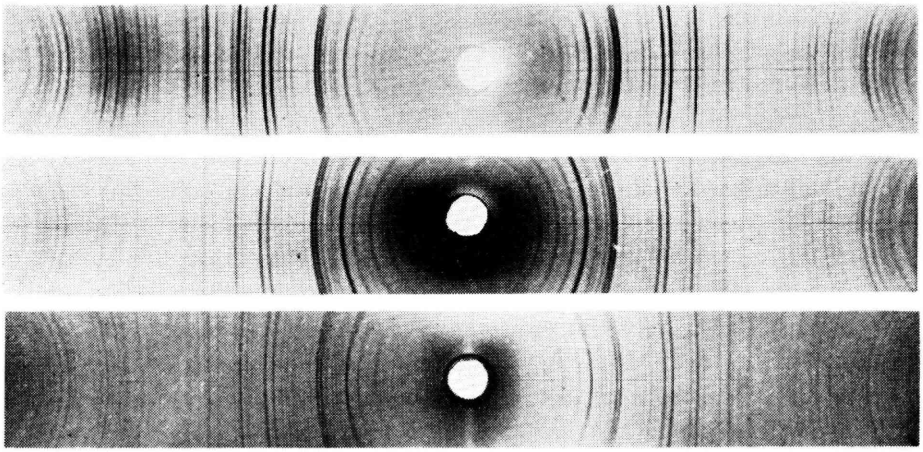

Fig. 15. X-ray Diffraction Patterns of Kotoite and Artificial Magnesium Orthoborate.
a. Kotoite, Holkol
b. Kotoite, Rézbanya, Romania
c. Artificial kotoite ($Mg_3B_2O_6$)

Lattice constants (WATANABE)	(SADANAGA)
$a_0=5.41$Å	$a_0=5.38_5$Å
$b_0=8.42$Å	$b_0=8.40_0$Å
$c_0=4.51$Å	$c_0=4.48_7$Å
$a_0 : b_0 : c_0=0.642 : 1 : 0.536$	$a_0 : b_0 : c_0=0.646 : 1 : 0.534$
a : b : c (artificial crystal) =0.6412 : 1 : 0.5494 (MALLARD)	
Z=2	Z=2
Space group : Undetermined	D_{2h}^{12}—Pnmn

The study on the crystal structure of kotoite was reported later by SADANAGA (1948).

4. Considerations on the Origin of Kotoite

As clarified in the foregoing descriptions, kotoite occurs in a special country rock of a contact deposit. In both occurrences at Holkol and Rézbánya, kotoite is associated with calcite and forms a kind of marble which may be called kotoite-marble. The mode of occurrence of this rock at Rézbánya has not been observed by the writer. However, according to his observations at Holkol, it is found only in the dolomite of the region, and, therefore, may be considered genetically closely related to this dolomite.

The dolomite near the Holkol deposit has undergone thermal metamorphism over a considerably wide area and has changed into crystalline dolomite (dolomite marble), while a part of the rock very near the contact has changed into brucite-marble. The crystalline dolomite adjacent to the kotoite-marble is chemically almost pure dolomite, as $SiO_2=2.5-2.7\%$, $Al_2O_3=1.0$ to 1.5%, $Fe_2O_3=0.3\%$,

$CaO = 30–32\%$, $MgO = 20–21\%$, and CO_2 (or ignition loss) = about 42–45%. The molecular ratio of CaO to MgO is within the limit of roughly 1.0 to 1.2. Mineralogically, crystalline dolomite is composed chiefly of mineral dolomite and contains accessory forsterite (occasionally chondrodite), spinel, and calcite.

The chemical composition of kotoite-marble is observed to be roughly equal to dolomite in content of SiO_2, Al_2O_3, and Fe_2O_3; the molecular ratio of CaO to MgO is mainly within the limit of 1.0 to 1.2; however, the CO_2 content decreases 26–28% in exchange for B_2O_3, of which as much as 9–12% can be contained. Mineralogically, there is a marked difference between the two rocks; that is, no mineral dolomite is found in the kotoite-marble but, instead, calcite and kotoite accompanied by a few other minerals. Therefore, the process of the formation of kotoite-marble from dolomite can be explained very easily, if the minor constituents are not considered.

That is, it is necessary in the formation of kotoite-marble from dolomite that much CO_2 be expelled from the latter and that new B_2O_3 enter the rock. In general, dolomite becomes periclase-marble when it undergoes intense thermometamorphism. This may be represented as follows:

$$\underset{\text{Dolomite}}{CaMg(CO_3)_2} \rightarrow \underset{\substack{\text{Periclase + Calcite} \\ \text{(periclase-marble)}}}{MgO + CaCO_3} + CO_2$$

The dolomite undergoes dissociation, and $MgCO_3$ is decomposed into MgO and CO_2. A chemical reaction similar to this can be postulated for the formation of kotoite-marble. If pure dolomite acquired a sufficient amount of B_2O_3 under high temperature, the following reaction would be expected.

$$\underset{\text{Dolomite}}{3CaMg(CO_3)_2} + B_2O_3 \rightarrow \underset{\substack{\text{Kotoite + Calcite} \\ \text{(kotoite-marble)}}}{Mg_3B_2O_6 + 3CaCO_3} + 3CO_2$$

That is, the magnesium carbonate in the dolomite dissociates into MgO and CO_2, and B_2O_3 combines with MgO to form kotoite. If such a relationship were to exist, pure kotoite-marble derived from pure dolomite should have a composition of $Mg_3B_2O_6 + 3CaCO_3$. Working from such a postulate, the writer computed the chemical composition of pure kotoite-marble; the results are given in the last line of Table 1. It is a matter of interest that these results are nearly coincident with those of the chemical analysis of the kotoite-marble from Holkol. This proves that the formation process of kotoite-marble may be represented by the reaction given in the above formula. Such a process can be termed "kotoitization." In this case, the difference in composition between natural kotoite-marble and "pure" kotoite-marble may come from the fact that the original dolomite is mixed with impurities and, therefore, the molecular ratio of CaO to MgO is not exactly one-to-one.

As previously mentioned, the dolomite had undergone thermal metamorphism over an extensive area before it changed into kotoite-marble. If the original rock contained impurities like SiO_2 and Al_2O_3, these might combine first with MgO from the dolomite molecule, such minerals as forsterite, spinel, calcite, etc. would form, and the remaining MgO in the mineral would form crystalline dolomite. If kotoitization took place after that, the mineral dolomite which remained in the original rock would change into kotoite, and the kotoite content of the resultant would be less than that of "pure" kotoite-marble. Therefore, the value for B_2O_3 should also be less than 14.19%, the amount thought to be contained in "pure" kotoite-marble. In many cases, the ratio of CaO to MgO in natural dolomite is more or less larger than one-to-one. Since kotoite content, and therefore the B_2O_3 content, will become less than those of "pure" kotoite-marble, 14.19% may be said to be the maximum value for B_2O_3 that kotoite marble can possess. Although it is not clear in what state B_2O_3 was supplied, it is very possible that materials like B, F, and Cl emanated from the magma and migrated into the surrounding rocks when the volatile matter—especially those elements mentioned above—was concentrated in the residual magma during the pegmatitic to pneumatolytic stages of the consolidation of granite magma. Many contact minerals or contact deposits are thought to have been formed in such a manner. If the surrounding rock was dolomite and the magmatic emanation was rich in B_2O_3, the formation of kotoite-marble from dolomite logically resulted in kotoitization.

SiO_2, K_2O, and other metallic elements are often contained also in the magmatic emanation and form the Holkol gold-copper-bearing diopside skarn. If the original dolomite is almost pure, the resulting kotoite-marble will also be almost pure, but if it contains a small amount of SiO_2, Al_2O_3, etc., forsterite-spinel-bearing kotoite-marble will be formed. When the original rock is somewhat rich in iron, ludwigite is found in place of kotoite and gives rise to ludwigite-bearing kotoite-marble. If the original rock is much richer in iron, or if the rock is supplied with excessive iron in addition to B_2O_3, kotoite will not be found in the rock, and magnetite and ludwigite are present instead (Geijer, 1928, 1939). This means that kotoite and magnetite cannot occur in association with each other.

Summary

1. In 1930–32, while studying the geology and ore deposits of Holkol mine in Suan, a gold mining district in Korea, the writer noticed the occurrence of a very fine granular mineral in the country rock of the deposit; and later the writer proved it to be a new mineral which has a chemical composition of $Mg_3B_2O_6$, and which had never before been found in nature. He named it kotoite in memory of Professor Bunjirō Kotō. Almost simultaneously, the writer recognized that an identical mineral is contained in the szaibelyite-bearing rock from Rézbénya in Transylvania in the Balkans.

2. Kotoite has the following properties:

Chemical formula: $Mg_3B_2O_6$

Chemical composition of the Holkol kotoite: SiO_2=1.32%, Al_2O_3=0.26%, Fe_2O_3=0.20%, MgO=62.78%, FeO=0.61%, CaO=0.18%, B_2O_3=35.20%, H_2O=0.05%, Total=100.60%; Theoretical value:

$MgO=63.46\%$, $B_2O_3=36.54\%$

Form: Orthorhombic system

Mode of occurrence: The mineral is found in a kind of marble (kotoite-marble) which was formed from dolomite by pneumatolytic replacement. It always occurs as fine granular microscopic crystals, hardly distinguishable by the naked eye.

Physical properties: Cleavage is perfect and parallel to (110); lamellar twinning is produced upon striking the crystal, and the plane of this twinning is assumed to be on (101); H=6.5; D=3.11 (Holkol specimen)

Optical properties: Colorless; refractive index, $\alpha=1.652$, $\beta=1.653$, $\gamma=1.673$, $\gamma-\alpha=0.021$ (Holkol specimen), $(+)2V=21°$, $r>v$, optical plane parallel to (010), and z=c

Physicochemical properties: Can hardly be fused by means of a blowpipe. The melting point is approximately 1,340° C; the value has not been determined exactly because of the presence of volatile matter such as B_2O_3. The mineral is relatively unstable when it is placed in hydrothermal conditions or exposed to air, and it alters to fibrous borate minerals. The mineral is almost insoluble in cold hydrochloric acid, but is easily soluble in warm concentrated acid. An artificial crystal can easily be obtained by direct fusion of MgO and B_2O_3 when mixed in fixed proportion in a platinum crucible.

Properties studied by X-ray: The following values were obtained by measuring the artificial crystal.

$a_0=5.41$Å, $b_0=8.42$Å, $c_0=4.51$Å (measured by WATANABE)

$a_0=5{,}385$Å, $b_0=8.40$Å, $c_0=4.48/$Å (measured by SADANAGA)

$a_0 : b_0 : c_0=0.642 : 1 : 0.536$ (WATANABE)

$a : b : c=0.6412 : 1 : 0.5494$ (Artificial crystal: measured by MALLARD)

$Z=2$, D_{2h}^{12}—Pnmn.

3. Kotoite-marble occurs as the country rock of the Holkol deposit, and the main gold-copper ore (or skarn consisting of diopside, clinohumite, phlogopite, etc.) is found in this marble. Therefore, the occurrence of this rock indicates the presence of gold-copper ore, and the rock plays an important role during the prospecting of the ore body.

4. Kotoite-marble consists chiefly of kotoite and calcite; the former makes up 25–35 per cent of the weight of the rock, and the latter about 60 per cent. A few accessory minerals, ludwigite, suanite, forsterite, and spinel are also contained. The chemical composition of this rock is as follows:

The principal components are $B_2O_3=10$–12%, $CaO=32$–35%, $MgO=20$–23%, and $CO_2=26$–28%; the minor components are $SiO_2=2$–4%, $Al_2O_3=0.2$–0.5%, and $Fe_2O_3=0.3$–0.4%. The molecular ratio of CaO to MgO is usually within the limits of 1.0–1.2.

5. Suanite is a new mineral which has the following composition:

$2MgO \cdot B_2O_3$.

6. A large amount of kotoite-marble occurs in the Holkol mine; it was mined as the boron ore by which borax was produced.

7. Kotoite has never been found alone, but always in association with the calcite that composes kotoite-marble; it occurs as very fine grains. Kotoite-marble is found surrounded by crystalline dolomite which suggests that the rock was formed from the latter by acquiring a supply of B_2O_3. As the kotoite has been formed from the mineral dolomite $CaCO_3 \cdot MgCO_3$ by replacing the CO_2 of $MgCO_3$ and by leaving $CaCO_3$ as calcite, the ratio of kotoite to calcite in the kotoite-marble is nearly constant.

8. Kotoite-marble is a rock which has been derived from dolomite by the introduction of volatile materials such as B, F, and Cl which were concentrated in the residual magma and emanated into the surrounding dolomite at a later stage of consolidation of the granite in the Suan district.

Additional note: In 1956 the third occurrence of kotoite was discovered by the author and A. KATO in Kamineichi dolomite quarry, Miyako, Iwate Prefecture, Japan. Some other occurrences in USSR and USA have recently been reported.

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MANCHURIA

A Summary of the Columnar Sections in Manchuria

Riuji Endo

More than twenty Japanese stratigraphers and paleontologists including Teiichi Kobayashi, Rinji Saito, Gijin Morita, Tokio Shikama, Mitsuo Noda, Shōichi Nishida, Shinya Minakawa, Rikizo Imaizumi, and the writer have been actively engaged in a geological survey of Manchuria for the past fifteen years. Some of the results of this work have already been published, principally in the Bulletin of the Geological Survey of Manchoukuo, the Memoirs of the Geological Survey of Manchoukuo, the Bulletin of the Central Museum of Manchoukuo, and the Bulletin of the Geological Society of Manchoukuo. However, a great deal of the most recent work has not yet been published. Moreover, almost all of the above bulletins have been burned or are so widely scattered that fairly complete runs are almost impossible to locate. Therefore, the writer desires to summarize the research of Japanese geologists on the columnar sections in Manchuria. It is believed that this may be of help to Japanese geologists and to others who may not be able to go to Manchuria for geological work.

A distinct stratigraphical boundary is located along the line which connects Cheng-te, Fu-hsin, Tieh-ling, Mo-chiang and An-tu in Manchuria and divides this vast area geologically into northern and southern districts.

The distribution of geological formations in the pre-Lower Jurassic Period is completely different on each side of the boundary line while those of the post-Lower Jurassic Period are quite similar to each other.

Granite, which was intruded in the form of batholiths in the Upper Palaeozoic, is the principal rock north of the boundary line. Therefore, as will be seen in the columnar section, none of the formations from Archaeozoic to Ordovician in age found in the northern area while those of the Devonian Period are not entirely developed in the southern district. Moreover, the depositional conditions under which the Upper Palaeozoic formations were laid down are entirely different in the northern and southern districts.

At the present time, it is not known whether the Triassic formation in the northern district is developed or not.

The terrestrial deposits of the Lower Jurassic to the Holocene are about the same in the northern and southern areas.

The summarized columnar sections based on the latest data for both northern and southern Manchuria are as follows:

A. Columnar Section of Southern Manchuria

Quaternary Period
Alluvial Series
Sand, gravel, and clay

Pleistocene Series
Ku-hsiang-tun Stage

Although the type locality of the present formation is the Wa-pen-yao-ho River, a tributary of the Wen-chuan River, near Harbin, North Manchuria, it occurs also in many valleys of the Jehol mountainland and Liao-ning Province.

The formation consists of loess, yellow clays and red clays. *Rhinoceros-Elephas* fauna is found in the loess. Thickness about 30 m.

Tertiary Period
Pliocene Series (Not developed)
Miocene Series (Not developed)
Oligocene Series
Eocene Series
Fu-shun Series (Eo-Oligocene?)

The Fu-shun Series is found in the entire Fu-shun coal field in Liao-ning Province and extends 20 km eastward from the eastern border of the coal field. The series consists of green shale, oil shale, coal, tuffaceous sandstone; the following well preserved plant fossils are found in the lower part of the oil shale:

Sequoia chinensis ENDO
Glyptostrobus europaeus (BR.) HEER
Fagus feroniae UNG.
Alnus kefersteini GOEPP.
Querqus drymeja UNG.
Carpinus grandis UNG.

The coal includes a great deal of amber containing excellently preserved insect remains such as *Cecidomiya, Exetastes, Componotus, Cainoblattiopsis*. Sheets of basalt appear between the main and the lower coal-bearing series. The series is about 900 m thick.

Cretaceous Period

Upper Series

Cheng-te conglomerate

The present formation crops out in the vicinities of Jehol and Luang-ping District, and consists of reddish-ochre conglomerate and coarse-grained sandstone. Thickness probably exceeds 300 m.

Middle Series

Lower Series

Sun-chia-wan Series

This formation directly overlies the coal-bearing series at the Fu-hsin coal fields, 140 km west of Hsinyang. Characterized by *Corbicula anderssoni* GRABAU and *Campeloma tani* GRABAU in its upper portion, by *Estheria middendorfi* MULLER in the middle portion, and tuffaceous sandstone of variegated color in the lower portion, usually underlain by a thick heavy-bedded conglomerate at the base. Thickness 800–1,200 m.

Miyanohara Series (Upper-Lower?)

The series is distributed extensively along the south side of the Tai-tzu-ho River, a tributary of the Liao-ho River from Wu-lung on the east to Tuan-shan-tzu on the west, with the Miyanohara station as its center. It consists of green-grayish coarse-grained sandstone, variegated shale, and white conglomerate with large pebbles. Thickness about 2,800 m.±

Flora: *Salvinia* sp.

Pinoxylon dakotense KNOWLTON

Protocedroxylon araucarioides GOTHAN

Jurassic Period

Upper Series

Fu-hsin Series

S. OISHI and G. MORITA called the Upper Jurassic formation of the South Manchurian type the Fu-hsin series. Typically developed in the Fu-hsin coal field, it consists of cross-bedded coarse sandstone, pale grayish shale, white tuffaceous fine-grained sandstone and conglomerate; its middle part contains first and second groups of coal seams. Several horizons of shale yield very well preserved fossils listed below. Thickness about 2,200 m.

Fossils:

Coniopteris hymenophylloides (BROGN.)

Ginkgoites cf. *sibirica* (HEER)

Baiera cf. *gracilis* (BUNB.)
Elatocladus manchurica (YOK.)
Phoenicopsis speciosa HEER
P. angustifolia HEER
Pityophyllum cf. *lindstroemi* NATH.
Sphenopteris goepperti DUNKER, etc.

Tsao-tzu-shan Stage

The present formation crops out on the northwestern slope of the 541-meter hill between Tsao-tzu-shan and Chiu-kang village in the eastern part of the Jehol mountainland. It consists of pale white limestone, pale gray to pale green shale, and thick conglomerates. Thickness about 250 m.

Fossils:

Manchurochelys manchoukuoensis ENDO & SHIKAMA
Yabeinosaurus tenuis ENDO & SHIKAMA
Estheria sp., *Lycoptera* sp.
Ephemeropsis trisetalis EICHWALD

Middle Series?

Lower Series?

Triassic Period

Chiu-fo-tang Series (Rhaeto-Lias?)

The Chiu-fo-tang Series is distributed rather extensively in the following areas: Chien-chan, Ling-nan, Ning-cheng, Feng-ning, Yi-hsien, Hei-chengtze and Chao-yang in the Jehol mountainland. Alternation of thin-bedded, pale gray to pale green shale and grayish white sandstone, tuffaceous conglomerates containing thin seams of oil shales. Thickness 620 m.

Fossils:

Monjurosuchus splendens ENDO
Rhynchosaurus orientalis ENDO & SHIKAMA
Lycoptera davidi (SAUVAGE)
Astacus licenti v. STRAELEN
Sinoblatta laiyangensis PING
Czenkanowskia rigida HEER
Schizolepsis jeholensis YABE & S. ENDO

Upper Series

Pei-piao Series (Noric—Rhaetic)

The Pei-piao Series is typically found in the Pei-piao coal field, 180 km ssw of Hsin-yang. It occurs also in other coal fields in Jehol Province such as

Chiao-yang, Wei-chang, Ying-hua and Nan-piao. Gray to black shale, sandstone, conglomerate, and pyroclastic rocks which contain many coal seams. Gray shale of the upper part yields insect remains such as *Mesoblattina sinica* PING and *Sinoperla abdorminalis* PING. The following, well preserved plant fossils are found in several horizons in this shale and the sandy shale complex. Thickness about 800–1,000 m.

Fossils:

Neocalamites hoerensis (SCHIMPER)
Cladophlebis haiburnensis (L. et H.)
C. denticulata (BR.)
Phoenicopsis cf. *manchuriensis* YABE & OISHI
Czekanowskia rigida HEER
Podozamites lanceolatus (L. et H.)
Ginkgoites sibirica (HEER)

Middle Series?
Lower Series?

Tai-tzu-ho System
Permian Period
Upper Series
Tsai-chia Series (Zechstein-Trias?)

Its type locality is Tsai-chia-tun along the Tai-tzu-ho River, about 4 km south of Pen-chi-hu. Its total thickness is estimated to be about 440 m. This series does not crop out in the southern part of the Liao-tung Peninsula but it is especially well developed in the vicinity of Pen-hsi-hu in the Tai-tzu-ho region. Variegated shale and thick complex of quartz sandstones. Thickness 480 m. The present series may correspond to the Gobangsan Series in Korea and the Shihhotze Series in North China.

Fossils:

Annularia crassiuscula HALLE
Cladophlebis Nystroemi HALLE
Gigantopteris nicotinaefolia SCHENK
Pecopteris samaropsis OGURA

The last listed species is a very remarkable one in that a seed of *Samaropsis affinis* type distinctly adheres to a frond of *Pecopteris arborescens*. The present specimen was collected by the writer in 1945 and described by Y. OGURA in a paper entitled "A new example of seed-bearing Pteridosperms from Manchuria" in the Proceedings of the Japan Academy (XXIV: 10) in 1948.

Lower Series
Liu-tang Series (Rotliegendes)

The type locality is the Liu-tang Mine, 2.7 km west of Pen-hsi-hu. This series does not crop out in the southern part of the Liao-tung Peninsula except at Fu-chou where its lower part alone is developed. However, its lithic character and fossils may be almost identical with those of the Tai-tzu-ho district. Alternation of gray to black sandstone and shales with many coal seams. Fire-clays and aluminuous shales are contained in the upper part of this series. Many marine fossils, *Chonetes latesinuata* SCHELLWIEN, *Productus taiyuanfuensis* GRABAU, *Aviculopecten manchuriensis* CHAO, and *Lima striatiplicata* CHAO, as well as many species of corals and sea-urchins are found in the dark-grayish shale from the lower part of the series at Niu-sin-tai coal field. This represents the last marine transgression in Manchuria. Moreover, many well preserved plant fossils are contained in several horizons throughout the series. Thickness about 55 m.

Fossils:

Pecopteris hirta HALLE
Cladophlebis Nystroemi HALLE
Sphenophyllum oblongifolium (G. & K.)
Calamites Suckowi (BRONGN.)
Annularia orientalis KAWASAKI
Lepidodendron oculis-felis (ABB.)
Stigmalia ficoides (GERM.)
Taeniopteris multinervis WELSS.
T. Schenkii STERZEL

Lowermost Series

Huangchi Series (Sakmarian)

The type locality of the Huang-chi Series is Huang-chi-kou, about 3 km west of Pen-hsi-hu; both lithic and faunal characteristics of the Tai-tzu-ho district and the southern part of the Liao-tung Peninsula are rather remarkably different in that no limestone strata are intercalated in the former while the latter contains many layers. There is alternation of pale black to gray sandstone and shale containing many coal seams. A good fire clay is found in the basal part. Several lenticular limestones containing *Pseudoschwagerina globosa* (SCHWAGER), *Schwagerina expansa* (LEE), *Productus taiyuanfuensis* GRABAU are intercalated in this series. About the same flora as that of the Liu-tang Series is found throughout this series. Thickness 90–100 m.

Carboniferous Period

Upper Series?

Middle Series

Pen-hsi-hu Series (Moscovian)

In general, the Pen-hsi-hu Series rests unconformably parallel upon the Ssu-yen Series of the Middle Ordovician and belongs to the Middle Carboniferous Moscovian. It consists mainly of the alternation of shale and sandstone intercalated with several layers of limestone. The predominant color is a remarkable reddish ochre. The reddish-ochre shale is well developed in the basal part of this series. This series often contains aluminous shale, fire clay, and thin coal measures. Nodular limonite ores are often contained in the reddish-ochre aluminous shales in the basal part. In the Tai-tzu-ho district, black to grayish lenticular cherts are sometimes found in the upper part of the series. Its total thickness is estimated at 70–90 m in the southern part of the Liaotung Peninsula and about 120 m in the Tai-tzu-ho district.

Fossils:

Fusulinella bocki MOLLER
F. praesimplex (LEE)
Fusulina cylindrica FISHER & DEWELPHEER
Spirifer mosquensis FISHER
S. jigulensis STUCK
Squamularia asiatica CHAO
Arachnastraea manchurica YABE & HAYASAKA
Syringopora reticulata GOLDFUSS
Chaetetes asiatica YABE & HAYASAKA

Lower Series?

Devonian Period (Not developed)
Silurian Period (Not developed)
Ordovician Period
Upper Series (Not developed)
Middle Series
Ssu-yen Series

Type locality is Ssu-yen-kou, just north of the Pen-hsi-hu Colliery, Liaoning Province. This series is relatively widely distributed in the Tai-tzu-ho, Pe-chi-li, Kuan-tung and Hun-chiang areas and also crops out sporadically in Jehol Province.

Gray to light gray banded limestone, dolomitic limestone with intraformational conglomerates. A remarkable *Stromatocerium* reef is found in the lower part. Several horizons of the banded limestone yield well preserved Actinoceroid fauna which are comparable to the Black River fauna in the United States. Thickness about 50–70 m.

Fossils:

Armenoceras richthofeni (FRECH)
A. yabei ENDO
A. orientale ENDO

A. elongatum ENDO
Polydesmia elegans (ENDO)
Nybyoceras foerstei ENDO
Sactoceras kobayashii ENDO
Maclurites bigsbyi HALL
M. nitida (ULRICH & SCOFIELD)

Lower Series

Kang-yao Series

The Kang-yao series is found in association with the overlying Ssu-yen Series throughout South Manchuria. There are notable fossil localities of this series in the vicinity of Shang-kan-yao and the northern foot of San-ling hill near the Fu-chou Colliery.

Gray to dark gray banded limestones, occasionally intercalated with sandy limestone and intraformational conglomerates. Thickness about 140 m.

Fossils:

Armenoceras tani (GRABAU)
Lophospira aojii ENDO
L. producta pagodai ENDO
Eotomaria barbouri GRABAU
E. ulrichi ENDO
Ctenodonta takahashii ENDO
Anthaspidella? radiata ENDO

Lowermost Series

Wu-ting Series

The Wu-ting Series is widely distributed along the course of the Tai-tzu-ho River, on the coast of the Gulf of Pe-chi-li, and in the Kuan-tung district. It also crops out sporadically in Jehol Province. Gray to dark arenaceous limestone, with several intraformational conglomerate. Thickness about 90 m.

Fossils:

Orthis nipponica KOBAYASHI
Raphistoma cf. *aequilaterum* KOKEN
Wutingia rectangulusa ENDO
Hystriculus granosus (ENDO)
Asaphellus orientalis ENDO
Basiliella wusungensis ENDO
B. spiculum (ENDO)

San-tao Series

The San-tao Series is widely distributed along the course of the Tai-tzu-ho River, on the coast of the Gulf of Pe-chi-li, and in the Kuan-tung district. It also crops out sporadically in Jehol Province. Arenaceous limestone with intraformational conglomerate, and shaly limestone in the lower part. Thickness about 55 m.

Fossils:

Calathium frechi ENDO
Anthaspidella? radiata ENDO
Piloceras manchuriensis ENDO
Penhsioceras fusiformae ENDO
Cameroceras cf. *styliforme* GRABAU

Wan-wan Series

The Wan-wan Series is widely distributed along the course of the Tai-tzu-ho River, on the coast of the Gulf of Pe-chi-li and in the Kuan-tung district. Gray massive limestone, calcareous shale with intraformational conglomerate and a thick complex of *Collenia* limestone in the lower part. Calcareous shale complex yields rather good trilobites and primitive cephalopods as well as well preserved Riberidae.

Fossils:

Tellerina orientalis RESSER & ENDO
Saukia ulrichi RESSER & ENDO
Calvinella striata RESSER & ENDO
Wanwanoceras peculiare KOBAYASHI
Ectenoceras ruedemanni KOBAYASHI
Eremoceras arcuata RESSER & ENDO
Wanwania cambrica KOBAYASHI
Wanwanella striata KOBAYASHI
Wanwanoides trigonalis KOBAYASHI
Ribeiria manchurica KOBAYASHI
Eopteria asiatica KOBAYASHI

Other primitive cephalopod specimens *Ellesmeroceras elongatum* KOBAYASHI, *Ectenoceras curvatum* KOBAYASHI, and *Multicameroceras multicameratum* KOBAYASHI are also found in the *Collenia* limestone of the basal part.

Cambrian Period

Upper Series (Chau-mi-tian Series)

Yen-chou Stage

In Kuan-tung district the Yen-chou stage crops out in a small area near the middle of Kan-tao-tzu Island.

On the coast of the Gulf of Pe-chi-li, it crops out on the summits of Tai-shan and Pai-shan mountains.

In the Liao-yang—Yen-tai area, it occurs on the cliffs near Yen-chou-cheng, where it extends both southwest and northeast.

In the neighborhood of Pen-hsi-hu it occurs in the valley of Huo-lien-chai. It is distributed also near Niu-hsin-tai and Hsiao-shih Collieries.

The Yen-chou stage occurs sporadically in several areas of eastern Jehol.

Gray limestone with intraformational conglomerate and thin beds of yellowish shale. The following three fossil zones are found in this stage. Thickness about 100 m.

Fossils:

Dictyella zone
- *Prosaukia? orientalis* Kobayashi
- *Pagodia divergens* Endo
- *Dictyella trigonalis* Kobayashi
- *D. wuhuensis* Kobayashi
- *Eoorthis pagodiformis* Kobayashi
- *Acrotreta kaoliensis* Endo

Pagodia buda zone
- *Huenella sexplicata* Kobayashi
- *Pagodia buda* Resser & Endo
- *P. trigonalis* Endo
- *Quadraticephalus calchas* (Walcott)
- *Saukia? orientalis* Resser & Endo
- *Ptychaspis sphaerica* Resser & Endo
- *Koldinioidia aspinosa* Kobayashi
- *Parakoldinioidia typicalis* Endo

Tsinania zone
- *Tsinania canens* Walcott
- *T. longicephala* Resser & Endo
- *Pagodia buda* Resser & Endo
- *Tellerina sulcatifera* Endo
- *Saukia? orientalis* Resser & Endo
- *Kaolishania pustulosa* Sun
- *Ptychaspis sphaerica* Resser & Endo
- *Parakoldinioidia typicalis* Endo
- *Asioptychaspis ceto* (Walcott)
- *Agnostus hoiformis* Kobayashi
- *Pseudagnostus solus* Endo
- *Paramansuyia planilimbata* Endo

Daizan Stage

The type of this stage is found on the northern slope of Dai-tzu hill, 1.6 km southeast of Chin-chia-cheng-tzu near the coast of the Gulf of Pe-chi-li. In addition to the type locality, the Daitzu Series has been recognized at Tan-shih-ling, 3.2 km southeast of the Yen-tai Colliery, and San-fan-la-tzu-shan on the eastern rim of Niu-hsin-tai Basin.

Black to gray limestone with intraformational conglomerate. Thickness about 25 m. *Paramansuyella granulosa* zone and *Paramansuyella puteata* zone are contained in this stage.

Fossils:

Paramansuyella granulosa zone

- *Paramansuyella granulosa* ENDO
- *P. planilimbata* ENDO
- *Mansuyella tokunagai* (KOBAYASHI)
- *Agnostus hoiformis* KOBAYASHI
- *Pseudagnostus cyclopygeformis* SUN
- *Crepicephalus chinchiaensis* ENDO
- *Hyolithes paishanensis* ENDO
- *Palaeostrophia orthia* (WALCOTT)
- *Acrotreta kaoliensis* ENDO

Paramansuyella puteata zone

- *Paramansuyella glabra* ENDO
- *P. puteata* ENDO
- *Maladioidella splendens* ENDO
- *M. convexolimbata* ENDO
- *Eymekops rectangularis* ENDO
- *Obolus sankiensis* KÔBAYASHI

Pai-shan Stage

The type locality of the Pai-shan stage is found on the northern slope of Pai-shan and Dai-shan near Chin-chia-cheng-tzu on the coast of the Gulf of Pe-chi-li. It occurs also in several comparatively small areas in Kuan-tung district. In the Liao-yang—Yen-tai area this formation crops out on the northern lower slope of Tang-shih-ling-shan.

Alternation of black, compact limestone and grayish, sandy limestone with quite a few intraformational conglomerates and pale yellowish shale. Thickness about 40 m. *Chuangia transversalis* and *Chuangia batia* as well as *Prochuangia* zones are found in this stage.

Chuangia transversalis zone

Fossils:

- *Billingsella simplex* RESSER & ENDO
- *Acrotreta paiensis* ENDO
- *Chuangia batia* (WALCOTT)

C. tolli Resser & Endo
Agnostus hoiformis Kobayashi
Pseudagnostus cyclopygeformis (Sun)
Crepicephalus orientalis Endo
Maladioides asiaticus Kobayashi
Kingstonia paichiaensis Kobayashi
Pagodia trisulcata Endo

Prochuangia zone

Fossils:

Prochuangia imamurai Endo
Manchurocephalus deprati (Mansuy)

Middle Series (Chang-hia Series)

Ku-shan Stage

The type locality of the Ku-shan stage is found in Chang-hia district, Shantung. In Manchuria, it is developed most typically in the area adjacent to the Gulf of Pe-chi-li. It is also found in both Kuan-tung and Tai-tzu-ho districts but becomes very thin there and in several places cannot be identified without careful examination.

Compact, dove-colored limestone with cherty matter, and dark-greenish, sandy shale as well as yellowish shale. The latter predominates in the lower part. Five fossil zones are contained in this stage. Thickness 20–60 m.

Blackwelderia longispina zone

Fossils:

Blackwelderia longispina Resser & Endo
Lorenzella ogurai Resser & Endo

Blackwelderia cornuta zone

Fossils:

Blackwelderia? cornuta Endo
B. granosa Endo
Teiniston alcon (Walcott)

Drepanura premesnili zone

Fossils:

Drepanura premesnili Bergeron
D. pusilla Resser & Endo
D. ketteleri Monke
Agnostus douvillei Bergeron
Liostracina krausei Monke
Shantungia spinifera Walcott
Damesella manchuriensis Resser & Endo
Stephanocare richthofeni Monke
Teiniston truncatus Endo

Damesella paronai (AIRAGHI)
Blackwelderia longispina RESSER & ENDO
Lorenzella rotundata RESSER & ENDO

Lorenzella-Lingulella zone

Fossils:

Lingulella hsiensis RESSER & ENDO
Obolella tschanghsingensis ENDO
Lorenzella ogurai RESSER & ENDO
Damesella damesi RESSER & ENDO
Blackwelderia spectabilis RESSER & ENDO

Koptura lisani zone

Fossils:

Lingulella tsuchidai ENDO
Koptura lisani (WALCOTT)
Damesella damesi RESSER & ENDO
D. latelimbata ENDO
Blackwelderia spectabilis RESSER & ENDO
Damesella paronai (AIRAGHI)
Fengtienia peculiaris ENDO

Taitzu Stage

The type locality of this stage is loated on the Pao-ching Ridge along the Tai-tzu-ho River. The Tai-tzu stage forms comparatively high hills and ridges throughout South Manchuria.

Ping-shan Ridge, La-chu-shan, Hsi-tai-shan and Chi-ting-shan in the Kuantung district; Dai-shan and Pai-shan on the coast of the Gulf of Pe-chi-li; Pao-chin Ridge, Iwayama and Wo-lung Ridge in the Tai-tzu-ho area are representative ridges consisted of this stage.

Alternation of gray to black oolitic limestone and compact limestone. The stage contains four fossil zones. *Dorypyge richthofeni* is the most characteristic species. Thickness 80–120 m.

Damesella-Teiniston zone

Fossils:

Agnostus damesi RESSER & ENDO
Solenoparia tersa ENDO
Damesella conica RESSER & ENDO
Teiniston lanciforme ENDO
Aojia reflexa ENDO
Paishania parallela ENDO

Amphoton zone

Fossils:

Manchuriella convexa (ENDO)

Amphoton deois (WALCOTT)
Elrathia conoidea (WALCOTT)
Aojia spinosa RESSER & ENDO
Solenoparia luna ENDO
S. hemicycla RESSER & ENDO
S. liaoyangensis ENDO
Anomocarella deflecta ENDO
A. orientalis ENDO
Dorypyge ricthofeni DAMES
Proasaphiscus ephori (WALCOTT)

Crepicephalina zone

Fossils:

Helcinella rugosa orientalis (WALCOTT)
Crepicephalina mukdensis RESSER & ENDO
C. quadrata RESSER & ENDO
C. pergranosa RESSER & ENDO
Anomocarella tumida ENDO
Aojia spinosa RESSER & ENDO
A. divergens ENDO
Elrathia taitzuensis ENDO
Drypyge richthofeni DAMES
Eymekops quadrilateralis ENDO
Solenoparia planifrons RESSER & ENDO
S. sobyosiensis ENDO
S. triangulata RESSER & ENDO

Anomocarella-Manchuriella-Ptychoparia zone

Fossils:

Taitzuia liaotungensis ENDO
T. granulosa ENDO
Proasaphiscus quadraticaudatus ENDO
Dorypyge richthofeni DAMES
Manchuriella granulosa ENDO
Nisusia concentrica RESSER & ENDO

Tang-shih Stage

The type locality occurs on the northeastern slope of Tang-shih-ling, 3.2 km southeast of Yen-tai Colliery, north of the Tai-tzu-ho River. This stage crops out extensively throughout the Kuan-tung, Pe-chi-li, and Tai-tzu-ho areas. It is thickest in the Kuan-tung district and gradually thins toward the north; the Tang-shih is distributed also in the eastern part of Jehol Province. Alternation of pale yellowish-brown shale and brownish, sandy shale with some reddish shale and lenticular oolitic limestone intercalated. Thickness about 25 m.

The state of preservation of the fossils in this stage is probably better than that of any of the other older formation in Manchuria. *Bailiella ulrichi* and *Proasaphiscus yabei* zones are included in this stage.

Bailiella ulrichi zone

Fossils:

Acrothele eryx (Walcott)
Bailiella ulrichi Resser & Endo

Proasaphiscus yabei zone

Fossils:

Acrothele eryx (Walcott)
Hyolithes cariniferus Resser & Endo
Proasaphiscus yabei Resser & Endo
Asaphiscus walcotti Resser & Endo

Lower Series (Man-tou Series)

Shih-chiao Stage

The type locality is on the low hill directly east of Shih-chiao-tzu Station on the An-tung—Hsin-yang Railroad Line. The present stage has, as far as is known, the same distribution as the underlying Misaki stage, with which it is closely associated in all sections of the Kuan-tung, Liao-yang—Yen-tai, and Pen-hsi-hu areas. It occurs on the coast of the Gulf of Pe-chi-li, namely, on Chang-ling-shan, 3.2 km east of Chin-chia-cheng-tzu, and on the southern slope of Chu-tzu-shan directly east of the same village. This stage is distributed rather extensively in the eastern part of Jehol Province.

Reddish-purple, micaceous shale and pale greenish shale with pale reddish lenticular limestone. Thickness 50–110 m.

Fossils:

Wimanella taei Resser & Endo
Hyolithes kuantungensis Resser & Endo
Ptychoparia orientalis Resser & Endo

Misaki Stage

The type locality of the Misaki stage is located on the southwestern slope of the 74 m hill, 1.6 km southwest of San-shih-li-pu, and on the northern slope of nearby Misaki-yama, slightly north of Chin-chou, Kuan-tung district.

The upper limit of the stage is not well defined in any area because there is transition into similar shales of the Shih-chiao stage. The Misaki stage crops out throughout South Manchuria wherever the Cambrian system occurs.

Reddish purple micaceous shale with lenticular pale reddish compact and oolitic limestone. Pale reddish compact banded limestone is found in the basal part.

The lenticular limestones are often composed of *Girvanella* remains. Several horizons of reddish shale and banded limestone yield rather well preserved specimens of *Redlichia chinensis* WALCOTT, *Cheiruroides orientalis* RESSER & ENDO, and *Lingulella yabei* RESSER & ENDO. Thickness about 90–200 m.

Proterozoic (Sinian)

Neo-Proterozoic

S. P'yongan-Liaotung (Heinan-Ryoto) type of the Sinian (type I)[1)]

This consists of the following (in descending order):

Series	Stage	Thickness
Nan-shan series	Nan-shan stage: almost entirely slate, interbedded with quartzite and limestone: thickness	400–800 m
	Ma-chia-tung stage: siliceous limestone: thickness	50–200 m
	Shih-san-li-t'ai stage: *Collenia* limestone: thickness	50–150 m
	Unconformity	
Kuan-tung series	Ying-cheng-tan stage; black limestone: thickness	370–400 m
	Onoda stage: platy limestone containing *Collenia:* thickness	270–400 m
	Kan-ching-tzu stage: dolomite and limestone containing *Collenia:* thickness	450–700 m
	Nan-kuan-ling stage: limestone, lower part contains impure limestone: thickness	800–1,000 m
	Chang-ling-tzu stage: phyllitic slate, upper part contains limestone: thickness	?–700 m
	Conformable	
Ta-ho-shang-shan series	Lung-tou stage: white quartzite: thickness	150 m
	Ying-ke-shih stage: phyllitic limestone and calcareous phyllite: thickness	30–200 m
	Cha-kou stage: quartzite: thickness	1,000 m
	Lung-wan-tang stage: platy quartzite: thickness	800 m
	Wai-tou-shan stage: quartzite: thickness	500 m
	Huang-ni-chuan stage: calcareous and phyllitic slate	

1) MATSUSHITA, Susumu (1935); Mem. Ryojun Coll. Eng., Vol. VIII, No. 2.

The type locality is the southwestern part of the Liao-tung Peninsula covering Lu-shun, Ta-lien, and Chin-chou. The age is Neo-Proterozoic. It is unconformably overlain by the Lower Cambrian. Intruded by the granite of, or separated by mylonite from, the Liaotung system.

N. P'yongan-Taitzuho (Heihoku-Taisika) type of the Sinian (type II)[2)]

This type consists of the following (in descending order):

Wu-hsing-shan series	Chin-chia black limestone: limestone: thickness	200–400 m
	Kao-cha-tun shale and sandstone: calcareous shale and siliceous sandstone: thickness	800–1,000 m
	Conformable	
Hsi-ho series	Chiao-tou quartzite: quartaite, siliceous slate in alternation: thickness	220–750 m
	Nan-fen shale and marl: shale and marl: thickness	380–1,200 m
	Chiao-yu-tai quartzite: quartzite: thickness	80–200 m

"Pe-chi-li series" is an alternate name for Chin-chia black limestone. The Yung-ning sandstone in the vicinity of Fu-chou is partly contemporaneous to the Kao-chia-tun shale and sandstone, although the greater part of the Yung-ning sandstone belongs to the Lower Cambrian. The type locality is the Fu-chou area, and along the course of the Tai-tzu-ho. The age is Neo-Proterozoic. It underlies unconformably the Lower Cambrian and overlies unconformably the Kung-chiang-ling granite and older complex formations. The Wu-hsing-shan series is correlated with a part of the Kuan-tung series. The Hsi-ho series containing wind-faceted pebbles may be partly contemporaneous with the Torridonian sandstone of England.

Kung-chang-ling (Kyuchorei) granite

Cataclastic rock containing quartz, plagioclase (albite-oligoclase), microcline (20–25%), and a small amount of mica.

Hsiang-lu-shan granite and Hsiao-li-kuo granite are included in this granite. The type locality is near the An-shan Iron Mine. The age is Proterozoic. It is intruded into the Liaotung and the Huchen systems. It is unconformably overlain by the Sinian system. There are two ages of intrusion of the granite, corresponding to the Hsiang-lu-shan and the Hsiao-li-kuo granites.

An-shan (Anzan) series

This series consists of the following (in descending order):

[2)] Aoji, Otoji (1928); Proc. Imp. Acad., Vol. IV, No. 10.

An-shan series	Shu-shan beds	Tuffaceous sandstone and shale interbedded with quartz porphyry: thickness unknown
	An-shan series (Restricted)	Phyllites, schistose grits, quartzites, actinolite schists, and banded iron ore: thickness 350–500 m

The type locality is near the An-shan Mine. The age is Proterozoic. This series corresponds to a part of the Nu-chen system. It unconformably underlies the Hsi-ho series (Sinian) and overlies unconformably Tui-mien-shan granite. It is intruded by Kung-chang-ling granite, and may be contemporaneous to the Chi-tung group in North China. The present series is also distributed at Kung-chang-ling Iron Mine, near Chiao-tou (along the Mukden—Antung Railway Line).

Eo-Proterozoic

Tui-mien-shen (Taimonzan) granite

The rock is of leucocratic and cataclastic structure, composed almost wholly of feldspar and quartz, but containing 4–5% microcline. Accessory minerals are apatite and sphene.

The type locality is near the An-shan Iron Mine. The age is probably Eo-Proterozoic. This granite is probably intruded into the Liao-tung system and is also overlain unconformably by the Nu-chen system and the An-shan series. The Tui-mien-shen granite occurs also near Tieh-ling.

Liao-ho (Ryoga) system[3)]

This system represents the oldest metamorphosed rocks undoubtedly of sedimentary origin. Order of succession (descending):

a. Upper (Kai-ping Series): Consists chiefly of greenish mica phyllite and mica schist commonly containing sillimanite and staurolite: thickness 10,000–15,000 m.
b. Middle (Ta-shih-chiao Series): Consists chiefly of crystalline dolomite and limestone, in places containing *Collenia*-like fossils: thickness 4,000 m.
c. Lower: Biotite schist, two-mica schist, staurolite-biotite schist, quartz schist, and limestone. Probably 1,000 m thick.

The type locality is the northern part of Liao-tung Peninsula including Hai-cheng and Kai-ping districts. The age is probably Archaeozoic or Eo-Proterozoic. It is unconformably overlain by the Hsi-ho series (Sinian), and intruded by the Kung-chang-ling granite (Proterozoic). There is no place of direct contact in the field, and it is not known whether the Nu-chen and the Liao-tung systems are younger or older than the Liao-ho system. The lowest part is indistinct because of

3) SAITO, Rinji (1936); Bull. Geol. Inst. Manchukuo, No. 93.

the injection of granite. It may be correlated with the Wu-tai system of Shan-hsi, North China.

The Liaoho system is extensively distributed in a wide area along the course of the Yalu River in An-tung and Tung-pien-tao, especially near Lin-chiang-hsien.

Archaeozoic Era

Liaotung (Ryoto) system

This system consists of epidote-mica schist, epidote-mica granite gneiss, and a small amount of amphibolite. The Influence of an intrusion of aplite is great. All of the rocks are of igneous origin. The process of metamorphism is inferred as follows:

a. Basic igneous rocks (plutonic or volcanic).
b. Intrusion of intermediate igneous rock.
c. Intrusion of basalt dikes.
d. Metamorphism to epidote-mica gneiss, epidote-mica schist.
e. Intrusion of granitic magma (muscovitization, potash feldspar metasomatism) to form epidote-mica granite-gneiss (injection gneiss, permeation gneiss).
f. Intrusion of "Halleflinta".

The type locality is Ta-ho-shang-shan, 5 km east of Chin-chou, Kuan-tung-chou. Age is probably Archaeozoic. It is separated from the overlying Liao-ho system by mylonite and was thought by SAWATARI to be older than that system. The lower limit is indistinct owing to migmatization. It is distributed in the southern part of Liao-tung Peninsula covering Kuan-tung-chou, Ta-ku-shan, An-tung, etc.

B. Columnar section of Northern Manchuria

Quaternary Period

Alluvial Series

Sand, gravel and clay

Pleistocene Series

Ku-hsiang-tun Stage

Ku-hsiang-tun, a treasury of Diluvium fossils, is a village located along the Wen-chuan-ho, a tributary of Sung-hua-chiang, 5 km sw of the center of Harbin. The Diluvium series crops out along the Wen-chuan-ho River and its tributary the Wa-pen-yao-ho River. The Diluvium series, which forms the terrace group in the vicinity of Harbin, is estimated to be about 25 km. In the vicinity of Ku-hsiang-tun, its average thickness is about 10 m. It consists of a succession of clay, mud, sand, sandy clay, and other sediments, and it is one kind of flood-plain lacustrine deposit. It is different from the Ma-lan loess in that remarkable gravel beds are not found in it. The succession of the Ku-hsiang-tun stage is as follows:

Ku-hsiang-tun formation	Lower part: Bluish-gray to dark gray clay bed and sandy clay bed	2.8 m
	Upper part: Yellowish-gray argillaceous sand to sandy clay bed	10 m
Forming of terrace:	Dissection of the Wa-pen-yao-ho (Wa-pen-yao stage)	
Wen-chuan ho bed:	Black mud bed (1 m$\pm$average thickness)	
Forming of terrace:	Dissection of the Wen-chuan ho (Sung-hua-chiang stage)	

Fossils:

Rhinoceros antiquitatis BLUM.
Canis lupus L.
Hyaena ultima MATSUMOTO
Equus przewalskii POLLI.
Capreolus manchuricus LYD.
Bos primigenius BOJ.
Elephas primigenius BLUM.
Bison occidentalis LUCAS.
Djalainor man.

Tertiary Period
Pliocene Series
Wu-yun Stage

Wu-yun is located along the Hei-lung-chiang, 90 km SE of Hei-ho, Hei-lung-chiang Province and is opposite Innokenchefskaya, USSR. Wu-yun village, Wu-yun hsien is one of the river ports between Hei-ho and Chia-mu-ssu. The vicinity of Wu-yun is about 100 m above sea level. Hills of low relief, 280–290 m above sea level, are distributed in the southern part.

The distribution area of the Tertiary system near Wu-yun is divided into two localities, namely, the coastal district of the Hei-lung-chiang, and a distant area, 20 km south of the bank of the river.

The succession, in descending order, is as follows:

1. White arkose sandstone. Thickness about 30 m.
   It sometimes grades into conglomerate. The diameter of the pebbles is less than one cm. The present bed intercalates lenticular clay. Cross-bedding is developed. Carbonaceous and siliceous wood is contained along the bedding planes.
2. Coal measure 0.3–0.8 m
3. Coaly shale 0.2–0.3 m
4. Grayish-white arenaceous shale 20 m

Coal measures intercalate coarse sandstone(2), 0.1 m thick. Fragments of plant fossils are found in the coaly shale (3) and grayish-white arenaceous shale (4).

Miocene Series
Tomonsi (Tu-men-tzu) stage

Grayish-white tuff: thickness	10±m
Coarse sandy shale: thickness	100±m
Diatomaceous sandy clay: thickness	1.5–4m
Conglomeratic sandstone: thickness	10±m
Basal conglomerate: thickness	2m

This formation rests upon Paleozoic hornfels and schists, granites, and the Hunchun group: it is covered by Diluvium. The type locality is Tu-men-tzu, Chien-tao Province, Manchuria. Fossils of *Pinus*, (*Abies*), *Querqus*, *Tilia*, *Carpinus* and *Juglans*, are found in several horizons.

Oligocene Series
Hun-chun Stage

The Hun-chun stage is an extension of the Kainei Series in northeastern Korea and was deposited in the concave depressions on the bedrock of several localities on the west coast of the Tou-men River in eastern Manchuria.

Arkose sandstone and red to green tuffaceous shale, containing coal seams, are present. Thickness 600 m. The following listed plant fossils are found in several horizons.

Acer arcticum HEER
Betula Brogniarti ETT.
B. prisca ETT.
Fagus Antipofi HEER
Platanus cf. *aceroides* GOEPP.
Populus arctica HEER
Sequioa Langsdorfii BRONGN.

Pliocene?

Cretaceous Period
Upper Series?
Middle Series
Hua-shan Stage

The Hua-shan stage crops out along both sides of the Mu-ling River, showing anticrinorium in E-W extension and conglomerate containing many fossils of conifers. Coals and bethonite are found in the lower part. Thickness 1,500–2,400 m.

Fossils:

Equisetites sp.
Cladophlebis denticulata BRONGN.
Sphenopteris Goepperti DUNBER

Onychiopsis elongata BRONGN.
Baiera manchurica YABE & OISHI
Nilssonia sp.

——————— ? ———————

Lower Series

Ta-la-tzu Stage

The Ta-la-tzu stage is distributed in an area situated approximately midway between the Ho-lung graben near San-tao-kou and the Tu-shan-tzu graben NW of the former, in eastern Manchuria.

Alternations of yellowish-brown sandstone and shale with oil shale are present. Pale yellowish-gray conglomerate is developed at the base. Thickness 1,000 m. The interesting fauna of *Sphaerium chientaoense* SUZUKI, *Viviparus* (*Tulotomoides*) *talatzuensis* SUZUKI, *Bulimus* cf. *chobnokyi* (SCHLOSSER) and a fish fossil, *Manchurichthys uwatokoi* SAITO, are found in some horizons of shales.

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Chuan-tou Stage (Jura-Cretaceous Period)

The Chuan-tou stage is typically found near Kao-tai-tzu, east of Chuan-tou station on the main railroad between Ta-lien and Chang-chun. It is found northeastward along the railroad from Chuan-tou via Kai-ping, Chang-tu, Ssu-ping-kai, to Chang-chun and from the latter place to east of Harbin. Reddish-purple loose sandstone, sandy tuff, conglomeratic shale with the basal conglomerate are present. Thickness 500 m.

Fossils:

Onychiopsis elongata (GEYL.)
Sphenopteris Goepperti DUNKER
Baiera manchurica YABE & OISHI
Phoenicopsis speciosa HEER
Podozamites lanceolatus (L. & H.)
Chelonia sp.

Jurassic Period

Lung-ching Stage

The Lung-ching is always developed in association with the Ta-la-tzu stage; therefore, some geologists insist that the present formation may be included in the latter stage. Reddish-brown sandy shale, pyroclastic rocks and a basal conglomerate are present. Coal and oil shale are contained in some horizons, and *Onychiopsis elongata* (GEYLER), *Taeniopsis Uwatokoi* OISHI, *Pityophyllum Nordenskijoldi* (HEER) are found in this stage.

Upper Series

Mi-shan Stage (Toyama Stage)

The present stage occurs typically in the Mi-shan coal field in northeastern Manchuria and it is distributed also in such coal fields as Hu-li-kang, Hu-lung, and Chao-ho.

The present stage may be equivalent to the Toyama stage in the Hulunbuir district.

There is alternation of black to gray shale and sandstone as well as conglomerates in the basal part, usually containing quite a few coal seams. Thickness 100–250 m. Several horizons of shale yield the following fine plant fossils:

Todites Williamsoni (BRONGN.)
Cladophlebis denticulata (BRONGN.)
C. lobifolia (PHILLIPS)
C. browniana (DUNKER)
Coniopteris hymenophylloides (BRONGN.)
Sphenopteris goepperti (DUNKER)
Elatocladus manchurica (YOKOYAMA)
Podozamites lanceolatus (L. & H.)
Ginkgoites cf. *sibirica* (HEER)
Pityophyllum Nordenskijoldi (HEER)

Middle Series?
Lower Series?
Triassic Period?

The Mammo Group was named by T. KOBAYASHI in 1942. The term was applied to a series of Paleozoic formations extending from central and north Manchuria eastward to the maritime provinces of USSR. and westward at least as far as Mongolia. Other outcrops are known in northeastern Korea.

Upper group

Permian

Pyoksong formation

The present formation is distributed in the south of the Tou-man River, in the most northeastern part of Korea.

It consists of sandstone, shale, hornfels, conglomerate, clay slate, limestone, chlorite schist, mica schist, and hornblendite.

Fossils:

Productus sp.
Spirifer sp.
Pseudodoliolina sp.
Parafusulina sp.

Permo-Carboniferous

Tou-man stage

The present stage crops out in the Chien-tao district in the southeastern part of Manchuria. Gray clayslate, black shale, black phyllitic clayslate, grayish-green conglomerate, mica schists, and arenaceous hornfels are present. Thickness about 1,000 m.

Fossils:

Chonetoides chonetoides (CHAO)
Spirifer cf. *mooskhailensis* DAVIDSON
Polypora manchoukuoensis MINATO
Waagenophyllum indicum (WAAGEN & WENTZEL)
Linoproductus lineatus (WAAGEN)
Spiriferina cristata SCHLOTHEIM
Neoschwagerina cf. *margaritae* DEPRAT
Yabeina hayasakai OZAWA

Middle group.

Carboniferous Period

Kirin Stage

The Kirin stage occurs typically in the Kirin sheet area and it is sporadically distributed in several areas of North Manchuria.

Brecciated conglomerate, limestone, hornfels, agglomerates, black shale and pale greenish tuff are present. Thickness more than 2,500 m.

Fossils:

Lonsdaleia floriformis LONSD.
Auloclisia sp., *Siphonodendron* sp.
Gigantella cf. *latissimus* (SOWERBY)
Dibunophyllum sp.

These fossils are found in the lower part of the stage and indicate Dinantian and Visean ages.

Devonian Period.

Upper Series

Hei-tai Stage (Frasnian)

The present stage occurs at Hei-tai in Shinano village (former name), Mi-shan-hsien.

Calcareous sandstone, conglomeratic arkose sandstone, coarse-grained sandstons as well as alternation of black shale and fine-grained sandstone are present. Thickness is uncertain.

Fossils:

Plectospirifer grabaui YABE & SUGIYAMA
Atrypa aspera (SCHLOTHEIM)

Favosites multispinulosus YABE & SUGIYAMA

Middle Series

Ho-lung-men Stage (Eifelian)

The present stage is found at a place 41 km NE of Hou-lung-men on the North Manchurian plateau. Conglomerate, green limestone, black limestone, purple shale and ochered phyllytic marls are present. Thickness is uncertain.

Fossils:

Gypidula cf. *mansuyi* GRABAU
Atrypa desquamata SOWERBY
Spirifer tokinensis MANSUY

Lower series

Ni-chiu-ho Stage (Coblenzian)

A black shale found beneath the gold placer deposit at Ni-chiu-ho in the northern part of the North Manchurian plateau is considered to be Coblenzian by YABE and SUGIYAMA.[4] It contains *Pleurodictyum nodai* YABE and SUGIYAMA, *Syringoxon* (?) sp., *Stropheodonta* cf. *sedgwicki* d'ARCHIAC & VERNEULI and an undertermined number of brachiopods.

Lowest group.

Silurian Period

The oldest fossils found are middle Silurian in age. They were collected from a limestone deposit at Erh-tao-kou west of Kirin[5] and include *Pseudoniphyma infundibula* YABE & EGUCHI, *Spongophyllum sugiyamai* YABE & EGUCHI, *Favosites* sp. nov., cf. *Striatopora cristata* (BLUMENBACH), *Cladopora* (?) sp., *Aulopora* (?) sp., *Pachypora* (?) sp.

Dark-gray shale

Fossils:

Pleurodictyum nodai YABE & SUGIYAMA
Stropheodonta cf. *sedgwicki* d'ARCHIAC & VELNEULI

Pre-Silurian Period

A complex of crystalline schists, gneiss and granite is characteristic of this period.

Additional important data has been found since 1945 concerning the items which were marked with[5] in the foregoing sections.

The geological age of the Chiu-fo-tung stage had been considered Cretaceous by many geologists in the Orient, because of the presence of *Lycoptera davidi* (SAUVAGE). However, the writer and Tokio SHIKAMA in studies of the *Lycoptera* bed found two distinct faunal groups—Tanankou and Tsao-tzu-shan fauna—in the

[4] YABE, H. and T. SUGIYAMA (1942); A lower Devonian faunule from North Manchuria: Proc. Imp. Acad. Tokyo, Vol. 18, No. 8.

[5] YABE, H. and EGUCHI, M. (1943); On a limestone with favosites from Erh-tao-kou, west of Kirin, Manchuria: Proc. Imp. Acad. Tokyo, Vol. 19.

Chiu-fo-tang stage. In the former fauna *Monjurosuchus splendens, Rhynchosausus orientalis,* and *Astacus licenti* together with *Lycoptera davidi* were found, while in the latter fauna *Manchurochelys manchoukuoensis* and *Yabeinosaurus tenuis* together with *Lycoptera* species were identified.

Unfortunately, these two faunal localities are about two hundred kilometers apart, so we can not correlate them directly. Therefore, the writer and SHIKAMA concluded that the Tsao-tzu-shan fauna and Ta-nan-kou fauna (the latter belongs to the Chiu-fo-tang stage in a strict sense) are Upper Jurassic and Rhaeto-lias in age.

The writer formerly reported the Ordovician stratigraphy as follows:

Middle Ordovician
- Ssu-yen formation

Lower Ordovician
- Wu-ting formation
- Kang-yao formation

Lowest Ordovician
- San-tao formation
- Wan-wan formation

Since the exact contact between the Wu-ting and Kang-yao stages had not been seen in one continuous section, the writer had determined the stratigraphic order by palaeontological data alone. However, in the spring of 1947 the writer restudied the Ordovician sections in Tai-tzu-ho district. It was definitely observed that the Kang-yao always rests conformably on the Wu-ting stage, contrary to the former report. Moreover, it was found that the trilobite species contained in the Wu-ting stage could be referred to the Canadian Period in North America as already pointed out by Teiichi KOBAYASHI in the Bull. of Geological Soc. of Japan (42: 498), 1935.

The Kang-yao includes many well preserved specimens of *Lophospira, Eotomaria, Helicotoma,* and *Solenospira* and it is reasonable that the present stage is referrable to the lower portion of the Stones River of N. America. Therefore, the writer wants to change the Ordovician sequences in Manchuria to the order listed in the above columnar section.

The formal report of the Djalainor skulls has not yet been published, but the writer has been studying the skulls during the past several years. The materials of Djalainor man are composed of a skull of a female and a skull of a male, left half of a mandible, a right ulna, a left ulna and a rib fragment. These skulls show characteristic features of the Mesolithic man in having a lower degree of the orbital and foraminal indices, relatively large value for the internal-bi-orbital breadth, very shallow fossa canina, downward-tapering maxilla and three foramina mentalia. Moreover it is very remarkable that these skulls are found together with many vertebrate skeletons and many chipped microlithic implements which indicate the late Pleistocene age. Many other skeletons of Djalainor man will probably be found in the future in Djalainor coal field.

Until a few years ago, the geological age of the Chuan-tou stage was disputed among the Manchurian stratigraphers, until Shigeo SAKAGUCHI, former member of the Coal Mining Co. of Manchuria, collected the fossils listed above in this formation at Hsi-ying-pan, Tieh-ling Prefecture, Liao-ning Province in 1943. He concluded that the present stage belongs to the lowest part of the Cretaceous Period or even to the boundary between the Cretaceous and Jurassic Periods.

The Quaternary Period in Manchuria

Tokio Shikama

1. Introduction

The study of Quaternary geology in Manchuria has not progressed as far as that of the pre-Tertiary, especially in stratigraphy. The stratigraphic order of the stages is unknown. It is noteworthy that the majority of Japanese geologists who worked in Manchuria were hired for surveys of ore deposits, and many geologic surveys were done. In these reports it is evident that "hard rock" geology was their major interest and the problems of the Quaternary system were treated very simply. The drift geology was mainly concerned with loess deposits, and it seems to the writer that even the drift of the upper half of the Tertiary formation was treated as lightly as the Quaternary system. Under such conditions, the following studies are particularly outstanding works: studies of the Quaternary volcanoes in northeastern Manchuria, studies of topographic planes in Jehol and Liao-tung, studies of the sand dunes and lake deposits in Mongolia, and studies of fossil beds especially in the areas near Ku-hsiang-tun, near Harbin and Djalainor[1]. Though special surveys of placer gold, diatom earth and peat, as well as surveys of ground water and dams, are, naturally, concerned with the Quaternary Period, they are not treated here in detail. At the present time, it is too early to give a general outline of the Manchurian Quaternary, owing to the lack of sufficient data on chronology. Study of the Quaternary Period has recently progressed remarkably in China proper (North and Central China) in contrast to the studies of Manchuria which are still in a preliminary stage.

Licent and Teilhard de Chardin (1930) established the stratigraphy of the Quaternary system at Ou-tao-chuan, southwest of Chang-chun and at Djalainor in northwestern Manchuria. Since then no further studies have appeared. However, Ou-tao-chuan was treated in a chronological study of the vicinity of Chang-chun by Sōki Yamamoto in 1948, and Djalainor was treated in a report on the discovery and study of a human skeleton found at Djalainor by Riuji Endo (1945, 1949). The Quaternary system in Jehol, which is adjacent to North China, has been studied more than in other districts of Manchuria. Following the geomorpho-

[1] The name is spelled various ways, such as Dalainor, Dalai Nor, Dalay Nor, Darinor, and Da-la-i-no-erh, "nor" or "no-erh" meaning "lake".

logic studies by BARBOUR in 1935, Fumio TADA published studies in the same line in 1937 based on his work with the First Scientific Expedition to Manchuria and Mongolia. The geomorphologic and stratigraphic studies in the vicinity of Pei-piao by Shigeru KUSAMITSU in 1942 further advanced knowledge of the Quaternary geology of Jehol. Knowledge of the Quaternary system in Liao-tung was accumulated by Japanese geologists over a long time but resulted in comparatively few publications. The most important, concerned with the excavations at Ku-hsiang-tun, Harbin, which was done as a part of the First Scientific Expedition to Manchuria and Mongolia, are by Shigeyasu TOKUNAGA and Nobuo NAORA (1934, 1936, 1939).[2)] They reported many fossils and human relics. However, their studies were based on pioneer work by Russian scholars such as LOUKASHKIN (1937) and PONOSOFF (1937). Stratigraphic knowledge was further clarified by the excavations of the Central National Museum of Manchoukuo in 1927–1928 (ENDO, 1942 and SHIKAMA, 1943). Paleontological and chronological study of the materials excavated by the Manchoukuo Museum was delayed or prevented as all the materials were scattered and lost due to the war.

2. Characteristic Features of the Quaternary System in Manchuria

Rinji SAITO (1940) divided the sedimentary facies in Manchuria into the south Manchurian type and the north Manchurian type and designated the boundary as a line which connects Wu-tan-cheng, Kai-yuan, Hui-nan, An-tu, Muson (Korea) and Ch'ongjin (Korea) (approximately the 43° parallel of north latitude); this is named the Hui-nan—Kai-yuan line. The Tertiary system located on the north side of this line represents the Siberian facies, while that on the south side is closely related to the north Chinese facies. However, the Hua-tien series, like the Feng-shan series, shows a transitional facies between the Siberian—north Japanese side and the north Chinese side. Therefore, it may not be possible to divide the system into two distinct areas. TEILHARD DE CHARDIN (1941) divided the Quaternary sedimentary facies into three large divisions: the north Chinese facies, the Manchurian facies, and the Mongolian facies. The north Chinese facies does not appear much beyond the Hui-nan—Kai-yuan line. Jehol belongs, on the whole, to the north Chinese facies, while the western slope of the Ta-hsing-an-ling range belongs clearly to the Mongolian facies. Although the Manchurian plain looks like a prolongation of the plains of North China, it is characterized by the Manchurian facies. The north Chinese facies and the Manchurian facies are bounded not by a line which runs east-west, but by a line which runs approximately NNE—SSW, a line which connects Cheng-chia-tun with Kai-yuan. The fluvio-lacustrine facies, which is most characteristic in the Manchurian facies, develops mainly along the Sung-hua-chiang (Sungari) River, upstream from Kiamusze (Chia-mu-ssu) and from

[2)] See also OKADA, Naoe, 1939, Prehistorical researches in Ku-hsiang-tun, in: *Mem. Inst. Sci. Res. Manchoukuo,* v. 3, no. 1. Inst. Science Research Manchoukuo, Hsin-ching, Manchuria. (J).

Pei-an in the north to the eastern foot of the Ta-hsing-an-ling range and south to the area including Chang-chun and Ssu-ping-kai. Its eastern limit is distinctly bounded by a line which connects Chi-lin with I-tung. In the area east of this line, piedmont facies such as terrace deposits, talus, and fans developed along each river, though on a small scale. These piedmont facies gradually pass into the above-mentioned fluvio-lacustrine facies. Roughly speaking, the loess-like deposits in the area between Lung-ching and Yen-chi (Chien-tao Province) and Sangsambong (Korea) along the Tu-men-chiang River are a prolongation of the Manchurian facies. The type of the Manchurian facies is the Ku-hsiang-tun formation which consists of loess, sand, and loam. The formation contains abundant fossils; in this respect the Manchurian facies is different from the north Chinese facies.

Should the type of the north Chinese facies in Manchuria be represented by the Liao-ho plain group, it may be preferable to set the type on the drifts, which are developed along the Lao-ha-ho River, particularly in the vicinity of Chih-feng, by slightly modifying the original view of the author. The coastal district of Liao-hsi, west of the lower Liao-ho River, clearly belongs to the north Chinese facies. The facies of the Liao-tung Peninsula are questionable, but in a broad sense they probably belong to the north Chinese facies.

Basaltic plateau occupy a vast area in northeastern Manchuria. The detailed eruptive stages of the basalts and their relation with the Ku-hsiang-tun formation have not yet been determined. The relation between the rock detritus formation of the Ta-hsing-an-ling mountain range and the Djalainor formation or Ku-hsiang-tun formation is also unknown. However, the relation between the Pai-tou-shan glacial stage and the volcanic activity, reported by Goro ASANO (1947), may give some assistance to the present problem.

3. Chronology

The formations ranging from the Pontian in the lower Pliocene to the Alluvium (H-K) were divided into six regions, namely, Jehol-Liao-hsi, Ta-shih-chiao, Liao-tung Peninsula, the coast of the Yellow Sea, Shen-yang, the Sung-hua-chaing districts, and they were correlated as shown in Table 1 (SHIKAMA, 1950A). Inner Mongolia, the mountain district of eastern Manchuria, and the marginal part of Korea are omitted as the Diluvium in these districts has not yet been studied, although they offer the data for chronological determinations. In Table 1, the general horizons recognized in north China are shown, and the horizons of Manchuria were correlated with those of north China. Erosion stages A-G are based on TEILHARD DE CHARDIN's classification, and 1–4 are noticeable deposition stages.

Among the four deposition stages in north China, namely, the Pao-te, San-men, Chou-kou-tien and Ma-lan, the Ma-lan and Chou-kou-tien belong to the Diluvium. In Manchuria, the Ma-lan stage is most extensively developed, while the Chou-kou-tien series is distributed sporadically. The occurrence of the San-men

Table 1. Correlation of the Younger Cenozoic System in Manchuria

	General succession of N. China	Lan-ho (TADA)	Ta-ling-ho (TADA)	Jehol (TADA)	Jehol--Liao-hsi	Vicinity of Ta-shih-chiao	Liao-tung Peninsula	Coast of the Yellow Sea	Chang-chun—Shen-yang	Sung-hua-chiang, Harbin
K2	Pan-chiao stage (G)		30-40 m terrace (ENDO, MORITA)		Present erosion	Forming of present small valleys	Forming of present small valleys Slight upheaval	Forming of up-heaved coast Muddy coast	Erosion of the present time	Erosion of Sung-hua-chiang stage
K1	Black earth stage				Black earth stage		Submergence of Ta-lien Bay Black earth Pu-lan-tien stage	Ta-ku-shan peat bed Redeposited clay bed	Black earth stage	Wen-chuan-ho bed (Wen-chuan-ho stage)
J3	Ma-lan stage ④ Djalaos sogor sand bed		First denuded plane 60-120 m	First denuded plane Chang-tu plane 60-120 m	Erosion of Lao-ha stage		Pi-tzu-wo stage (period) 20-50 m	Upheaval Erosion	Upheaval Erosion	Erosion of Wa-pen-yao stage
J2	(F) Ma-lan loess	Loess	Loess	Loess	Chih-feng stage: Redeposited loess (partially gravel bed) Eroded Liao-ho stage Jehol loess	Kai-ping clay group (Elephant of Pei-piao)	Pu-lan-tien clay group Base of Pi-tzu-wo plane (Ta-lien mammoth)	Ta-yang-ho yellow clay bed	Liao-ho plain group (mammoth) Hun-ho clay bed Ying-cheng-tzu gravel-clay Chang-chun clay bed	Ku-hsiang-tun formation: Upper Lower
J1	Ching-shui stage (E)	200 m a Denuded plane	Second denuded plane 180-200 m	Second denuded plane Tung-liao plane 180-200 m	Erosion	Erosion and up-heaval More than 30 m was dissected	Kuang-ning-ssu plane 120-200 m Liao-tung peneplain	Erosion of Liao-tung stage	Erosion of bed rock Effusion of basalt	
	Chou-kou-tien stage ③				Loam Reddish clay group	Hsiao-sheng-shui-ssu group Niu-hsin-shan group	Reddish clay		Chang-tu fissure bed (Red formation)	
I2	Huang-shui stage (D)	280 m b Denuded plane	Third denuded plane Chahtara plain 280-300 m	Third denuded plane 280 m	Erosion of Taling-ho stage	Forming of caves and fissures			Forming of caves and fissures	
I1	San-men stage ②									
H	Fen-ho stage (C)	400 m c Denuded plane	Fourth denuded plane 400-420 m	Fourth denuded plane Chahatam plane 400-420 m					Sand	
	Pao-te stage (B) ①	480 m d Denuded	460-490 m	460 m	Pei-piao red earth bed Ling-yuan red earth bed		Chin-chou clay group	Chuang-ho red clay bed	Red sand and clay	
G	Tang-hsien stage (A)	560 m e Denuded plane	Fifth denuded plane Kien-ping plane 540 m	Fifth denuded plane 560 m					Gravel and sand	

series in Manchuria is not confirmed, while the Pao-te series is found only in Jehol Province and in the Liao-tung Peninsula.

Based on observation of deposits of the later Cenozoic era distributed between Chang-chun and Pai-cheng-tzu and between Ssu-ping-kai and Cheng-chia-tun, Sōki YAMAMOTO (1948) divided it into seven sedimentary stages, in ascending order, as follows:

Gravel	(Tang-hsien stage)
Red sand and clay	(Pao-te stage)
Sand	(Fen-ho stage)
Bluish gray clay	(San-men stage)
Gravel	(Ching-sui stage)
Brown clay	(Ma-lan stage)
Sandy clay	(Pan-chiao stage)

He also pointed out three remarkable features as follows: (1) the clay in the Pao-te and San-men stages is not reddish in general, (2) the development of sand in the Fen-ho stage is poor, and (3) a downwarping occurred prior to the Malan stage. YAMAMOTO's division has not been confirmed from the paleontological point of view. His division is unique in that he applied a deposition stage to each erosion stage of Tang-hsien, Fen-ho, Ching-shui, and Pan-chiao.

At any rate, it is certain that level planes, such as erosion or denuded planes, are very important in the chronology of the Quaternary period. Studies of this line have not progressed to an extent that the level planes in all of Manchuria can be correlated. There are piedmont plains developed in a position lower than the so-called Mongolian peneplain or Pei-tai peneplain. For example, the hilly plain at Fu-lung-chuan and the erosion planes of sand and gravel underlying the loess belong to the piedmont plain.

Erosion of the Ching-shui stage is generally found in Manchuria; for example, the eroison of the Liao-tung peneplain corresponds to this stage. The Kuang-ning-ssu plane (120–200 m), which was studied by Zenkyō IMAMURA and Teijirō TSUCHIDA (1935), and many other high-level planes are cut directly into the basal rock. In some parts, the planes coincide with the deposition planes of the Pu-lan-tien clay group or the Kai-ping clay group in the valley bottoms. However, considering that the plane of unconformity between the Pu-lan-tien clay and the reddish clay formation may correspond to the Kuang-ning-ssu plane, the author correlated the erosion of the Liao-tung peneplain with the Ching-shui stage (1950A). The erosion stage of Ta-ling-ho, which makes the unconformity between the Pei-piao red earth bed and the reddish clay formation, may correspond to the Huang-shui stage. The Fen-ho stage is not common in Manchuria. In the post-Ma-lan stage, since the sedimentary facies in Manchuria are well developed as compared to those of north China, it is possible to study in detail the erosion stages in the post-Huangshui stage.

In a certain sense, the division of the level planes of Jehol by Fumio TADA is contrary to Soki YAMAMOTO's views. In contrast with YAMAMOTO, TADA divided the denudation stages only, leaving the relations between the denudation stages and the deposition stages unknown (TADA, 1937). TADA distinguished about six horizons of denuded planes in the regions of Lan-ho, Lao-ha-ho, and Ta-ling-ho, and correlated them with those of north China. It seems that TADA owes his classification to the developmental history of the topography at Szechingtao in Chih-feng district, which was studied by BARBOUR. The present writer correlated the chronology in Manchuria with the new chronology in north China and revised the correlation table. The present erosion in the post-Lao-ha erosion stage was named the Ling-ho stage by BARBOUR. However, since it is liable to be confused with CHARDIN's Ling-ho stage and it is also not so important, the use of BARBOUR's Ling-ho stage has been avoided in this paper. BARBOUR's loam formation in TADA's correlation was correlated not to the San-men series, but to the Chou-kou-tien series. The Ta-ling Ho erosion stage was merely an erosion stage between the red earth stage and the loam stage, and it is as yet unknown if it can be correlated with the erosion stage between Huangshui and Fen-ho or that between Pao-te and Yu-she. At any rate, the denuded planes reported by TADA from Jehol are three, between the Kien-ping plane and the Tung-liao plane, and they correspond to the three stages of erosion in north China.

Table 2. Correlation of Erosion Planes in North China and Manchuria.

North China		Manchuria
a.	Tang-hsien stage erosion (Foundation of Pao-te series).	Kien-ping plane. Fifth denuded plane. Fu-lung-chuan plane. Roppyakuzan plane.
b.	Erosion between Pao-te and Yu-she series.	Denuded plane.
c.	Fen-ho stage erosion (between Yu-she and San-men).	Chahatam plane. Fourth denuded plane.
d.	Huangshui stage erosion (between Chou-kou-tien and San-men).	Liao-tung stage erosion (Chatara plane. Third denuded plane).
e.	Ching-shui stage erosion (between Chou-kou-tien and Ma-lan).	Liao-tung stage erosion (Tung-liao plane. Second denuded plane. Kuang-ning-ssu plane).
f.	Liao-ho stage erosion (between Ma-lan loess and Djalaossogor sand bed).	Erosion between loess and redeposited loess. Wo-pen-yao stage erosion (Chang-tu plane. First denuded plane).
g.	Pan-chiao stage erosion (Erosion of the present time).	Sung-hua-chiang stage erosion.

In Pei-piao district, the presence of reddish clay formation between the red earth and the loess was pointed out by Shigeru KUSAMITSU and the number of erosion planes increased.

The Ching-shui, or the Liao-tung, erosion stage is very important as it divides the Diluvium into upper and lower parts; thus the confirmation of this stage will be most important for the chronology of the Diluvium in Manchuria.

4. Hsiao-sheng-shui-ssu Group and Niu-hsin-shan Group

In 1942, the presence of cave deposits in the magnesite quarry at Ta-shih-chiao was brought to light. In the same year, Mitsuo NODA did field work at this place, and in 1943 the writer and Shigeru KUSAMITSU visited there and collected many fossils. There is a fissure-like cave (25 m long and 5 to 10 m wide) on the slope of a hill, 60 m in relative height and 130 m above sea level, at the magnesite quarry of Hsiao-sheng-shui-ssu. The deposits in the cave consist of a white sand bed (lower part) and a reddish-brown residual clay bed (upper part). The residual clay filled up small fissures and depressions which are found in the *Karrenfeld* in the upper part of the quarry. The hill of Hsiao-sheng-shui-ssu itself is a kind of monadnock, and the formation of residual clay seems to have acompanied the erosion of the monadnock. Consequently, the cave deposits seem to be older than the Kai-ping clay group, which is distributed extensively from the foot of the hill to the valley bottoms. The writer proposes to name this the Hsiao-sheng-shui-ssu group.

Niu-hsin-shan is a small hill 69 m above sea level, located about 4 km south of Ta-shih-chiao station on the Lien-Ching Railway Line. It consists of magnesite and there is a fissure running north-south in the part about 62 m in relative height and 40 m above sea level (the southwestern part of the hill and facing the railway track). This fissure is filled with gravelly clay. The clay consists mainly of breccia of magnesite, and the greater part of the breccia is cemented by clacareous matter. Many fossil bones are found in this breccia formation. The upper part of this fissure is also filled with reddish-brown residual clay. There is another fissure at a point about 20 m above sea level on the eastern slope of the same hill. The interior is filled by coarse gravelly clay which is not cemented by calcareous matter, and a fossil deer had been previously collected from the clay. This bed is considered to lie in the upper horizon as compared with the above-mentioned breccia formation. The writer named the fissure deposit at Niu-hsin-shan the Niu-hsin-shan group.

Niu-hsin-shan group	Lower part:	Breccial clay (breccia bed) *Trogontherium* bed
	Upper part:	Gravelly clay bed and Reddish-brown residual clay bed

The foot of the hill is also extensively covered by the Kai-ping clay group.

The lower bed closely resembles the breccia bed of the *Sinanthropus* group at Chou-kou-tien. The fossils collected from the lower bed at Niu-hsin-shan are as follows:

Cervus sp.	limb bones
Lepus sp.	teeth
Trogontherium cf. *cuvieri* FISCHER	skull, R M_1 or M_3
Castor sp.	lower right jaw
Microtus sp.	teeth
Erinaceous cf. *algai* YOUNG	skull, lower jaw
Canis (?) sp.	skull
Felis sp.	skull
Phasianus sp.	skeleton
Ohidia, gen. & sp. indet.	
Geoclemys reevesii (GRAY)	plastron
Anura , gen. & sp. indet.	humerus

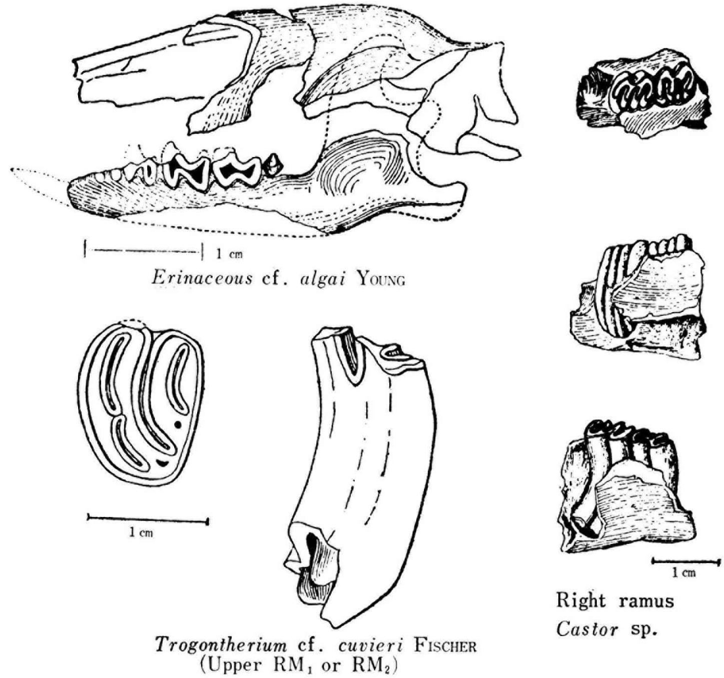


Fig. 1. Fossils from the Niu-hsin-shan Group.

Among the above-listed fossils, *Phasianus* is most abundant, and therefore it is no exaggeration to say that the present bed is the *Phasianus* bed. Since *Trogontherium* cf. *cuvieri* occurs in the *Sinanthropus* group at Chou-kou-tien, it is an important datum by which the present bed can be correlated with the *Sinanthropus* group. *Castor* sp. is not similar to *Castor* from the *Sinanthropus* group and *Sinocastor* from China; it is rather nearer to *Eucastor,* the living beaver in Canada. These two species of beaver rarely occur in Manchuria. The lower part of the Niu-hsing-shan group is correlated with the *Sinanthropus* group at Chou-kou-tien, and the sand bed in the lower part of the Hsiao-sheng-shui-ssu group may be older, in spite of its occurrence in a higher horizon than the former. The upper part of the Niu-hsin-shan group may be regarded as approximately the same age as the clay bed in the upper part of the Hsiao-shang-shui-ssu group. Thus it has been confirmed that the cave-fissure deposits of the Chou-kou-tien stage are distributed in south Manchuria.

Table 3. Correlation of the Niu-hsin-shan Group and the Hsiao-sheng-shui-ssu Group.

Kaiping clay group	
Upper part of the Niu-hsin-shan group	Upper part of the Hsiao-sheng-shui-ssu group
Lower part of the Niu-hsin-shan group	
	Lower part of the Hsiao-sheng-shui-ssu group

According to Mitsuo NODA (1930), the same fissure deposits are found in a limestone fissure in the vicinity of Chang-tu, between Chang-chun and Shen-yang, from which an antler of *Cervus hortulorum grayi* (ZDANSKY) was collected.

5. Liao-ho Plain Group

In south Manchuria, loess or loess-like clay is extensively distributed. According to Fusao UEDA and Masao SASAKURA (1937), the Diluvium series in Chin-chou, Jehol, and Hsing-an Provinces fills the great valleys and covers the hills, and it consists of loess, sandy loess, and aeolian sands. The loess is mainly developed in the southern region and it grades into the sandy loess in the central region. A basal gravel bed is occasionally found and a gravel bed is sometimes intercalated in the middle part. Distribution centers of the loess are Cheng-te, Chang-shan-yu (between Cheng-te and Ku-pei-kou), Ku-pei-kou, Huai-jou (south of Mi-yun), Hsing-lun-hsien, Ping-chuan, Kuan-cheng, Sa-ho-chiao, Chih-feng, Ling-yuan, Chao-yang, Chien-chang (another name for Ling-yuan), and Sui-chung. The sandy loess is distributed extensively and covers the hills in the area north of the line which connects Chih-feng, Pien-chiang-shan, and Kuo-chia-tun as far as Wu-tan-cheng. The sandy loess where it covers the hills is relatively thin, but in the valley bottoms it is as thick as 20 to 30 m and is also intercalated with gravel beds.

In the Liao-hsi district, which is the coastal area of Liao-tung Bay east of Shan-hai-kuan, especially in the wide valleys of the hills of old mature stage in the Sui-chung district, a loess bed is distributed at a height of scores of meters above sea level. This loess bed intercalates gravel beds and differs somewhat from the loess in north China. A reddish clay bed is sporadically developed in its lower part. In the valleys which dissected this loess bed, black earth bed has been deposited, one to 2 m thick, and a part of it has changed into a peatlike substance. It is note worthy that the loess bed in Liao-hsi resembles the Kai-ping clay in Liao-tung on the whole rather than the loess in Jehol. The same relation is found at Ta-ku-shan and along the Chuang-ho River—the Liao-tung Peninsula on the coast of the Yellow Sea. In the area south of the Chuang-ho, a *terra rossa*-like red clay, which resembles the Chin-chou clay found in the vicinitys of Chin-chou, is developed extensively and covers the plane of the low level hills on the coast. However, in the Ta-ku-shan district, it is completely absent and a yellow clay bed (the Ta-yang-ho yellow clay bed) is extensively distributed. Its characteristics are not very different from that in Liao-hsi. The deposition plane is scores of meters above sea level and it coincides with the Pi-tzu-wo plane, and some of the yellow clay was deposited secondarily in the lower area. On the greater part of the coast a peat bed (Ta-ku-shan peat bed) is found, which is mined by the inhabitants[3)] (Aoji, 1925). This peat bed may be correlated with those in Pyongan-pukto and the Chongju district in Pyongan-namdo, Korea. Such peat beds are extensively distributed in the bay head of an old stage along the drowned coast of the north coast of the Yellow Sea.

In the Liao-tung Peninsula, a remarkable red earth is developed in the Chin-chou district and its characteristics resemble the Pei-piao red earth in Jehol. Though the red earth yields no fossils and positive data are not yet found, the writer wants to correlate tentatively this red earth and the Pei-piao red earth (Chin-chou clay group) with the Pao-te red earth. Red earth is also sporadically distributed on the hills of low altitude in the so-called Liao-tung plain situated between Chin-chou and Ta-shih-chiao (Hanai, 1928). Heretofore these red earths have been regarded as *terra rossa* which is due to the weathering of limestone. However, the red earth is found in places other than limestone districts, and in the limestone districts of northeastern Manchuria, such red earth is not found even in the form of *rendzina*. Therefore, the writer strongly doubts whether such a reddish clay group is distributed in northeastern Manchuria. The Pu-lan-tien clay bed forms the Pi-tzu-wo plane in the vicinity of Pu-lan-tien. The clay is yellowish gray and dense. Its prolongation may be the mammoth-bearing clay bed at Lung-wang-tan in Ta-lien. The Pu-lan-tien peat bed, bearing seeds of Indian lotus (germination experiments were made), was deposited in the bottoms of valleys which dissected the hills consisting of the Pu-lan-tien clay bed. This Pu-lan-tien peat bed is merely a prolongation of the Ta-ku-shan peat bed.

In the Kai-ping and Ta-shih-chiao districts, the Kai-ping clay group, which is the prolongation of the Pu-lan-tien clay bed, is extensively distributed on the low level planes about 7 m above sea level. Small erosion valleys have been developed

3) In Chang-chia-pu, 20 km northeast of Ta-ku-shan, there is a peat bed at a depth of about 1 m, which is 80 cm thick. In Chien-shan-tzu, 8 km northeast of Chang-chia-pu, it is 1 to 2 m thick.

in a part of the Kai-ping clay group by present erosion. There are many gullies on the clay which cover the slopes of hills. These gullies may continue to the small erosion ravines in the valleys. The formation from which *Palaeoloxodon namadicus* was collected, in the vicinity of Pėi-piao, may be a prolongation of the present clay bed. According to Rinji SAITO (1939), in Tang-kang-tzu hot spring south of An-shan, the earthy formations in descending order from the surface are; black earth (6.2 to 15 m), loess (4.5 to 14.5 m), and sand bed (2.9 to 6.9 m). This is also a northward prolongation of the Kai-ping clay group. According to Shoichi NISHIDA (1939), the following section was obtained in the vicinity of Hsing-cheng hot spring, Chin-chou Province:

1.	Surface soil	60 cm
2.	Dark-brown fine sand	60 ,,
3.	Brown coarse sand	80 ,,
4.	Gray-brown coarse sand	150 ,,
5.	Gravel (pebbles 3 to 5 cm in diam.)	100 ,,
6.	Gravel (pebbles 5 to 10 cm in diam.)	300 ,,
7.	Light-green clay	90 ,,

Granite

This area is the alluvial coast of Po Hai, where sand and gravel transported by the Liao-ho River are extensively distributed. The area surrounded by Shen-yang, Hsin-min, Hei-shan, Hai-cheng and Ying-kou is a representative area of alluvial deposits. Liao-tung Bay, which had extended as far as Shen-yang and Hsin-min in the early Alluvium, may have been buried by the prolongation of deltas formed by the Ta-liao-ho (Liao-ho), Tai-tzu-ho, Hun-ho, Sha-ho, Hsiao-ling-ho and other rivers.

According to Kuman HARAGUCHI (1939), who surveyed the dam of the Liao-ho reservoir northwest of Kai-yuan, loess 20 m thick overlies the Chuan-tou formation on the hills between Hou-to-lo and Chai-chia-wo-peng, and mammoth and deer were collected in the vicinity of Pao-li-chen. On the left bank of the Liao-ho, loess was deposited, while on the right bank aeolian sands (one to 2 m) are found on the surface, and sand mixed with clay is developed under the surface sands. HARAGUCHI considers that this sand bed is younger than the loess.

A thick group of yellow clay is developed in an area from Shen-yang to Chang-chun and forms hills of strong relief (the Liao-ho plain group). The group in part consists of homogeneous compact loesslike clay, though partly mixed with gravel. Mammoth remains were found in the gravel bed which forms a terrace in the Ying-cheng-tzu coal mine, and also from the same bed at Liu-ho east of Shen-yang. In short, the Liao-ho plain group is the southern prolongation of the Ku-hsiang-tun formation and corresponds to the marginal part of the Manchurian facies or the transition part of the north Chinese facies. The Chuan-tou formation (Cretaceous) near Chang-tu extends as far as north of Chang-chun and is overlain by the clay of the Liao-ho plain group. As is seen in Ping-ting-shan at Ta-tun, south of Chang-chun, there is a basalt flow which truncates the Chiang-tu bed and seems to be overlain by the clay group. This basalt flow may have some relation with the volcanic activities of Chi-hising Volcano and Pai-tou-shan as well as the formation of basalt plateaus in Mu-tan-chiang Province.

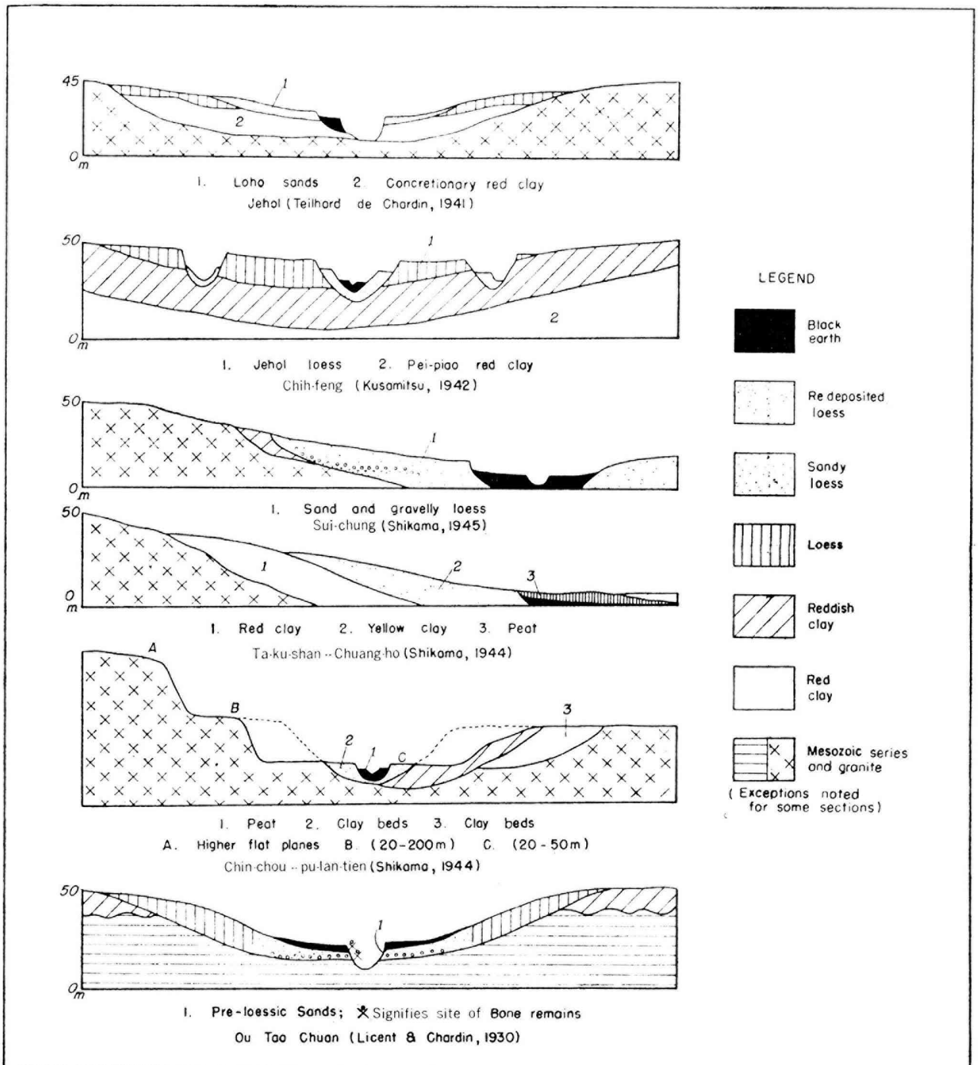


Fig. 2. Diagrammatic Section of Quaternary Sediments in Manchuria.

In 1930, LICENT and TEILHARD DE CHARDIN reported the following fossils, which are equivalent to the Ku-hsiang-tun facies, from Ou Tao Chuang, southwest of Chang-chun: *Elephas* sp., *Equus hemionus*, *Equus* cf. *przewalskyi*, *Cervus ordosianus*, *Gazella* sp., *and Bison* sp.

They reported the presence of a red coarse-grained gravel bed which forms the

Chang-chun hills plane and underlies the Liao-ho plain group, and assigned it to the San-men series. However, the writer considers that it probably belongs to the Chou-kou-tien stage. Moreover, they also reported the presence of white gravel bed (8 to 12 m) in the basal part of the yellow clay bed in the interior of the basin. This may be the sandy facies that is seen in the lower part of the Ku-hsiang-tun formation. The above-mentioned section reported by YAMAMOTO is located in the vicinity of this place, and it is, so to speak, the type section of the area along with the so-called Hei-liao divide (NIINOMY, 1930). The stage of formation of this divide, namely, the stage when the water courses of the Liao-ho and Sung-hua-chiang were fixed, may have been after the deposition of the Liao-ho plain group and before the deposition of the black earth. That is, it was a recurring upheaval which accompanied the Lao-ho erosion. This upheaval movement coincides with the development of a large-scale terrace-forming movement in the Japanese Islands at the end of the J_2 stage (Musasino terrace—Du_1 plane) (SHIKAMA, 1950B). If the Hei-liao divide can be regarded as the Korean direction, it is considered that this movement may be related with the movement which caused the declination of high level planes in Korea and subsequently caused the difference between the topography of the east coast and that of the west coast in Korea (KOBAYASHI, 1931). The subsidence topography of the Liao-tung Peninsula is in accord with the subsidence topography of the west coast of Korea. The northwestern prolongation of the eastern shore line in Korea coincides with the Hei-liao divide. It is worth considering whether the movement of the Hei-liao divide had already started at the Ching-shui stage or not. Since the boundary between the Manchurian facies and the north Chinese facies approximately coincides with the Hei-liao divide, the first movements of the Hei-liao divide may already have begun in the Ching-shui stage. According to Kunitarō NIINOMY the Nen-chiang and Liao-ho were originally one continuous river; then they were cut in two by the Hei-liao divide and the Nen-chiang became a tributary of the Sung-hua-chiang. The cutting of this antecedent valley probably occurred in the Lao-ha stage. If the Nen-chiang and Liao-ho had flowed southward as one river, the Manchurian facies and north Chinese facies would have come into contact along it, and the Ssu-ping-chieh—Cheng-chia-tun (Liao-yuan) districts would not have been dissected. Therefore, NIINOMY's opinion conflicts with the facts. It is more reasonable to consider that one continuous river flowed northward and emptied into the Sung-hua-chiang, and the Lao-ha River flowed via the upper stream of the former Liao-ho and poured into the Sung-hua-chiang. It is noticeable that the district of Cheng-chia-tun, Kan-an, Chien-kuo-chi, and Ta-lai is a vast alluvial zone and no hill consisting of loess is found.

The localities where fossils have been found in the Liao-ho plain group are as follows:

(1) Water reservoir at Lung-wang-tan, Ta-lien (TOKUNAGA & NAORA, 1939): In 1921, an elephant tusk and a tooth were found in the clay and gravel bed under the river bed during the engineering work. They are in the possession of OKUWA.

(2) Water reservoir at Lo-chia-tun in the vicinity of Ta-lien: Elephant tusk.

(3) Creek connecting the first with the third creek at Ling-shui-ho, Hsiao-ping-tao-hui in Ta-lien district: Tusk, vertebrae, and scapula of mammoth were found in 1916; they are owned by the former Museum of Port Arthur.

(4) Southwest of Chao-yang in Jehol Province: *Rhinoceros antiquitatis* was found by TEILHARD DE CHARDIN in the loess.

(5) Chao-yang-kou, north of Chih-feng, Jehol Province: *Rhinoceros antiquitatis* (molar), *Ovis ammon* (occipital bone), mammoth and bone implements were found by Saburō SHIMIZU, Isao MATSUZAWA, and others in the loess deposits.

(6) Shore of Lake Borden, Jehol Province: Fragment of deer antler which was artificially worked and skull of *Meles*. They were found by Kyukichi KISHIDA in 1920.

(7) Luan-ping district in Jehol Province: Megacerid.

(8) Hsin-min Hsien, Feng-tien Province (Shen-yan Province): A skull with horn cores of *Bos primigenius*. It is said that this specimen was at one time possessed by the Shen-yang Museum. It was found in the sand bed.

(9) Liu-ho (A village now called Chih-an-pu): Molar of mammoth found in a river bed.

(10) Hsiao-ku-lun (Ku-lun-chieh) in Jehol Province: Molar of mammoth once in collection of the Geological Survey Museum of the South Manchurian Railway Co. under Japanese mandate in Ta-lien.

(11) Ssu-ping-chieh in Chi-lin Province: Fragment of incisor of mammoth and fragment of horn core of *Bos primigenius* which were possessed by the former Museum of Port Arthur.

(12) Kung-chu-ling in Chi-lin Province: Tusk and femur of mammoth as well as skull, and molar of *Rhinoceros antiquitatis* and other bones which were found in the loess-like clay and were possessed by the former Manchurian Medical College in Mukden.

(13) Huo-shih-ling (Ying-cheng-tzu) coal mine (near Chiu-tai), east of Chang-chun.

(14) Ou-tao-chuan, southwest of Chang-chun.

(15) In the vicinity of Pei-piao: *Palaeoloxodon namadicus*.

6. Ku-hsiang-tung Formation

Fossil mammalian discoveries in north Manchuria (after TOKUNAGA and NAORA (1939):

1905—A. D. HITROB collected a buffalo skull on the River Bodounet, the upper stream of the Sung-hua-chiang, and sent it to the Kiakhata Museum (USSR). It was later studied by M. PAVLOW.

1909—BAIKOB found a bone which is probably mammoth on the bank of Mu-tan Chiang south of Ning-ku-ta (Ning-an).

1911—Baikob found a fossil bone on the River Ushagou in the vicinity of Mt. Hunchung.

1918—The skulls of mammoth, *Bison*, *Rhinoceros* and others were found in the upper deposit at the Dalay Nor coal mine.

1923—*Rhinoceros* was found on the bank of the Nen-chiang.

1924—Mammoth was found at Shduch'ya village on the River Derubur (Reka Derbul or Chieh-erh-pu-erh-lo Ho), a tributary of the Argun River, in the Barwa district.

1925—*Rhinoceros* and mammoth were found alongside the lower stream of the Nen-chiang, 5 km from Fularki (Fu-la-erh-chi).

1926—A tusk of mammoth was unearthed in a cliff 100 m east of Nichiro Kyokai College, Harbin.

1926—*Bison* was discovered on the River Umingora (I-min Ho), 25 km south of Hai-la-erh.

1927—Mammoth was found 10 km from Bodounet where buffalo was unearthed in 1905.

1927—*Bison* and mammoth were found at "Gordor" (probably Gorbunor [O-erh-pu-no-erh] village) on the left bank of the River Mergera (Mo-erh Ho) 80 km north of Yakeshih (Ya-ko-shih) station.

1927—Cranium of *Rhinoceros* was unearthed 12 km southwest of Man-chou-li station (Lu-pin). Mammoth was found near a school in Man-chou-li.

1927—A milk molar of mammoth was discovered at Tao-lai-chao on the bank of the Sung-hua-chiang.

1927—Mammoth was found during the sinking of a well in the vicinity of No. 551 Branch Office in Harbin.

1927—*Rhinoceros* and mammoth were found in a cliff of a small river 2 km from the No-erh Railway.

1927—Fossils of mammoth were found on the banks of the I-min-ho and the Uhelohe River, a tributary of the former.

1928—A fossil bone was found during the sinking of a well at Cartu Station. (Location uncertain; may be Ho-erh-hung-te near Hai-la-erh).

1928—Vertebrae of *Rhinoceros* were found 20 km northwest of Hai-la-erh.

1928–29—Belebeki (phonetic rendering) collected many fossil bones from the bottom of the Sung-hua-chiang between Harbin and Chenghe. (Location of Chenghe uncertain; may be Tung-ho, Lat. 45° 59', Long. 128° 43').

1930—A bison skull was unearthed on the Amur River in the vicinity of Hei-ho (Ai-hun).

1931—The Harbin Museum and the Peiping Geological Survey carried out excavations at Ku-hsiang-tun.

1932—Mandible of *Rhinoceros* and other fossils were recovered from sand in the river bed of Sung-hua-chiang during the construction of piers.[4)]

4) Ed. Note:— This refers to the construction of a bridge where the railroad from Chang-chun to Harbin crosses the Sung-hua Chiang.

1933—The first digging at Ku-hsiang-tun by Shigeyasu TOKUNAGA, Nobuo NAORA, and others who took part in the First Scientific Expedition to Manchoukuo and Mongolia.

1934—The second digging at Ku-hsiang-tun by TOKUNAGA and NAORA (also Shimeji OTA and Seikō MAKIDA).

1937—The first digging at Ku-shiang-tun by the Central Museum of Manchoukuo (Riuji ENDO, Wataru ISHIJIMA, and Naoei OKUDA).

1938—The second digging at Ku-hsiang-tun by the same museum (Tokio SHIKAMA and Mitsuo NODA, also ENDO, ISHIJIMA and OKUDA).

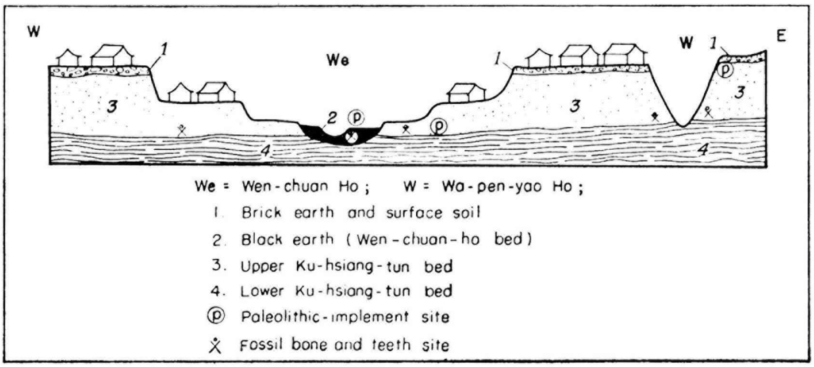


Fig. 3. Profile in Vicinity of Ku-Hsiang-Tun.

Ku-hsiang-tun, a treasury of Diluvium fossils, is a village located along the Wen-chuan-ho, a tributary of Sung-hua-chiang, 5 km southwest of the center of Harbin. The Diluvium series crop out along the Wen-chuan-ho and its tributary Wa-pen-yao-chuan. The Diluvium series, which forms the terrace group in the vicinity of Harbin, is estimated to be about 25 km. In the vicinity of Ku-hsiang-tun, its average thickness is about 10 m. It consists of a succession of clay, mud, sand, sandy clay and other sediments, and it is a flood plain lacustrine deposit. It is different from the Ma-lan loess while remarkable gravel beds are not found in it. The succession of the Ku-hsiang-tun formation is as follows (SHIKAMA, 1941):

Ku-hsiang-tun formation	Lower part:	Bluish-gray to dark-gray clay bed and sandy clay bed	2.8 m
	Upper part:	Yellowish-gray argillaceous sand to sandy clay bed	10 m
Forming of terrace:		Dissection of the Wa-pen-yao-chuan (Wa-pen-yao stage)	
Wen-chuan-ho bed:		Black mud bed (one m average thickness)	

Forming of terrace:	Dissection of the Wen-chuan Ho (Sung-hua-chiang stage)

Though the upper Ku-hsiang-tung formation consists of apparently homogeneous loesslike clay, it is remarkably arenaceous as compared with the Ma-lan loess.

Lower bed

The variation is remarkable; a clay bed is predominant in the lower part and an arenaceous clay bed in the upper part. The beds are, in ascending order:

a) Dark-gray clay bed (2.7 m maximum thickness): It consists of fine-grained and highly coagulated clay, and it passes into dark compact massive clay and in places into yellow clay in the upper. Lenticular zone of yellow compact medium-grained sand is intercalated within it.

b) Bluish-gray arenaceous clay bed (1–2 m): Arenaceous clay or arenaceous mud in which a fine blue color is predominant. Compact, soft and massive. Driftwood and other inclusions are scanty.

Upper bed

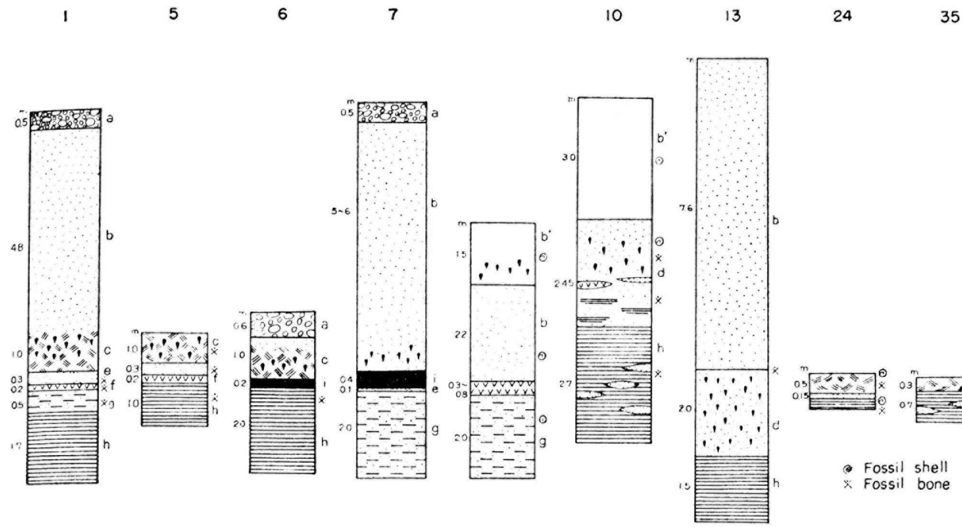
In general, sands predominate and cross-bedding is common in its lower part. One kind of basal gravel is found in the lowest part and it seems that a slight unconformity exists, though not yet confirmed.

c) Bluish-gray clay bed consisting of clay pebbles (0.8 m maximum thickness, 0.2 m average thickness): It is well exposed along the Wa-pen-yao Ho and sometimes it is intercalated in lenticular form. The pebbles consist of well-rounded clay pebbles or breccia, 1 mm in diameter, which are derived from b bed. It may be a kind of basal conglomerate. It contains sporadically dark-colored compact humuslike or peatlike clay, and it also contains much driftwood.

d) Yellowish-gray to yellowish-brown sands, argillaceous sands, and arenaceous clay bed (10 m maximum thickness. Its upper limit is still unknown). Cross-laminae are predominant in the lower part, and bog irons of 5–10 mm wide are distributed uniformly. This bed corresponds with TOKUNAGA and NAORA's loesslike clay bed as well as PONOSOFF's argillaceous loesslike clay bed. The upper part of this bed has been changed partially into black porous soil and in the part near the surface PONOSOFF recognized some podsolization. In some parts the following minute land molluscs are aggregated densely.

Gyraulus schmacheri CLESSIN
Lymnaea (*Galva*) *pervia* MARTENS
L. (*Radix*) *auricularia coreana* MARTENS

Mammals and other fossils are abundant in the lower part of the *d* bed, where cross-laminae are predominant, and in the upper part of the beds of *c*, *b* and *a*. Zoning based on fossils is impossible. The upper and lower part are of similar character; they are probably of the same age. Most fossil mammals are water-worn fragments and a complete skeleton is seldom found. In this respect the bed coincides with the flood-plain deposits which are rich in cross-laminae. A Mousterian-type point was found in the upper part of the *a* bed. Localities No. 19 and No. 20 (Fig.



(Numbers refer to locations in text and fig. 5.)
(PONOSOFF, 1937)

Fig. 4. Cross-section of each Excavation Trench (1938).

5), in which the most abundant fossils and human relics were found in the second digging by TOKUNAGA and NAORA, are in the upper part of the *a* bed and the localities do not belong to the Wen-chuan-ho bed. The Wen-chuan-ho bed contains many fossil bones which were carried from the Ku-hsiang-tun formation by running water. The fossils of *Juglans manchurica* Max. are an example of the peculiar fossils of this bed. Fragments of fossil bones which were carried from the Ku-hsiang-tun formation or the Wen-chuan-ho bed by running water are found on the present river bed mixed with bones of domestic animals of the present time. The width of the river flood plain of the Wen-chuan-ho, namely, that of the deposition plain of the Wen-chuan-ho bed, is estimated to be about 240 to 260 m. It is flat and is utilized as a clay pit by brick-manufacturing factories at Ku-hsiang-tun; in this way, the presence of fossil bones became known. Many excavation trenches by TOKUNAGA and NAORA are located in the vicinity of the confluence of the Wen-chuan-ho and Wa-pen-yao-chuan and at a point downstream from the railroad bridge which crosses the Wen-chuan-ho. They dug in the deposition plane of the Wen-chuan-ho in each excavation. The Wen-chuan-ho bed is thickest in the vicinity of the bridge. In contrast, the Ku-hsiang-tun formation crops out in the area downstream from the confluence of the Wen-chuan-ho and Wa-pen-yao-chuan.

In the second digging by the Central Museum of Manchoukuo, stress was laid on research into the Ku-hsiang-tun formation and every possible effort was made in the excavation at the Wa-pen-yao-ho. Excavation sites Nos. 1, 2 and 8 (Fig. 5) were in the Wen-chuan-ho bed alone. Many good specimens were collected by dredging the river floor. This method was faster than digging in the solid beds.

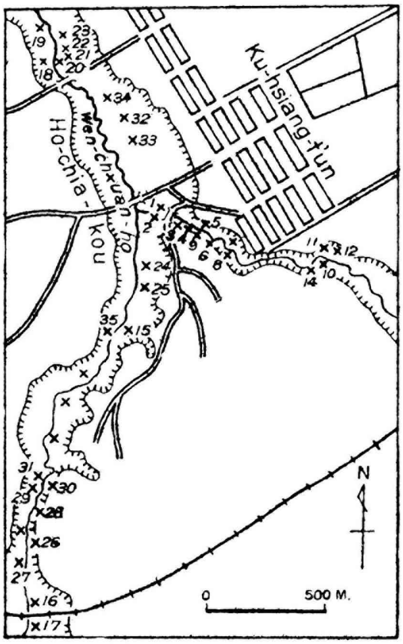


Fig. 5. Distribution Map of the Excavation Trench at Ku-Hsiang-Tun in 1938. (Numbers refer to text and fig. 4.)

The fossils from the Ku-hsiang-tun are abundant, and if the Tokunaga and Naora collection is included, they are as follows:

MOLLUSCA

1. *Unio eulasiae amurensis* Mouson
2. *Cristaria plicata* (Lea.) var. Suzuki
3. *Sphaerium lacustre compresum* Mouson
*4. *Valvata piscinalis manchurica* Suzuki
*5. *Stenothyra tokunagai* Suzuki
6. *Bulimus ussuriensis harupinensis* Suzuki
7. *B.* (*Parafossarulus*) *striatulus* Benson
8. *B.* (*Gobbia*) *kiusiuensis naorai* Suzuki
9. *Semisulcospira cancelata amurensis* (Gers.)
10. *Carychium pessimum gerstfeldti* Schi.
11. *Aplexa hypnorum* (L.) subsp.
12. *Lymnaea* (*Galba*) *pervia* Martens
13. *L.* (*Stagnicola*) *tokunagai* Suzuki
14. *L.* (*Radix*) *auricularia eoreana* Martens
15. *L.* (*Radix*) *plicatula* Benson
16. *Anisus gredderi* (Biel.)
*17. *Hippeutis manchuricus* Suzuki

18. *Succinea pfeifferi pingi* SUZUKI
19. *S. alpestris* ALDER
20. *Cochlicopa lubrica* (MULL)
21. *Vertigo alpestris* ALDER
22. *V. alpestris harbinensis* SUZUKI
*23. *Gastrocopta coreana* PILS.
*24. *Vallonia chinensis* SUZUKI
25. *Gonyodiscus ruderata pauper* (GOULD)
26. *Euconulus* sp.
27. *Bradybaena staoi* SUZUKI
28. *B. virgo* (PILS.)

INSECTA

Coleoptera indet. NAORA

PISCES

1. *Ctenopharyngdon* cf. *idella* (VALD.)
2. *C.* sp.
3. *Carassius* sp.
4. *Pelteobagrus* sp.
5. *Leiocassis* sp.

AVES

1. *Struthio* sp.
2. *Phasianus* sp.

REPTILIA

Amyda maackii (BRANDT.)

MAMMALIA

CARNIVORA

1. *Canis lupus* L.
2. *C.* sp.
3. *Nyctereutes* sp.
4. *Vulpes* cf. *vulpes* (L.)
5. *Ursus* cf. *spelaeus* BLUM.
6. *Meles* sp.
7. *Mustela* cf. *sibirica* PALLAS
8. *Hyaena ultima* MATSUMOTO
9. *Panthera tigris* (L.)
10. *Felis catus* L.

RODENTIA

1. *Clethrionomys rufocanus* (SUND.)
2. *Microtus* cf. *ratticeps* (YOUNG)
3. *Microtus* cf. *pelliceus* THOMAS
4. *M.* (*Lasiopadomys*) *brandti* (RADDE)
5. *M. obscurus* (EVERS)
6. *M.* cf. *mongolicus* RADDE
7. *M. Stenocranius gregalis* (PALL.)
8. *Cricetulus griseus* MILNE-EDWARDS
9. *Siphneus* sp.
10. *Ochotona* cf. *mantchurica* THOMAS
11. *Citellus mongolicus* (MILNE-EDWARDS)
12. *Marmota mantchurica* TOKUNAGA & NAORA
13. *M. robusta* (MILNE-EDWARDS)
14. *M. bobac sibirica* (RADDE)
15. *Tamias* sp.
16. *Castor orientalis* TOKUNAGA & NAORA

PERISSODACTYLA

1. *Atelodus antiquitatis* (BLUM.)
2. *Rhinoceros sinensis* OWEN
3. *R.* cf. *mercki* JÄGER
4. *Equus przewalskii* POL.
5. *E. hemionus* PALLAS

ARTIODACTYLA

1. *Sus continentalis* NEHR.
2. *S.* cf. *lydekkeri* ZD.
3. *Capreolus mantchuricus* (NOAK)
4. *Cervus* (*Cervus*) *canadensis xanthopygus* MILNE-EDWARDS
5. *C.* (*Cervus*) *elaphus* L.
6. *C.* (*Sinomegaceroides*) *ordosianus* YOUNG
7. *C.* (*Rusa*) *elegans* TEILHARD DE CHARDIN & PIVETEAU
8. *C.* (*Sika*) *horthulorum grayi* (ZDANSKY)
9. *C.* (*Sika*) *nippon mantchuricus* (SWINHOE)
10. *Alces* sp.
11. *Elaphurus* cf. *menziesianus* (SOW.)
12. Giraffidae, gen. & sp. indet.
13. *Gazella* cf. *gutturosa* PALLAS
14. *Spiroceros kiakhtensis* PAVLOVA
15. *Bos primigenius* BOJ.
16. *Bison priscus* BOJ.
17. *Bubalus teilhardi* YOUNG

18. *Probubalus* sp.
19. *Bibos kuhsiangtungensis* Tok. & Naora
20. *Camelus* sp.

PROBOSCIDEA

1. *Mammuthus primigenius* (Blum.)
2. *Parelephas armeniacus* (Falconer)

PRIMATES

1. Gen & sp. indt.

Among them, Mollusca were identified mainly by Kōichi Suzuki (1935). However, it is not clear how many species were from the Ku-hsiang-tun formation and how many from the Wen-chuan-ho bed; moreover, the fossiliferous horizons in the Ku-hsiang-tun formation itself are indist nct. Therefore, the writer listed them merely as one group. The following plant fossils were reported by Tokunaga and Naora, and most of them belong to the Wen-chuan-ho bed.

1. *Trapa natans* L. subsp.
2. *Salix* sp.
3. *Juglans manchurica naorai* Endo
4. *J. manchurica tokunagai* Endo
5. *Betula alba* L.
6. *Hordeum* sp.

According to the writer's identification (Endo, 1942), the collection from the second digging of the Central Museum of Manchoukuo expedition (in 1939) follows. From this list, one may see the frequency of fossils from the Ku-hsiang-tun formation, and of these, which were washed out by water. The numbers that follow the names of bone indicate the number of specimens; the fossils without number mean that only one specimen was found. (The trench numbers refer to Fig. 5).

Trench No. 1

Equus hemionus Pallas . . . . lower tooth
Bos primigenius Boj. lower jaw, phalange
Alces sp. . . . . antler
Atelodus antiquitatis (Blum.) . . . . skull fragment, scapula fragment
Bison priscus Boj. . . . . humerus, scapula
Cervus (Sika) nippon mantchuricus (Swinh.) . . pelvis

Trench No. 2

Atelodus antiquitatis (Blum.) . . . . upper tooth, axis, manus.
Equus hemionus B.oj . . . . lower teeth (3), phalange

Cervus (Sika) nippon mantchuricus (SWINH.) .lower teeth (2), axis, pes, manus, Femur
Capreolus sp. ....humerus
Bos primigenius BOJ. ....pes, manus, tibia (?), pelvis, bone implements (9)
Canis lupus L. ....manus

Trench No. 3

Bovidae ....upper tooth
Bos primigenius BOJ. ....manus
Atelodus antiquitatis (BLUM.) ....skull fragment, pes.
Felidae ....manus

Trench No. 4

Atelodus antiquitatis (BLUM.) ....upper tooth, vertebrate, femur

Trench No. 5

Atelodus antiquitatis (BLUM.) ....lower teeth (4), skull fragments (2), atlas, cervical vertebrae (3), lumbar vertebrae (2), femur (3), manus, costa (3)
Equus hemionus PALLAS ....phalange
Cervus (Sika) nippon mantchuricus (SWINH.) .lumbar vertebrae (3), femur
Bos primigenius BOJ. ....lower teeth (6), manus, pes (2), calcaneum (2), scapula, ulna
Gazella cf. *gutturosa* PALLAS ....horn core
Nyctereutes sp. ....femur
Felidae...............................manus
Mammuthus primigenius (BLUM.) ....vertebra, costa

Trench No. 6

Equus hemionus PALLAS ....pes, manus (2)
Capreolus mantchuricus (NOAK) ....antler, scapula, lower tooth
Cervus (Sika) nippon mantchuricus (SWINH.) .pes. lumbar vertebrae, atlas, pelvis, femur, ulna
Bos primigenius BOJ. ....horn core, lumbar vertebrae (2), manus (2)
Felidae...............................manus
Mammuthus primigenius (BLUM.) ....costa (12)
Bone implements 12

Trench No. 10

Atelodus antiquitatis (BLUM.) ....upper tooth

Equus hemionus PALLAS .... phalange, manus (2)
Cervus sp. .... radius
Bos primigenius BOJ. .... lower tooth, calcaneum, manus, radius, tibia, scapula, astragalus
Bone implement 1

Trench No. 13

Equus hemionus PALLAS .... phalange
Capreolus sp. .... scapula
Bison priscus BOJ. .... ulna, calcaneum
Mammuthus primigenius (BLUM.) .... crapus, scapula

Trench No. 18

Equus hemionus PALLAS .... manus
Cervus (Sika) nippon mantchuricus (SWINH.) . femur
Bison priscus BOJ. .... calcaneum, tibia
Martes sp. .... lower jaw

Trench No. 32

Pisces .... operculum
Struthio sp. .... egg shell
Atelodus antiquitatis (BLUM.) .... lower tooth, axis, pelvis, manus
Equus hemionus PALLAS .... lower tooth, manus, phalange
Capreolus mantchuricus (NOAK) .... humerus, phalange, calcaneum, costa
Bos primigenius BOJ. .... lower tooth, lower jaws (2)
Stone implement 1

Trench No. 33

Equus hemionus PALLAS .... lower tooth
Cervus sp. .... femur, sternum
Meles sp. .... femur

Trench No. 35

Atelodus antiquitatis (BLUM.) .... upper tooth, lumbar vertebra, axis, manus, radius, scapula (2), humerus, costa
Equus hemionus PALLAS .... upper tooth, lower teeth (2), manus
Cervus (Sika) nippon mantchuricus (SWINH.) . atlas, ulna, manus, pelvis
Bos primigenius BOJ. .... upper teeth (2), lower tooth, calcaneum, astragalus, ulna
Mammuthus primigenius (BLUM.) .... tusk, molar
Bone implement 1

Dredged from the Wenchuanho River

Atelodus antiquitatis (Blum.)	upper teeth (13), lower teeth (5), manus (2), skull fragments (2), radius, ulna, cervical vertebrae (3), pelvis (2)
Equus hemionus Pallas	lower teeth (9), upper teeth (5), lower jaw, manus (3), phalanges (3) metatarsus (5), phalanges (2)
Capreolus mantchuricus (Noak)	antler. manus (3), calcaneum (2), phalange, manus, scapula, radius, humerus
Cervus canadensis xanthopygus M.E.	antler
Cervus (Sika) nippon mantchuricus (Swinh.) .	teeth (4), humerus (6), manus (7), phalanges (2), lumbar vertebrae, costa, astragalus, carpus
Bos primigenius Boj.	lower teeth (7), upper teeth (7), phalange, calcaneum (3), tibia, metatarsus (5), costa (5), lumbar vertebrae (2), pelvis, radius, astragalus
Bos sp.	lower jaw
Bison priscus Boj.	ulna
Bison sp.	tibia
Canis lupus L.	skull, teeth (10), manus
*Canida*e	manus, humerus, radius
Microtus sp.	lower jaw (many)
Siphneus sp.	lower jaw (many)
Mammuthus primigenius (Blum.)	manus
Phasianus sp.	scapula

Of the above fossils, most abundant are rhinoceros, wild Bovidae (*Bison*), wild horse, and deer; and rats are next. Rodentia were especially abundant in No. 19 trench. In the above list, *Equus przewalskii* was included in E. *hemionus*. The presence of *Struthio, Castor, Gazella, Bubalus,* and *Camelus* is interesting. According to Tokunaga and Naora, mammals of 61 species in all show the following percentages. Numbers in parenthesis indicate specific number of specimens.

	Percentage of living species	Percentage of extinct species
Carnivora	9% (6)	8% (5)
Rodentia	19% (12)	6% (4)
Artiodactyla	14% (9)	29% (18)
Perissodactyla	3% (2)	6% (4)
Proboscidea	—	1% (1)

Of these 61 species, the numbers of extinct and living species respectively are 32 (52%) and 29 (47%). Forest, steppe and marsh-river animals are respectively 26 (42%), 30 (49%) and 5 (8%). Species now living in Manchuria are 20 (32%), while those living outside of Manchuria are 8 (13%). Of the extinct species, 5 (8%) are known in the Far East, 7 (11%) are reported from outside of Manchuria, and the remaining 21 (34%) are found in Manchuria alone. It is said that 8 (13%) were found in the lower Pleistocene, while 53 (85%) were collected from the middle and upper Pleistocene (the Ma-lan stage). The percentage of the extinct species is not as great as the 75% of the *Sinanthropus* group at Chou-kou-tien; however, it surpasses the 43% of the Sjara-Ossa-Gol bed at Ordos and 28% of the lower bed of Afontova along the River Yenisei. Thus, the fauna belongs approximately to the range from the middle to the late Pleistocene.

In the list of mollusca, five species marked with asterisks are said not to be known as living species.

The climatic conditions of 52 mammalian fossils from the Ku-hsiang-tun formation are as follows (numbers in parentheses indicate specific numbers of specimens):

	Living species (21 species)	Extinct species (31 species)	Total
Species which lived under approximately the same climatic conditions as at present:	30% (16)	28% (15)	58%
Boreal type	7% (4)	19% (10)	26%
Tropical type	1% (1)	11% (6)	12%

That is, among the living species, the species which correspond to the present climatic conditions of north Manchuria are abundant. If the extinct species are included, the percentage becomes 58%, so it is probable that the climate of that age was not very different from the present climate. The species of the frigid type which migrated southward and those of the tropical type which migrated northward exist together. It is inferred that the yearly variation between the summer and winter seasons was conspicuous. However, species which live in more frigid areas, such as *Rangifer* and *Ovibos*, were not found at all. This can be said not only of Ku-hsiang-tun but of all Manchuria. The southern limit of distribution of mammoth is Ta-lien, 39° north latitude, while in south Hokkaido it is 42° north latitude.

No human skeletons were found; however, some bone and stone implements have been found. Because of the conditions of the locality, stone implements are very rare; however, those of *racloir* type have been found. The lithic characters are basalt, quartz, chert, and other rocks. Artificially worked bone implements are rather abundant, and many implements such as spear-heads, chisels, and knives have been found. In addition, bone pieces cut to fairly uniform length, bone pieces with traces showing that they were bound by strings, a rhinoceros skull with hammer impressions, and a deer-antler implement were unearthed.

Coarse and fine implements are mixed with microlithic implements. The degree of culture generally corresponds with that of Mousterian-Aurignacian in western Europe. However, it is also said that this culture, together with that of Dalay Nor, may be correlated with the Siberian paleolithic culture (TOKUNAGA & NAORA, 1936). At least, the abundance of bone implements is a remarkable feature. It is considered that the remains of human culture may belong to loess camps. Some charcoal lumps were found, so it is noted that fire was used by paleolithic men. PONOSOFF collected some paleolithic stone implements in the upper part of the upper bed and he correlated them with Magdalenian. However, according to CHARDIN and PEI Wei-chung, the implements which were considered paleolithic by TOKUNAGA and NAORA belong, on the whole, to the mesolithic. However, in this case the frequency of stone implements in the Ku-hsiang-tun formation and in the Wen-chuan-ho bed is not yet distinct. A splendid stone implement collected in No. 32 trench by the writer and others in the course of the digging in 1938 was of Mousterian type; this stone implement was collected at the lowest part of the upper bed.

The Ku-hsiang-tun formation is rich in fossils and paleolithic remains, and it is a valuable formation which may be correlated with the Ordos. In 1943, the writer correlated these two localities as follows:

Manchuria	Ordos	
Wen-chuan-ho bed	Black earth	—Culture of black earth stage
Upper Ku-hsiang-tun formation	Sjara-Osso-Gol bed	—Culture of mesolithic type (Azilian type culture)
Lower Ku-hsiang-tun formation	Lower part of the Sjara-Osso-Gol bed	—Culture of Moustero-Aurignacian type
-?-	Ma-lan loess	—Moustero-Aurignacian

In general, in a chronological correlation with European cultures, the paleolithic remains from north Manchuria to eastern Siberia show features ranging from Mousterian to Magdalenian, and they belong to an age with the Würm glacier stage as the center.

It is inferred that the Ku-hsiang-tun formation is rather extensively distributed in the drainage basin of the Sung-hua-chiang, and the following fossil localities are known:

1. Tao-lai-chao, Chi-lin (Kirin) Province: Mammoth.
2. San-ko-shu, northeast of Harbin: Mammoth, *Bison, Bubalus, Equus*
3. "Tanolin" tunnel,[5] Chi-tao-kou, Pin-chiang (Pinkiang) Province: Mammoth.
4. Mu-leng coal mine, Pin-chiang Province: Artificially worked deer antler (*Cervus elaphus?*) from the surface soil in the upper bed of the mine.
5. In the vicinity of Hei-ho (Ai-hun): Skull of *Bison* from the sands along the river.

[5] Ed. Note: Precise location unknown.

6. Niu-la-cheng-tzu, Pin-chiang Province, adjoining village west of Ku-hsiang-tun: Mammoth.
7. River floor of Sung-hua Chiang at a suburb of Harbin: Mammoth.
8. In the vicinity of Fularki Station (Fu-la-erh-chi) along the Nen-chiang, Hei-lung-chiang Province: *Rhinoceros antiquitatis*.
9. Tsitsihar (Chi-chi-ha-erh), Hei-lung-chiang Province: Molar of mammoth unearthed when the Tsitsihar castle was constructed about 300 years ago and formerly possessed by the Li family (Now in the National Science Museum in Tokyo).
10. Foot of the Ta-hsing-an-ling range, Hsing-an Province: *Poephagus grumiens* (Przew.)
11. Hai-lun.
12. Ko-shan and Pai-chuan: Splendid tusks, skull, mandible, and other bones of mammoth.
13. Along the La-lin-ho, south of Harbin: Mammoth.
14. In the vicinity of Ningguda (Ning-an) along the A-shi-ho.
15. In the vicinity of Man-kou (Tien-tsao-kang): *Gazella*.
16. East of Fu-yu and Ta-lai: Mammoth.
17. Iyasaka village and Ta-ku-tung in the vicinity of Chu-lien: Mammoth.
18. Hao-li-kang (Hao-li) coal field.
19. Shang-i-hsiang and Ssu-tung in the vicinity of Yen-chi, Chien-tao Province: Mammoth.

    Ssu-tung is located on the Tu-men Chiang and opposite Sangsambong in Korea. In both localities, loess-like clay which is equivalent to the Ku-hsiang-tun formation is developed. At the digging in 1936, Tamezō Mori and Fu-cheng Chao collected the following fossils from the yellow clay bed which underlies the yellowish clay bed at Ta-ma-lu-kou, Shang-i-hsiang. However, most of them are fragments.

    Cervus elaphus L.
    C. sp.
    Equus sp.
    Atelodus sp.
    Mammuthus primigenius (Blum.)

7. Djalainor (Darinor) Formation

The Djalainor coal mine in Hsing-an Province is north of Lake Djalai (Dalai Nor or Hu-lun Chin), and is situated at a corner of the Mongolian facies.

According to Tolmatchev's report in 1927, a columnar section of a trench in the Djalainor coal mine shows the following, in descending order:

1. Surface soil bed of humus .... 3.5 m
2. Dried sand bed .... 2 ,,
3. Compact mud bed .... 1 ,,

4. Sand bed .... 2 ,,
5. Perpetually frozen mud bed .... 1 ,,
6. ,, ,, small-grained gravel bed .... 1 ,,
7. Clay-like shale bed .... 3 ,,

Unconformity

8. Coal seam .... 6.5 ,,
9. Gray clayey earth bed

The 1st to 7th beds belong to the Quaternary period, and a skull of *Rhinoceros antiquitatis*, a tusk of mammoth, a skull of *Bison* and others were collected from the 5th through 7th beds. Artificially worked deer antlers were found in the upper part of the frozen bed. Some of the deer antlers are shaped like a square hammer-head with a rectangular hole. A similar implement was collected at Chih-feng, and sculptured vertebral bone of *Rhinoceros antiquitatis* was collected in a sand dune near Hailar (Hai-la-erh).

In 1933, Djalainor skull No. I was found in the gray sand bed with gravel which is situated between the surface soil and the coal seam. Then in 1943 Yoshirō YUDA found skull No. II. These skulls were studied by Riuji ENDO (1944). In September, 1944, Endō and Wen Chung PEI surveyed the field and collected the so-called skull No. III, namely, the left half of a mandible, right ulna, left ulna, and a fragment of a rib together with several mammalian fossils and about 10,000 microlithic implements. According to ENDŌ, a section of the Nan-mei-kou open mine shows the following, in descending order:

1. Surface soil (5 to 10 cm)
2. Peat bed (10 to 30 cm)
3. Yellowish-brown gravel bed (15 to 30 cm) with fresh water bivalve shells
4. Grayish sand bed (one to 2 m)
5. Gray to yellowish-gray sand bed with gravel (2 to 4 m)
6. Gravel bed (one m)
7. Coal seam

It is said that skull No. I was found in the 5th bed, which may correspond to TOLMATCHEV's 6th bed. Skull No. II was collected at the 3rd colliery; the section in this vicinity is similar to that of Nan-mei-kou, and it is said that skull No. II was unearthed from the fine sands with gravel, about 10 m below the surface. Among the mammalian fossils collected by ENDŌ and others were *Rhinoceros antiquitatis* Blum, mammoth, *Equus przewalskyi* Polliakoff.

Skull No. I probably belonged to a middle-aged female, while skull No. II belonged to a middle-aged male. The breadth of orbit is rather large and the breadth of foramen magnum is relatively narrow. The basion-bregma height, maximum length, and maximum breadth are 147 mm, 177 mm and 137 mm respectively. The head had suffered some deformation, that is, it shows that the forehead had been strongly pressed by some plate or hide during life.

Many microlithic implements are abundantly scattered on the terraces on the west side of the River Moutonaya, which runs between Lake Dalay and Dalay Nor mine. These implements are arrowheads, spearheads, knives, flakes, scrapers, and cores which were made of agate, obsidian, or vein quartz. According to PEI's opinion, these implements belong to the Lin-hsi type culture and indicate the mesolithic age. Around the Nan-mei-kou open mine, some microlithic stone implements of the Lin-hsi type were found, and, in addition, one bifacial implement of definite paleolithic appearance was formerly collected.

According to Hoichi YOSHIZAWA and Jun'ichi IWAI (1937), the formation underlying the alluvial deposits of the River Hailar [Hai-la-erh Ho] and the sandy clay bed in the lowland north of Lake Djalai belong to the Hailar formation and can be correlated with the Djalainor formation. Mammoth and *Bison* were found during the construction of bridge piers in the River Hailar north of Hailar.

The Hulunbuyer formation in the Hulunbuyer plain[6] is composed of aeolian sands, consisting of fine grains of quartz and feldspar. Though the plain shows a rolling topography on a large scale, it may have been sand dunes at the time of its deposition. It alternates with the Hailar formation of lacustrine facies. A river terrace formation crops out at 5 to 19 m above the present alluvial plain and consists of gravels. The boring cores obtained in the Hulunbuyer plain indicate the following successions:

East of Hailar

1.1 m ....Surface soil
32.0 ,, ...Yellowish-brown to yellowish-gray fine sands
34.0 ,, ...Arenaceous clay
40.5 ,, ...Gravel-bearing blue clay
46.8 ,, ...Gravel

North of Hailar (Ta-liang-shang)

1.0 ,, ...Brown sand
5.0 ,, ...Light brown clay
9.0 ,, ...Grayish-white fine sand
13.0 ,, ...Light brown clay, mixed with sand
15.0 ,, ...Light brown fine sand
19.0 ,, ...Brown fine gravel
20.0 ,, ...Coarse sand
22.0 ,, ...Light brown fine sand
31.0 ,, ...Coarse sand
32.0 ,, ...Gravel
37.0 ,, ...Light brown sand
38.2 ,, ...Light brown coarse sand

5 km north of "Oronur", northeast of Kanchur
(Kan-chu-erh-miao)

0.9 m ....Surface soil

6) Ed. Note: The Hulunbuyer plain is the area between the two lakes Hu-lun Chin (or Dalay Nuur) and Pei-erh Hu (or Buyr Nuur).

4.9 ,, ... Grayish-white clay
12.5 ,, ... Blue clay mixed with sand
17.0 ,, ... Black clay
18.3 ,, ... Fine gravel
? . . . . Brown clay

In the San-ho[7] district the surface soil, about 1 m thick, is underlain by a gravel bed about 2 m thick, with alternation of clay and sand, or alternation of gravel and clay, from which mammoth and other fossils were unearthed.

According to Fusao UEDA and Masao SASAKURA (1937), an aeolian sand bed is extensively developed in the area north of Wu-tan-cheng, Hsing-an-hsi (west Hsing-an) Province, and shows the Mongolian facies. A tableland 20–40 m above the adjoining alluvial plain is distributed along the south bank of the River Shara-muren (Hsi-la-mu-lun Ho). Remarkable aeolian sand, 60 or 70 m thick, is extensively distributed near Lin-hsi, in the area between Ta-pan-shang and Lin-tung and in the Chakhar (Chahar) district, just north of Lin-hsi, as well as in the area between Hsi-ching-peng and Tarinor (Ta-erh Hu). The aeolian sand is developed in the meridional direction along the margin of Ta-hsing-an-ling mountain range from the east of Tarinor. A white clay bed, several meters thick, is developed in the lower part of the basin 100 m southeast of Ta-wang-miao on the southeastern shore of Tarinor ("nor" means lake in the Mongolian language), and from this bed the following fossils have been found:[8] *Lymnaea* (*Radix*) *teilhardi* (PING), *Gyraulus chiliensis* (PING), and *Pisidium* sp.

The above fossiliferous bed is also developed in the sand-dune zone, 20 km south of Tarinor, and its succession is as follows, in descending order:

1. Surface soil and sand . . . . 60 cm
2. Brown sand . . . . 30 ,,
3. Black sand . . . . 15 ,,
4. White clay . . . . 20 ,, (fossiliferous bed)
5. Sand . . . .

The result of boring at Dalainor city is as follows:

	Thickness
1. Surface soil and sand 2. Blackish-brown surface soil	5 m
3. Light brown fine sand 4. Small gravel	5 ,,
5. Gravel 6. Blue clay	5 ,,

7) Ed. Note: The San-ho district is an area about 120 km north of Hai-la-erh, where several rivers flow into the Argun River.

8) In 1931, Isao Matsuzawa, Namio Egami, and others collected fresh water shells from the brown sand bed (overlain by the Ma-lan loess) on the south bank of the River Balga in the vicinity of Ulan-hosho and on the east bank of the River Nuhus in the neighborhood of Zakustai-Sume. According to Koichi Suzuki, the following fossils are among them:

Lymnaea (*Galba*) *pervia* von MARTENS, *L.* (*Radix*) *auricularia obriquatus* von MARTENS, *Anisius* (*Gyraulus*) *gredleri* ("BIELZ" GREDLER), and *A.* (*Segmentin*) *nitidellus* von MARTENS.

7. Reddish-brown arenaceous clay mixed with gravel .... 5 „
8. Light bluish clay .... 5 „
9. Reddish-brown fine sand .... 5 „
10. Light blue clay .... 5 „
11. Brown fine sand .... 5 „
12. Dark brown clay mixed with earth and sand .... 5 „
13. Hard-textured clay .... 5 „

8. Terrace Gravel Beds and Basalt Plateaus

Terrace gravel beds are distributed everywhere in the mountainous regions of Ta-hsing-an-ling, Hsiao-hsing-an-ling, and Chang-pai-shan, and basaltic plateaus are also extensively developed. These piedmont facies pass gradually into the Manchurian facies.

Dilluvial terraces, 50 m above the adjacent plain, are distributed along the Amur River on the northern slope of the Hsiao-hsing-an-ling from the River Fupiehlahe (Fa-pieh-la-ho), upstream from Hei-ho to the Wu-yun district. A succession of gravel and clay is distributed along the Pei-Hei Line (Horiuchi *et al.*, 1937).[9] A gravel bed is developed on the northern slope of Hsiao-hsing-an-ling and a thick clayey bed crops out on the southern slope and is divided into the lower gravel bed (10 to 20 m) and the upper clay bed. Cobbles as large as a human head are mixed in in the area west of Aigun (Ai-hun). Gravels of the gravel bed along the rivers Chan-ho and Ko-erh-fen-ho in the west of the Nan-pei-ho (Chan-ho- is east of Nan-pei-ho) consist of chert, radiolarian chert, quartzite, graywacke and clayslate. It is said that the upper clay bed is developed under the alluvial deposits along the Hu-yu-erh-ho (Wu-yu-erh-ho), Na-mu-erh-ho (Nan-yeng ho) and their tributaries, and it is estimated to be 60 or 70 meters thick. It contains bentonite at Lung-an (Lung-men) and Pei-an, while it also includes lignite at Tai-an.

In the districts of Pai-chuan, Hai-lun, and Sui-hua the lower part consists of a sandy bed with much cross-laminae, while the upper part is composed of a clay bed with bentonite. The thickness is estimated to be 60 or 70 m, as seen along the Pin-Pei Line.[10] That is, the formation in this district is distinctly a prolongation of the Ku-hsiang-tun formation.

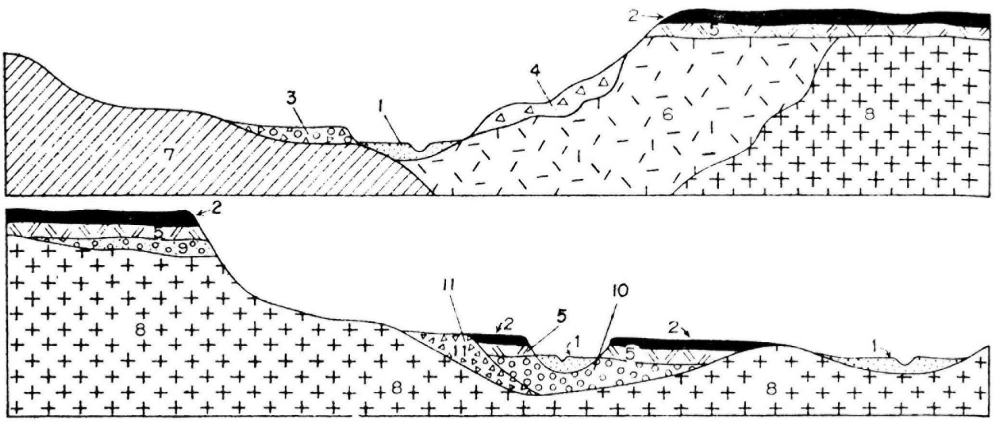
Terrace gravel beds are also distributed along the Nen-chiang.

Basaltic plateaus, 20 to 40 m above the adjacent plain, are distributed along the Kan-ho and No-min-ho on the eastern slope of the Ta-hsing-an-ling. These plateaus and diluvial plateaus are rather difficult to distinguish topographically.

Thick alluvial deposits of fluvial origin are developed along the Hoi-lung-chiang (Amur River) and Nen-chiang and consist of arenaceous clay, sand, and

[9] Ed. Note: Pei-an to Hei-ho (Ai-hun) railway.
[10] Ed. Note: Ha-erh-pin to Pei-an railway.

gravel. A gravel bed several meters thick has been found 5 m below the earth surface in Hei-ho (Ai-gun) city.



1. Alluvium
2. Soil above basalt
3. Terrace deposits or fanglomerate
4. Talus deposits
5. Basalt
6. Andesite
7. Mesozoic
8. Granite
9. Sand and gravel below mesa basalt (Tertiary)
10. Sand and gravel below lower-level basalt
11. Decomposed zone of granite

Fig. 6. Pleistocene in Pin-Chiang, San-Chiang and Chi-Lin Provinces (Takeyama and Asano, 1937).

In a vast triangular area, which is surrounded by the Ussuri River (Wu-su-li-chiang) and the Sung-hua-chiang with Khabarovsk as its apex—namely, the downstream plain composed of thick alluvial deposits—the ground is subsiding. The northeastern prolongation of the Ku-hsiang-tun formation can be found here and there, mostly forming terraces. One example is the area between Harbin and Fu-chin. A gravel bed, 20 m thick, is found in the vicinity of I-lan (Asano, 1937). A succession of light yellowish-brown arenaceous clay and clay is developed at Fu-chin. Mammoth was unearthed at Ta-ku-tung near Fu-chin. A gravel bed is also found in the Hao-kang coal mine near Hao-li. A gravel bed is most typically developed in the vicinity of Ta-ping-chen along the Wo-ken-ho. A gravel bed is also distributed in the vicinity of Mi-shan south of Tung-an and in the neighborhood of Po-li. In the vicinity of Ping-yang (Ping-yang-chen) a gravel bed is developed under the basaltic lava flow in association with basaltic plateaus. Terraces composed of gravel beds more than 10 m in thickness are distributed in the districts of Mu-tan-chiang, Tung-ning and Tung-king-cheng (Tung-ching-cheng). There are two kinds of gravel beds. One is the gravel bed underlying the plateau basalt and the other is that underlying the new basalt flows which occupy the present river valleys. It is considered that the latter belongs to the Diluvium series. According to Shigemitsu OKADA and Shoichi NISHIDA (1940), the Diluvium series in the vicinity of Tu-men-tzu, Chien-tao Province, is a terrace deposit and consists of gravel and clay. It is distinguished from the Tertiary gravel bed by its basalt pebbles. Most of the pebbles are composed of basalt, and contain secondary placer gold which was washed out from the gold-bearing Tertiary system.

Basaltic plateaus in Mu-tan-chiang and Tung-hua Provinces cover a vast area. In the district from Chi-lin (Kirin) Province to Tung-hua Province in the upper stream of the second Sung-hua-chiang,[11] diatom earth is distributed along the inclined slope of each riverhead of each small river which dissected the low tableland consisting of basalt. According to Shōichi NISHIDA (1941), the diatom earth was formed in the marshes on the basaltic plateaus, and is intercalated between a gravel bed and clay bed; it is estimated to be 1 to 2.5 m thick. The following species of diatoms are found:

Melosira ambigus (GRUN) O. MULL.
Diatoma anceps (EHR.)
Fragilaria virescens RALFS.
Navicula koreana SKORTZOV
N. mutica KUTZ.
Pinnularia distinguenda CLEVE.
P. brevicostata CLEVE.
Synedra vaucheriae KUTZ. var. *truncata* (GREV.) GRUN.

The surface soil in north Manchuria is different from that of south Manchuria. It is pitch black to grayish-black and can be divided into black soil and alkali soil. The black soil covers the hills of the Diluvial series and forms the so-called black earth zone. It is a tschernosem. It is distributed in the area of the diluvial hills in the vicinity of No-ho, Tai-an, Ko-shan, Pei-an, and Lung-chen (Lung-men) north of Ning-nien as well as the eastern marginal hills in the Hai-lun. Pai-chuan district. The thickness is estimated to be 0.5 to 2 m. The surface soil in the area from the steppe lying in the Tsitsihar (Chui-chi-ha-erh) district to the drainage basin of the Hu-yu-erh-ho is composed of leached tschernosem and the thickness is estimated to be 0.3 to 2 m. The alkali soil consists of solonetz; it is distributed as far as central Manchuria and is particularly remarkable in the areas from the vicinity of Tai-lai and Chen-tung to the area west of Tao-nan, the district of Kai-tung, and the vicinity of Chang-yu and Tu-chuan. In the sand-dune district, alkali-soda is exuded on the earth's surface in the dry season.

9. Problems of the Glacial Age in Manchuria

Kazuo FUJITA (1947) mentioned the following noticeable fact in his survey report of the Ta-hsing-an-ling mountain range. A rock detritus bed which con-

[11] Ed. Note: The second Sung-hua-chiang refers to the river above the junction with the Nen-chiang, or the part south of Fu-yu.

sists of fist-sized breccias is found at 200 to 300 m above the adjacent plain (1,000 m average elevation above sea level), and these breccias are frozen by pure ice. He maintained that this detritus was produced under a very cold climate in which the daily and yearly ranges of temperature were very large and vegetation could not grow. The present flora might have migrated in the successive temperate period.

Permanently frozen beds, which predominate in Siberia, might be formed under climatic conditions similar to the present Siberian climate, where the winter is long with very severe cold and scanty rainfall and the temperature in summer is relatively low. However, it is inferred that there was an age of severe cold in the past when the lower limit of the frozen bed was lowered as much as several hundred meters.

FUJITA opposed PLAETSCHKE's view that the permanently frozen bed and the glacial topography of the northern Ta-hsing-an-ling are associated. FUJITA maintained that the permanently frozen bed was formed in an arid high-latitude zone, while the mountain glaciers in east Siberia, which may be related to the glaciated stages of Pai-tou-shan and Kan-po-ho (KANO, 1937), were formed in a period when the air temperatures were rising, which may not have always coincided with the most flourishing stage of the permanently frozen bed. FUJITA's opinion is similar to SIMPSON's view. Though there may be some differences between the glacial ages of north Europe and of north Manchuria, the extent of the difference has not yet been determined. If the detritus bed, i.e., the permanently frozen bed, is prolonged toward the west, it may be correlatable with the frozen bed in Transbaikalia or in the Djalainor district. If the Djalainor formation, the mammoth-bearing frozen bed at Peryozovka, and the fossil bed at Afontova (Magdalenian) correspond with the severe cold stage of these frozen beds, then the Würm glacier stage in north Europe may correspond with the stage of permanently frozen bed in north Manchuria. If this is true, glaciers may not have developed in north Manchuria. This problem may be settled to some extent by the correlation of the Wisconsin glacial stage throughout Kamchatka, Alaska, and Canada.

Cirques on Pai-tou-shan (each *cirque* on Taishō peak, Matengu and Sōgan), U-shaped valleys above the timber line (2,000 m), a *cirque* on Mt. Minami Potai, and the *cirque* group on Kanbo peak are found in very scanty snow-fall districts of the present time. According to Gorō ASANO (1947), the Pai-tou glacier stage is considered to have come after the pumice eruption of Pai-tou-shan and before the mud lava eruption. The scantiness of *Pinus pumila* on Pai-tou-shan may be due to the eruption of the mud lava. The formation of the caldera, the formation of *cirques*, the migration of *P. pumila*, the eruption of mud lava, and the recession of *P. pumila* may have occurred in this order. It is regrettable that the relation between the Pai-tou glacial stage and the Ku-hsiang-tun formation has not yet been determined. This problem cannot be solved by studying only the relation between the plateau basalt and the Sangsambong clay bed, which is equivalent to the Ku-hsiang-tun formation and distributed in Sangsambong, Tonggwan-dong, Yen-chi, Lung-ching-chieh, and vicinity. We acutely feel the lack of data for Siberia.

10. Conclusion

1. The Quaternary system in Manchuria is roughly divided into three divisions, namely, the north Chinese facies (loess facies), the Mongolian facies (aeolian facies), and the Manchurian facies (flood-plain lacustrine facies). The first facies is distributed in the districts of Liao-hsi and Liao-tung with Jehol as its center. The second facies is mainly developed in the area west of the western slope of Ta-hsing-an-ling range, while the third facies is distributed mainly along the Sung-hua-chiang with the Manchurian plain as its distributive center. The trend of the boundary line between the north Chinese facies and the Manchurian facies is approximately NNE—SSW; it is a line connecting Cheng-chia-tun and Kai-yuan and corresponds to the Hei-liao divide. A piedmont facies is developed in the mountain district, and basaltic plateaus are also extensively distributed.

2. Types of the north Chinese facies, Mongolian facies, and Manchurian facies are the Liao-ho plain group, Djalainor formation, and Ku-hsiang-tun formation respectively.

3. Chronology of the Quaternary system in Manchuria approximately corresponds with that of north China and is divided into three sedimentation stages: the Chou-kou-tien stage in the lower Pleistocene, the Ma-lan stage in the upper Pleistocene, and the black earth stage in the Holocene, in ascending order. The Malan series is better developed than in north China, while the Chou-kou-tien series is not so remarkable. The Liao-tung stage, which is equivalent to the Ching-shui stage in north China, is found between the above-mentioned two stages (Chou-kou-tien and Ma-lan) and was a remarkable erosion stage. The so-called Liao-tung peneplain was formed in this stage. The flows of plateau basalt may have occurred then. Moreover, the Liao-ho erosion stage intervened between the Jehol loess, which corresponds with the Ma-lan loess, and the redeposited loess (equivalent to the Ku-hsiang-tun formation). The present erosion stage is the Sung-hua-chiang stage which can be correlated with the Pan-chiao stage in north China. The erosion stage between the Ma-lan stage and black earth stage (the Wen-chuan-ho) is the Wa-pen-yao stage or the Lao-ha stage.

4. Fissure deposits of the Chou-kou-tien type are found in the Hsiao-sheng-shui-ssu group or the Niu-hsin-shan group, and the lower part of the Niu-hsin-shan group is correlatable with the *Sinanthropus* group at Chou-kou-tien.

5. The complete formation of the Hei-liao divide was in the Lao-ho stage. Its slow upheaval movement may correspond with the terrace movement of Du_1 plane on the Japanese Islands, and it seems that a tectonic movement which divided the Manchurian facies and north Chinese facies was in progress from the Ching-shui stage. The Hei-liao divide is related to the tilting movement of the Korean Peninsula.

6. The fossil facies of the Ku-hsiang-tun formation is rich and contains plants, Mollusca, Insecta, Pisces, Reptilia, Aves, Mammalia, and others. The percentage of extinct Mammalia is less than the 75% of the *Sinathropus* group in Chou-kou-tien, but it surpasses the 43% of the Sjara-Osso-Gol in Ordos; it indicates an age of approximately middle to later Pleistocene. Rhinoceros, bison, wild horse, and deer are most abundant, and the appearances of *Struthio, Castor, Gazella, Bubalus,* and *Camelus* are noticeable. *Rangifer* has not been found.

7. The stone implement culture of the Ku-hsiang-tun formation shows the facies from the Mousterian to the Magdalenian, and was developed with the Würm glacier stage as the center. However, some geologists consider it to be a mesolithic culture.

8. Three human skulls (the Djalainor man) were found from the Djalainor formation. Stone implements which were unearthed with the skulls are small and are regarded to belong to the mesolithic culture.

9. It is considered that there is some relation between the detritus bed—permanently frozen bed on the Ta-hsing-an-ling range and the Würm glacier stage in Europe or the Wisconsin glacier stage in North America. The problem of the relation between the permanently frozen bed and the Djalainor formation or the Ku-hsiang-tun formation should be given attention in the future.

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Metallic Deposits in Manchuria

Tsutomu OGURA

1. History of Research on Ore Deposits

Japanese geologists had surveyed and studied ore deposits in Manchuria without distinguishing between metals and nonmetals. As early as the Sino-Japanese (1894–1895) and Russo-Japanese wars (1904–1905), mining investigations had been undertaken; afterward, research by the Geological Survey of the South Manchuria Railway Co., the Ryojun College of Engineering established in 1924, and universities and other organizations in Japan was carried out. After the establishment of Manchoukuo in 1932, government officials and company engineers took over these tasks.

According to tradition, mining operations in Manchuria began in the Kokuli age, *ca*. 950, but there is no direct evidence, such as mining ruins, for such a date. In some cases, there is comparatively recent evidence, the age of which can be estimated, but in very few instances do operations seem to have continued for a lengthy period.

The discovery and exploitation of mineral resources is dependent to a great degree on the human element and natural conditions such as climate and topography. In this connection it should be remembered that Manchuria was a thinly populated land with great areas unexplored and unpopulated, and that the inhabitants were unfamiliar with mining methods. Therefore, the development of mining could not be expected in difficult-to-reach districts. But the climatic conditions in Manchuria are favorable to the discovery of deposits. Generally the soil mantle is thin and bedrock crops out on the mountainland. Consequently, outcrops of deposits are easy to discover, and it sometimes happens that important ore bodies lie at relatively shallow depths.

After the establishment of Manchoukuo in 1932, research on Manchurian mineral resources and geology progressed, materials on ore deposits increased, and abandoned and newly discovered deposits were actively opened up. At the end of the war, there were more than 100 metal mines distributed all over Manchuria. Most of them were in southeastern and southwestern Manchuria; mines were rarely found in the central plain or in the northern mountainland and plateau.

2. Topography and Geology of Manchuria

Topographically and geologically, Manchuria may be conveniently divided into four regions:

Southeast mountainland	Liao-tung, Chi-lin, An-tung, Chien-tao districts.
Central plain	Liao-ho, Nen-chiang, Sun-hua-chiang districts.
Southwest mountainland	Chin-chou, Je-ho districts.
North mountainland and plateau	Ta-hsing-an-ling Mts., Hsiao-hsing-an-ling Mts., Hai-la-erh district.

(1) The southeast mountainland includes a wide area to the southeast of a line which may be drawn from southwestern Liao-tung to Fu-yuan in the lower reaches of the Sung-hua-chiang, through Mukden, Hsin-ching, and Harbin. On the southeast it borders the northwestern region of Korea and the Soviet coastal province, taking a fusiform shape elongated in a NE-SW direction. Liao-tung, Chang-pai, and Wan-ta mountains make a backbone, from northeast to southwest, and the Saha-ling and Lao-chang-kuan-sui-ling mountains lie parallel to these ranges. These principal ranges tower over 1,000 m above sea level and their features are deeply incised.

As to the distribution of geologic formations in this mountainland, the Archean and Proterozoic formations are developed chiefly in the Liao-tung Peninsula, the Lower Paleozoic formation occupies scattered areas in Liao-tung and the vicinity of the Tai-tzu-ho River, and the Upper Paleozoic is developed in association with the Lower Paleozoic and also in the Chilin and Tung-an districts. The Mesozoic formation exists chiefly on the northwestern and southeastern borders, and the Tertiary along the northwestern border or outer rim of the Mesozoic. Igneous rocks are granite, gneissose granite and basalt, occupying over two-thirds of the region; there is also a small quantity of basic intrusive rocks. These formations stretch northeast to southwest, being parallel to the outline of the region, with a zonal distribution.

The principal deposits of the region, gold, silver, lead, zinc, and copper, and minor deposits of tungsten, antimony, and chromium are genetically related to the igneous activities of the early Mesozoic age. Such bedded deposits as iron, aluminum, magnesium, and pyrite are characterized by their association with the Proterozoic to Paleozoic formations.

(2) The central plain occupies a wide area 1,300 km N-S and 400 km E-W in the Manchurian plain, covering the drainage basins of the Liao-ho, the Nen-chiang and the Sung-hua-chiang. It has altitudes of 40 m above sea level in the southern part near Hsin-min-tun, 300 m in the northern end near Mo-erh-ken and 300 m at the highest point in the central part near the Hei-Liao divide.

This region consists essentially of Quaternary sediments, and notable mineral resources are not known.

(3) The southwestern mountainland includes Chin-chou and Jehol districts. The highland mountain ranges parallel each other in a NE-SW direction. There is a gradual change in elevation from the northwestern part, which is more than 1,000 m above sea level, down toward the southeast which is 300 m above sea level.

In this region the Archean formation principally occupies the central part, the Lower Paleozoic the southeastern, and the Mesozoic the central and southeastern parts. Granite is developed in places, and basalt in a wide area of the northwestern part. These formations are parallel to the NE-SW orientation of the southeastern mountainland. Principal metallic deposits of this region are gold, silver, lead, zinc, manganese, iron, tungsten and mercury ores. These deposits are genetically related to the igneous activities of the Mesozoic age.

(4) The north mountainland and plateau include the Hsiao-hsing-an-ling, Ta-hsing-an-ling mountains and the Hai-la-erh plateau. The Hsiao-hsing-an-ling mountains stretch from northwest to southeast and attain an altitude of 1,400 m above sea level, the Ta-hsing-an-ling mountains run from NNE to SSW and have a maximum altitude of 1,700 m. The Hai-la-erh plateau has an average altitude of 550 m, with much barren area.

The region is primarily occupied by granite; Lower and Upper Paleozoic and Mesozoic formations are distributed in an east-west direction and neovolcanic rocks are rare. The plateau district is covered mostly by desert deposits. Mineral resources are generally poor, and metallic deposits are placer gold and smaller amounts of copper and lead ores.

3. Formation of Ore Deposits and Their Age

Metallic deposits in Manchuria include gold, silver, lead, zinc, iron, copper, and manganese (magnesium and aluminum) as well as tungsten, pyrite, mercury, molybdenum, chromium, uranium, niobium, and tantalum ores. These deposits may be classified on the basis of igneous and sedimentary origin. It is a significant fact that in Manchuria iron, placer gold, manganese, and pyrite deposits of sedimentary origin and iron deposits of dynamometamorphic origin are developed on a large scale, whereas in Japan metallic deposits of igneous origin are by far superior to those of sedimentary origin. Deposits may also be classified on the basis of the mode of occurrence; deposits bedded in stratified rocks and metallic deposits are genetically related to igneous rocks.

Concerning the bedded deposits, the geological age, kind of ore, and area of occurrence of the bedded deposits are shown as follows.

Geological age		Kind of ore	Area
Archean			
Proterozoic			
	Liaoho system	Banded iron ore	SE mountainland .... An-shan
		Magnesite	SE mountainland .... Ta-shih-chiao
		Iron ore	SE mountainland .... Ta-li-tzu, Chi-tao-kou
	Sinian system	Iron ore	SE mountainland .... Lao-ling, Hsu-chia-tun
		Manganese ore	SW mountainland .... Wa-fang-tzu
Lower Paleozoic			
Upper Paleozoic		Iron ore	SE mountainland .... Niu-hsin-tai
		Pyrite	SE mountainland .... Pen-hsi-hu, Yen-tai
		Aluminous shale	SE mountainland .... Pen-hsi-hu, Yen-tai, Niu-hsin-tai, Hsiao-shih
Mesozoic			
Cenozoic		Placer gold	All regions

Igneous activity may be divided into six periods: 1. pre-Paleozoic (granite family), 2. Paleozoic (ultrabasic rock), 3. Early Mesozoic (granite, diorite, granite-porphyry, pegmatite), 4. Jurassic (intermediate rock), 5. Late Mesozoic (granite, diorite, granite-porphyry, quartz-porphyry, porphyrite, trachyte, andesite), and 6. Tertiary to Recent (alkali trachyte, basalt). Of these the activities of the Early and Late Mesozoic periods were most important for the formation of ore deposits.

Principal metallic deposits having direct and indirect genetic relations to igneous activity are as follows:

Age	Kind of rock	Area	Kind of ore
Early Mesozoic	Granite, granite-porphyry	SE mountainland	Lead, zinc, copper, molybdenum, tungsten, gold, antimony

	Granite, granite-porphyry	sw mountain-land	Gold
	Pegmatite	SE and SW mountainlands	Uranium, niobium, tantalum
	Serpentine	sw mountain-land	Chromite
Mesozoic	Gabbro	sw mountain-land	Vanadium-iron ore
	Andesite	sw mountain-land	Silver, lead
Late Mesozoic	Granite	sw mountain-land	Gold, manganese, mercury, silver, zinc, copper, iron, tungsten, molybdenum

In view of these facts, we know that the principal sedimentary deposits in Manchuria, were formed in the Paleozoic or earlier that the origin of igneous metallic deposits, irrespective of the kind of ore, is related to early Mesozoic igneous activity in the southeastern area, and that the formation of deposits in the southwest had an intimate relation to the igneous activity associated with the so-called Yenshan crustal movement in the early to late Mesozoic age.

4. Kinds and Classification of Ore Deposits

Metallic deposits in Manchuria do not show much variety; there are about ten workable deposits: gold, silver, lead, zinc, iron, copper, manganese, pyrite, tungsten, and molybdenum. Minor ores of mercury, antimony, chromium and uranium were mined to some extent. Aluminum and magnesium ores are not considered in this review.

The ores may be classified into the following types of deposits:

Type of deposit	Kind of ore
Magmatic segregation deposits	Vanadium-iron ore, chromite
Pegmatite deposits	Uranium, niobium, tantalum
Contact-metamorphic deposits	Gold, silver, lead, zinc, iron, copper, manganese, molybdenum
Fissure fillings and metasomatic deposits	Gold, silver, lead, zinc, copper, iron, manganese, pyrite, tungsten, molybdenum, antimony, mercury
Impregnation	Copper, pyrite, molybdenum
Sedimentary deposits	Iron, manganese, pyrite, aluminum
Placer	Gold
Dynamometamorphic deposits	Iron

On the Gold Ore Deposit of Chia-pi-kou and Lao-chin-chang

Hiroshi OZAKI

1. Location

The mines are located at about 170 km east of Pan-shih Station on the Feng-tien-Chi-lin Line. There is an automobile road between the station and the mines, but it has to cross the Sung-hua-chiang River twice, at Hua-tien and Hung-shih-la-tzu and the wooden bridges at these points are subject to damage. In addition, the river course above Hung-shih-la-tzu meanders and in many places the road has been cut in the cliffs and has many curves and changes in grade.

The ore is transported between Lao-chin-chang and Chia-pi-kou by means of an aerial ropeway, but men and materials have to depend upon truck service over the road, which is 16 km long.

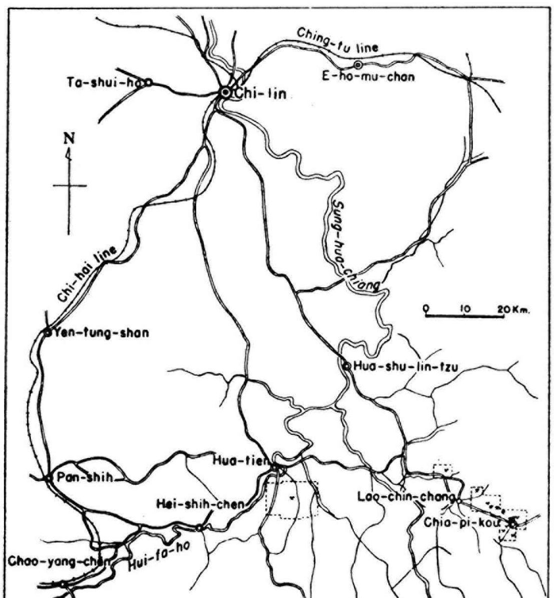

Fig. 1. Map Showing the Location of Chia-pi-kou and Lao-chin-chang Gold Mines.

2. History

Placer gold fields in Manchuria were discovered by smugglers of ginseng during the Ching dynasty. The gold fields were exploited in accordance with the size of the deposits, and Chia-pi-kou and Lao-chin-chang are among the most famous gold fields.

The valleys of Chia-pi-kou were worked out everywhere by multitudes of Chinese from the downstream area. At the top of the creek they discovered a large outcrop of a gold-quartz vein, more than 4 m wide, and the mining operations were changed from placer mining to gold vein mining. At the peak period, around 1847, the number of men mining gold was reported to be forty thousand.

The gold-quartz vein was divided along the outcrop into appropriate lengths, and a gang including as many as thirty persons was assigned to work each section. The old names of pits, such as Pa-jen-pan and Shih-san-jen-pan, literally "eight-man gang" and "thirteen-man gang," remind us of the ancient work system.

Because of primitive mining methods, the work may have been checked in some places by gushing water. However, important bonanzas were worked to greater depths by setting closely-spaced wooden pumps along the slope and removing water by a relay method with hand buckets.

The rich ore may have been worked by a selective mining method, as the pillars left in the old work places show a grade of over 10 gr of gold per ton, hence the crude ore at that time may have been richer than 20 gr per ton.

In 1902, just after the North Manchurian Incident, Russians entered the area and set up a boiler plant preparatory to starting mining operations, but they left at the outbreak of the Russo-Japanese War in 1904. In 1915 mining rights were obtained by a Sino-Japanese corporation, but the mine was not taken over and no enterprise resulted.

Since then, the actual administrative rights of the mine remained in the hands of the Han family, descendants of the initial owner of the mine.

In June 1938, upon investigation of the mine, the Manchurian Mining Company (Manshu Kozan K. K.) decided to reopen the mine and introduce modern mining methods. The company established an all-sliming flotation plant with a capacity of 3,000 tons a month at Chia-pi-kou and planned to start exploitation there.

Later, Lao-chin-chang was transferred from the Manchurian Gold Mining Company to the Manchurian Mining Company. Regular operation of the Chia-pi-kou mine was begun in 1940, and of the Lao-chin-chang in 1942, but security and transportation problems have greatly hampered the construction work.

Separate descriptions will be given of these two mines.

3. Geology and Ore Deposits

A. Chia-pi-kou Mine[1]

1. *General geology*

The rocks present in the mine area may be classified as follows:

Gneiss group
- Amphibole granite gneiss
- Injection gneiss
- Aplitic granite gneiss
- Amphibole diorite
- Amphibolite
- Hornfels

Dike rocks
- Porphyrite
- Porphyry
- Felsite
- Spherulitic granophyre

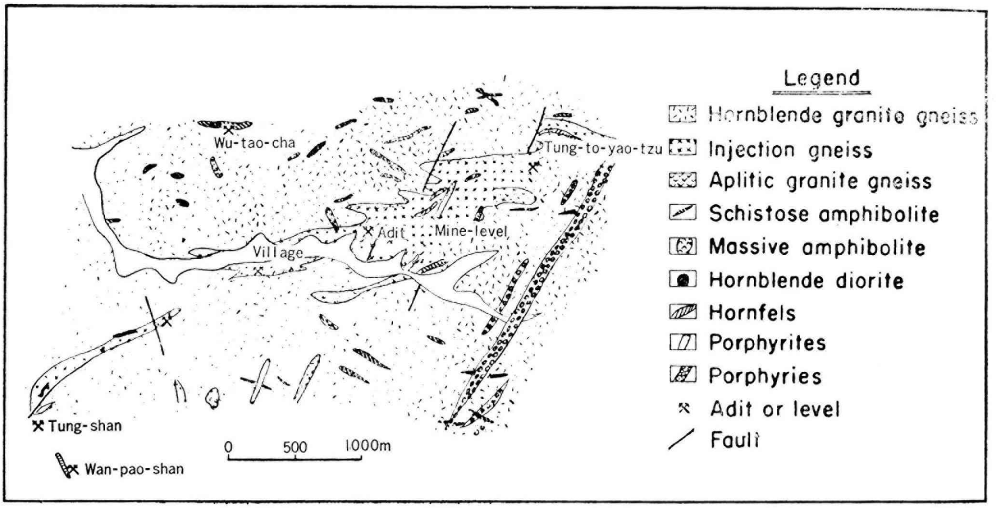

Fig. 2. Geological Map of Chia-pi-kou Gold Mine.

Amphibole granite gneiss is widely distributed in this district, and poorly defined bands of injection gneiss striking northeast within the granite area form an important ore zone. Hornfels appear in a schlieren-like form along the schistosity only in the central part of the injection gneiss. Hornfels are not seen in the sur-

[1] M. Hotta made a detailed investigation of the mine for his graduation thesis during the author's tenure of office there. The material for the major part of this chapter was supplied by his investigation.

rounding hornblende granitic gneiss. Amphibolite is generally not present in the central part of the injection gneiss, but is commonly found along the schistosity of hornblende granitic gneiss, and in deposits of various sizes. The planes of schistosity of the gneiss group generally trend E-W, and dip 20°–50°S. However, the trend of the gneiss group located east of the main adit is N70°–80°E and to the west the trend becomes N70°–80°W so that the schistosity trend forms a convex curve bending southward. The dip angle of the schistosity varies only slightly. But there is an area between the Honko pit and Tung-to-yao-tzu where the strata are almost horizontal, and around Tung-shan-chin-chang in the south dips are as gentle as 20°.

A noteworthy feature is the relation between injection gneiss and hornblende gneiss. The injection gneiss may be seen as large roof pendants within the hornblende granite gneiss, and the injection gneiss masses are apt to become narrower deep underground. The trend of injection gneiss is generally northeast on the surface, but at its boundary with the hornblende gneiss interfingering occurs underground, though it may be obscure. The branched portions generally trend east in accord with the general trend of schistosity of the district.

The amphibolite in the honrblende granitic gneiss often shows sharp boundaries, but the boundaries of the other gneiss types are generally not clear.

Hornfels and ordinary amphibolite are found within the injection gneiss and hornblende granite gneiss, respectively, as schlieren-like inclusions or as roof pendants parallel to the schistosity. The widths of the distinctive masses generally range from 1 to 10 m.

Hornblende diorite and aplitic granite gneiss are thought to be injections into other types of gneiss. Hornblende diorite is found underground at Tung-to-yao-tzu as an extremely small mass; its relation to the gneiss is not clear. It may represent a magma of aplitic granite gneiss at its end period. The rock is fine- or medium-grained and might be properly called gneissose granite; it also has intercalated amphibolite.

The majority of the faults of the district strike within a range of N20°W to N30°E and are almost vertical. They cross the schistosity at nearly right angles. A fault at the eastern end of Pa-jen-pan has a throw of over 100 m, but elsewhere the throw is generally not more than 10 m.

Dikes generally have an orientation similar to the faults of this district. As stated above, the rock can be divided roughly into a gneiss group and dikes. The gneiss group shows a common schistosity trend. It is generally characterized by such features as richness of epidote; presence of mosaic-like, fine-grained green mica; formation of green mica from the cleavage or the periphery of hornblende, where the latter is present; and remarkable saussuritization of plagioclase. These characteristics may be the result of certain deuteric actions affecting the gneiss group.

Dikes are also generally subject to deuteric action, but they fail to show as many mineralogical similarities as the gneiss group. However, there are dikes intermediate between porphyry and spherulitic granophyre in character, which indicates that the rocks may form a series.

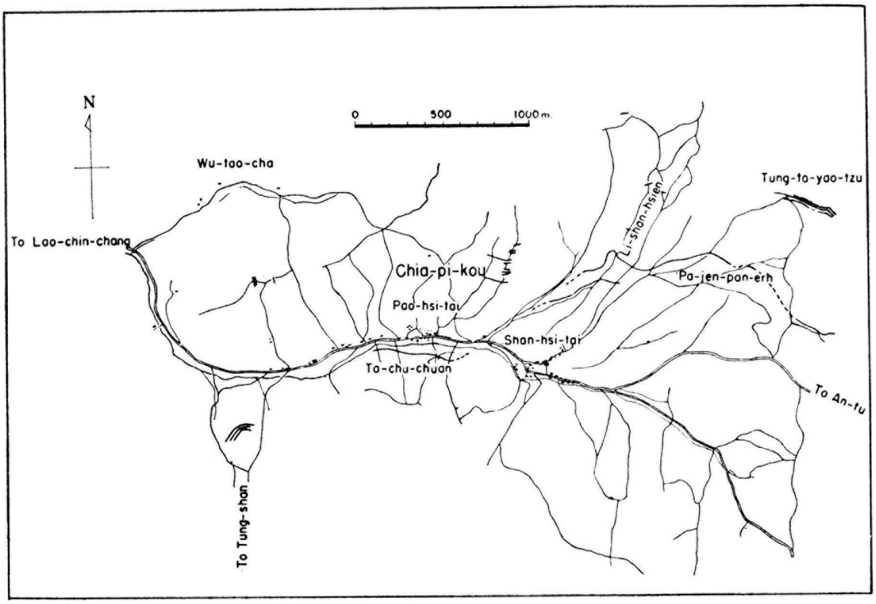

Fig. 3. Map Showing the Distribution of Gold-bearing Quartz Veins at Chia-pi-kou Gold Mine.

2. *Ore deposits and ore*

Within the Chia-pi-kou area, exploitation proceeded at Tung-ta-yao-tzu, Pa-jen-pan main pit, Li-shan-hsien, Ta-chu-chuan, Hsia-hsi-tai, Chu-pao-shan, Tung-shan, Wan-pao-shan, Wu-tao-cha and elsewhere.

Of these locations, the Pa-jen-pan main pit, Li-shan-hsien, Hsia-hsi-tai, Tung-shan, and Wu-tao-cha were thought to be the most promising. The vein at Pa-jen-pan, with a uniform thickness of over 4 m, and the several veins at Li-shan-hsien with thicknesses ranging from 50 to 100 cm, are the best veins of the mine.

The dip and strike of these veins is generally in accordance with that of the country rock, and so the veins of the northern side are at an apparently lower horizon. Thus, Tung-to-yao-tzu———Pa-jen-pan, Li-shan-hsien———Hsia-hsi-tai———Chu-pao-shan———Tung-shan is the apparent order of succession. Wu-tao-cha is located on the western extension of the Tung-to-yao-tzu vein and extends for about 2.3 km.

a. Subsurface geology

As stated above, the mine has numerous ore veins, which were worked by Chinese miners as deep as the ground water level or even deeper. Prospecting tunnels were driven by Japanese engineers after the reopening of the mine, and the veins have now been surveyed in detail. As a result working faces have been confined to Pa-jen-pan, Li-shan-hsien, Tung-shan, and Wu-tao-cha.

The main pit and adit were opened to work Pa-jen-pan and Li-shan-hsien from the hanging wall side and in a direction oblique to the strike line. The shaft of Hsia-hsi-tai was driven from the hanging wall side to the vein. Level pits were driven at Tung-shan and Wu-tao-cha from outcrops; but at Tung-shan, a crosscut tunnel was built 30 m below the main level for use as a haulage road as the mining work progressed.

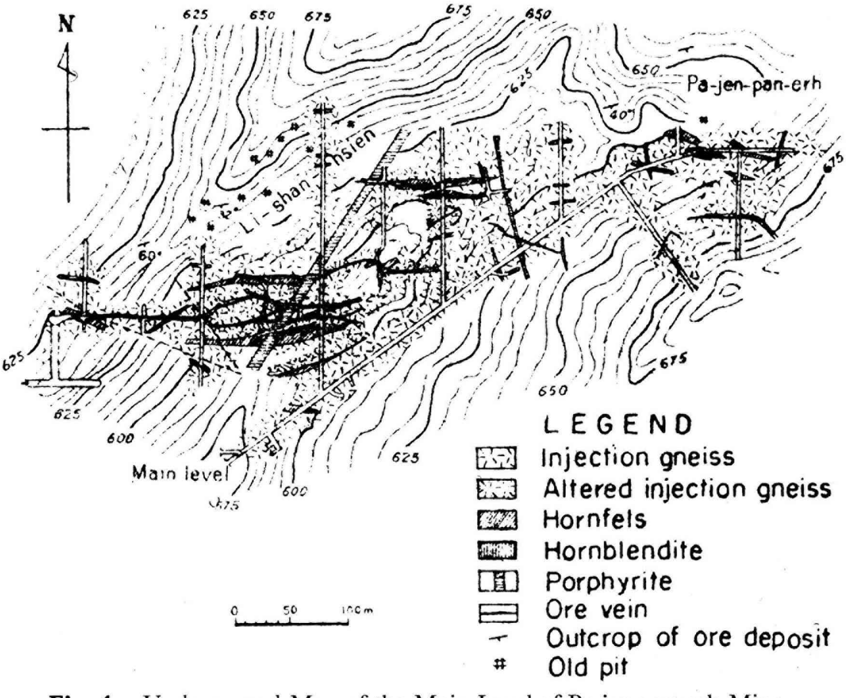

Fig. 4. Underground Map of the Main Level of Pa-jen-pan-erh Mine (According to M. HOTTA)

The vein of Pa-jen-pan has been prospected and mined by the main pit and adit. At its west end the vein has been changed into siderite, thin stringers of which occur within the undulating hornfels. By carefully tracing the thin, white stringers, a quartz veinlet 5–10 cm thick was seen to reappear in the driving head. Its thickness increases to 40–50 cm at a spot about 40–50 m to the east, and at last the veinlet becomes a solid vein more than 2 m thick.

The main body of the Pa-jen-pan ore vein is generally 2–4 m thick, and has scores of smaller veins branching from it on the foot wall side. Each branch vein has a thickness of 5–20 cm and contains much pyrite and a minute amount of chalcopyrite. The veins have a high gold content and may contain scores of grams of gold per ton. Some of the old workings are thought to be relics of selective mining on the bonanzas of branch veins. The main vein of Pa-jen-pan has a horizontal extension of about 400 m and is as thick as 8 m at its east end, where it is faulted by a vertical fault which trends north. This fault is the largest one of the area, but it cannot be detected at the surface. Two prospecting tunnels were driven through the fault plane to search for the extension of the vein, but failed to reveal the vein within a distance of 100 m.

The walls of the main vein consist of hornfels or schist; however, to the south, they dip down and become thin and the vein tends to border directly on the gneiss.

A characteristic of the Pa-jen-pan is the absence of parallel veins. There are a few quartz veinlets, but they are quite barren of gold.

Li-shan-hsien is found within the western extension of the hornfels zone that forms the country rock of the Pa-jen-pan deposit.

The zone may also be called, more broadly, a zone of injection granite, but in many cases the rock constituting the walls of the veins is found to be either fine-grained mica schist or hornfels. Such wall rocks may not be more than several meters thick but are a noticeable characteristic.

The biotite schist contains small isoclinal folds on the walls of the ore veins, and in some spots the veins are seen to run along a gently inclined fault plane.

Li-shan-hsien has as many as 10 parallel veins which are interlaced to form a large network.

The length of the veins ranges from 80 to 120 m, and the thickness from 50 to 100 cm, but the horizontal extension of a vein rarely exceeds 250 m. If the veins should extend into an anticlinal structure of the country rock, they would gradually become thinner or eventually peter out.

The veins are generally rich in sulphide, and portions contain visible gold grains.

An interesting point is the fact that a horizon corresponding to the extension of the Pa-jen-pan vein, namely some lower veins of Li-shan-hsien, contained scheelite in many places, although gold was not necessarily plentiful in this part.

Wolframite is rarely found in the rich ore, which is filled with chalcopyrite-gold-bithmuthinite-galena-quartz stringers according to the report by Hotta. The author unfortunately has failed to discover such ore during several years of studying this mine in operation. On the basis of his experience, the author believes that the rich ore of the mine, associated with chalcopyrite and galena, might correspond to the upper veins of Li-shan-hsien.

Li-shan-hsien, with a uniform gold content, generally 10–15 gm per ton, is a very important site in the mine. The veins of Li-shan-hsien are narrow to the west for a distance of 120 m and then fade away.

The country rock at the western part shows a gradual transition from dark green mica schist to injection gneiss, and with detailed measurement of the dip angles a gentle anticline structure can be detected there. The dip tends to become gentle in the part where the veins fade away.

The character of the veins and the grade of ore at Pa-jen-pan and Li-shan-hsien have obviously been influenced by the character and structure of wall rocks. The veins are pierced by N-S trending dikes but the dikes do not appear to have affected the grade of ore of the veins.

The veins of Hsia-hsi-tai are found on the southern bank of the stream that flows south of the village of Chia-pi-kou. They should lie at a horizon of about 200 m, stratigraphically higher than the uppermost vein of Li-shan-hsien.

The outcrop was disturbed by random workings in the past, but pieces of rich ore, often as high as 100 gm of gold per ton, were obtained from the refuse dump. Therefore, a shaft was sunk there to pursue the veins. As a result, two ore veins with thicknesses from 30 to 50 cm were encountered. They have a general E-W strike and dip 25°S. The lower vein contains a higher grade ore. It diverges into two veins which reunite further on. The length along the strike is more than 100 m, and the ore assays at 7–8 grams of gold per ton. It is characterized by a country rock of dark gray mica schist (farther outside there is an injection gneiss), and also by the presence of some galena in the ore vein. The galena consists mainly of small crystals of less than 1 mm, and the crystal form is scarcely visible to the naked eye. The lead content of the vein is less than 0.5 percent, and thus of no commercial value. Unlike Li-shan-hsien, the Hsia-hsi-tai vein does not contain scheelite.

The Tung-shan vein is located at about 2.8 km southwest of the main adit. It occurs in a horizon higher than that of the vein of Hsia-hsi-tai. It has a strike of N 60°E, dips 20°S, and is nearly parallel to the veins of Li-shan-hsien and Hsia-hsi-tai. The Tung-shan vein has not been developed deep underground, so the interval from there to the Hsia-hsi-tai vein is not known. The distance has been roughly estimated to be 200–300 m. The Tung-shan vein has a total length of 400m, of which 100–120m are fairly uniform, with an enlarged portion of about 2m, but the western end becomes gradually thin. The eastern end of the vein is exposed on the surface, and has been eroded, but the deeper part has not yet been worked. It contains pyrite, a minute quantity of chalcopyrite, and small crystals of galena. In places a grade of 3 per cent lead is maintained for a horizontal distance of 20 m. Zincblende is also contained in minute amounts, but is invisible to the naked eye.

This vein has the lowest gold content of all the veins in the Chia-pi-kou area, having an average of 4–5 gm of gold per ton.

The vein of Wu-tao-cha is located 1.3 km northwest of the main adit, and 1.7 km west-northwest of the veins of Li-shan-hsien. It is thus some distance from the other veins of Chia-pi-kou. The area around the vein consists of hornblende granite gneiss, but the immediate wall consists of several meters of schist, which is a prospecting criterion. The main ore consists of chalcopyrite and pyrite, with a copper content of 0.5–0.6 per cent, but the gold content is not high, being possibly 5–6 gm per ton. The vein has a length of 100 m, and for the most part, has a thickness of 20 cm. Only very rarely is it more than 50 cm thick.

b. Ore

Throughout the veins of the Chia-pi-kou area, the ore consists mainly of translucent white quartz. Although the ore is not characterized by banding or brecciation, the sulphide minerals are often arranged in obscure bands.

In the case of the Tung-shan veins, the galena assumes a banded arrangement at the central part of the vein.

The gold is apt to be accompanied by sulphides, especially pyrite and chalcopyrite. The copper content rarely exceeds one per cent. The ore can be roughly divided into the following five types:

Type 1. The ore consists mainly of chalcopyrite and pyrite with associated magnetite and pyrrhotite; this is the dominant and the rich-ore type in Chia-pi-kou. The ore minerals are primarily in small crystals scarcely visible to the naked eye, but the pyrite of Pa-jen-pan is rather coarse, not infrequently attaining a size of several millimeters.

Under the microscope, the ore rich in sulphide minerals shows an undulating, brecciated structure of vein quartz. Pyrite appears in vein form within the brecciated part of the quartz, and chalcopyrite fills the fissures of pyrite. In a few cases pyrrhotite and gold-grains are in association with chalcopyrite.

Representative localities of this ore are Pa-jen-pan and Li-shan-hsien, the latter having an especially high copper content, for the most part over 0.3 per cent, and containing over 20 gm per ton of gold. However, the amounts of copper and gold are not necessarily proportional.

Type 2. Magnetite, sericite, and a little calcite are crowded together to form gray-black bands.

Type 3. This is a rich gold ore containing tabular crystals of wolframite, and a large amount of associated chalcopyrite and pyrite. Ore of this type was reported by HOTTA to occur very rarely, and the author could not obtain any such sample, even after careful inspection underground. Because of the nature of the ore it is probable that the type might be found at Pa-jen-pan or Li-shan-hsien.

Type 4. Ore containing scheelite is found in the lower vein of the western part of Li-shan-hsien, and in the low grade ore. The ore has a rather low sulphide mineral content, and crystals of pale brownish scheelite of finger to head size are scattered throughout the white quartz. Portions, however, contain 0.3 per cent WO_3 (tungsten oxide).

Type 5. Ore with galena and pyrite is present in the veins of Tung-shan. Ore of this type occurs in the uppermost horizon of the Chia-pi-kou area.

The ore veins of Hsia-hsi-tai are intermediate between type 1 and type 4 and contain pyrite, chalcopyrite, and a little galena.

3. *Ore minerals and paragenesis*

a. Ore minerals

As far as the ore minerals within the Chia-pi-kou area are concerned, the minerals formed at higher temperatures are in the ore veins of the apparent lower horizons. The ore minerals are magnetite pyrrhotite, wolframite, scheelite, pyrite, chalcopyrite, galena, marcasite, gold, hematite, and bismuthinite; the gangue minerals are quartz, sericite, calcite, siderite, and chlorite. The crystallization of quartz and calcite obviously took place during more than two periods. Some quartz has penetrated through the dikes that dissected the ore veins. Calcite is found for the most part at the tapering portion oi the veins.

Quartz No. 1: The major part of the quartz belongs to this type. It is white and massive, and the brecciated portion has been mineralized to form the rich ore.

Siderite: The siderite had a very long period of crystallization. It started crystallizing in the early period and was accompanied by the chalcopyrite of a later period.

Scheelite: The scheelite is deep orange-yellow and is found as pockets or stringers in quartz veins. It is crossed by stringers of quartz-siderite-pyrite, and in places shows a crystallization contemporaneous with grayish calcite.

Wolframite: According to Hotta, rich ore of wolframite is rarely found. It forms deep brownish tabular crystals. He reported that it shows a reflection color similar to that of magnetite, has a very low hardness and polarization colors. It may represent the earliest stage of crystallization of all metallic minerals and may be nearly comparable to pyrite. The fissures of wolframite are often filled with stringers of chalcopyrite-gold-bismuthinite-galena-quartz, and the surface is often crusted with bismuthinite, according to Hotta. Manganese is detected rarely in qualitative analyses, so the mineral may be ferberitic wolframite.

Of the tungsten-minerals, scheelite often accompanies calcite, and wolframite is associated with pyrite.

Scheelite may be a little earlier than wolframite in the period of crystallization.

Calcite No. 1: This is the calcite of the earlier stage of crystallization. The grayish crystals, 0.5–1.0 mm in size, are found as aggregates and as indistinct veins within the quartz vein or sericitized country rock.

Pyrite: Pyrite is the dominant ore mineral. It is found as aggregates of small individual crystals or in massive form. In addition, it is widespread in the country rock in veinlets of quartz-pyrite-chlorite-sericite. Fairly coarse pyrite crystals, in pieces, 2–3 mm and larger, are often found in the vein of Pa-jen-pan.

Hematite: Only a very minute amount of hematite occurs; it is rarely associated with pyrite.

Magnetite: For the most part magnetite is closely associated with sericite, but it replaces siderite locally along the cleavage.

Sericite: Sericite is closely associated with magnetite, and often forms gray stringers within the quartz.

Calcite No. 2: This calcite is hardly visible to the naked eye. It is associated with aggregates of magnetite-sericite. Elsewhere it is in narrow veins belonging to the later stage of crystallization.

Pyrrhotite: Pyrrhotite is found uniformly but in small amounts, and is always associated with chalcopyrite.

Chalcopyrite: Chalcopyrite is one of the most important ore minerals and ranks next to pyrite in abundance. It was precipitated along the quartz fissures in association with pyrite and siderite and shows no crystal form. It is accompanied by pyrrhotite, or magnetite, or occurs as fissure fillings in the other minerals in association with galena, gold, and bismuthinite.

Galena: It is reported that in the veins of the lower horizon, a minute amount of galena is found, rarely, in fissures of wolframite in association with chalcopyrite and gold. As the veins become stratigraphically higher, the amount of galena increases gradually and may reach 3 per cent, as in the veins of Tung-shan. It is associated with a minute amount of zincblende.

Gold: Gold is present in association with chalcopyrite; it fills the fissures of wolframite or the fissures of quartz. It is found, rarely, in association with magnetite. The gold content is apt to be lower where scheelite is present. However, the exact relationship between these two minerals is not known. The gold content does not increase with an increase in the amount of galena. In general 4–5 gm per ton of gold are present where there is an appreciable amount of chalcopyrite or pyrite.

Bismuthinite: Bismuthinite is hardly discernible under the microscope. In the Wu-lung Mine, Antung Province, a barren quartz vein was found to contain as much as 10 gm of gold per ton where bismuthinite was present. Therefore, an occurrence of bismuthinite in this area would be worthy of notice.

Calcite No. 3: This is the calcite of the last crystallization. It was found by Hotta at only one spot and consists of a white vein formed of an aggregate of microcrystalline calcite. One side of the vein is marked in places with large crystals of colorless, transparent calcite.

Quartz No. 2: The porphyrite, penetrating the lower veins of Li-shan-hsien, is traversed by quartz veinlets, parallel with the principal ore vein near its hanging wall. These consist of gray quartz with a thickness of about 10 cm. No metallic mineral is present.

Marcasite: Marcasite is closely associated with pyrite, and is thought to be a secondary mineral.

Chlorite: Chlorite forms stringers along the fissures of quartz and often has a ribbon-like appearance. Chlorite is often present in the boundaries between quartz and other minerals. The chlorite is generally green, and, rarely, is deep yellowish. It is considered a remnant of the country rock captured in the vein, and is dominated by "dirty" appearing material.

b. Paragenesis

The order of crystallization, as established by surface and underground survey as well as by microscopic studies, is shown in the following list:

Quartz
Siderite
Scheelite
Wolframite
Calcite

Pyrite
Hematite
Magnetite
Sericite
Pyrrhotite
Chalcopyrite
Galena
Gold
Bismuthinite

4. *Conclusion*

Numerous quartz veins have been found in this area. Those veins that are colorless, transparent or white, coarse-grained, and lacking in sulphide are generally barren of gold; the gold is generally associated with sulphide minerals. The deposits which are closely related to the hornfels schlieren that form a roof pendant within the gneiss generally have a high gold content. It was learned that the old prospecting adits were generally driven along the quartz veins within the green country rock.

Locally veins in association with the green dikes were also prospected, but without success.

The trend of the gold-bearing quartz veins, in accord with that of the country rock, is roughly E-W, and the veins dip 20°–30°S.

The principal veins which have been worked are the Tung-to-yao-tzu, Wu-tao-cha, Pa-jen-pan, Li-shan-hsien, Hsia-hsi-tai, and Tung-shan veins, in apparent ascending order. The largest of these is Pa-jen-pan; the richest ones may be Pa-jen-pan and Li-shan-hsien. Pa-jen-pan probably contains wolframite, and Li-shan-hsien, scheelite.

The veins of Hsia-hsi-tai and Tung-shan, the apparent upper veins, contain galena. This may indicate a gradual gradation to low temperature during genesis, in view of the mineral compositions.

B. Lao-chin-chang Mine

1. *General geology*

The following rocks are present in the area:

Hornfels
Metamorphosed porphyrite
Amphibole diorite
Garnet-bearing amphibole schist
Quartz monzonite
Gold-bearing quartz veins and microgranite
Quartz porphyry and felsite
Porphyrite

Gold-bearing quartz veins were intruded into quartz monzonite or were injected as fine veins into the shear zone of the quartz monzonite, which is associated with hornfels, and form a broad silicified belt. They extend for 5 km and have a general northwest strike. The strike shows a degree of deviation at the northwestern part, becoming N20°W at Ta-chin-niu.

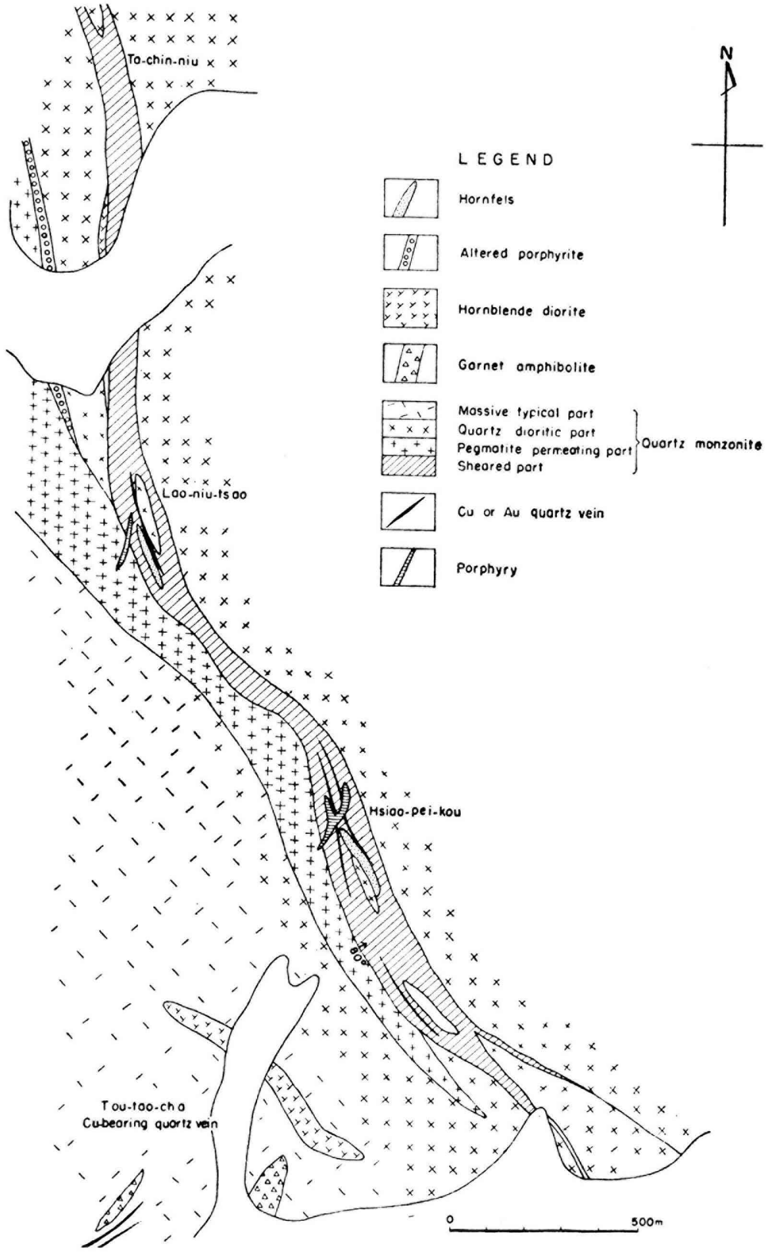

Fig. 5. Geological Map of Lao-chin-chang.

Quartz monzonite is found in the southwestern mountains of the ore deposit zone. It is a massive rock often containing garnet and encloses amphibole diorite and garnet-bearing amphibole schist. At Tou-tao-cha a copper vein of small horizontal extent, with an average thickness of 20–30 cm, has been found within the quartz monzonite. The ore contains 0.6–1.2 per cent copper. The northwestern part of the ore deposit zone consists of a quartz diorite-like rock which encloses thin layers of garnet-bearing amphibolite and large masses of amphibole diorite. The beds have a schistosity which trends N30°–50°W. The quartz monzonite is generally gray, and the quartz in many cases cloudy white, especially in the southwestern masses of the ore deposit zone.

Amphibole schist and diorite may be roof pendants within the monzonite rocks.

A shear zone trending northwest runs along the petrographic boundary of the quartz monzonite rock. It is as broad as 200 m at the southeast part around Hsiao-pei-kou and Lao-niu-kou. In this zone the dark gray portion and the purple schistose rock are finely alternated. They dip 70°–80° NE or are almost vertical.

The shear zone gradually becomes narrower to the north-northwest. At Ta-chin-niu it is 50 m wide. Farther to the north-northwest it finally becomes the schistose rock of both walls of the ore vein.

2. *Ore deposits and ore*

The ore deposits are the silicified part of the brecciated zone and the fissure-filling vein within the shear zone. Quartz veins are often found within the quartz monzonite rocks, but they are almost barren of gold. The only exception is the copper vein worked at Tou-tao-kou.

Quartz monzonite assumes a batholith-like aspect. Its injection may have caused a shear zone along the pre-existing hornfels, and the formation of the ore deposits within this shear zone.

Under the microscope, the twin lamellae of feldspar are seen to be very strongly curved, showing that the quartz monzonite was subjected to crushing.

Gold is associated with the portions containing minute crystals of pyrite and chalcopyrite. Underground samples were taken of the vein at Ta-chin-niu in portions where sulphide was present and where it was absent. Where sulphide was present the gold content was found to be 19 gm per ton whereas only a trace of gold was found where no sulphide was present.

The most prominent deposit consists of the veins of Hsiao-pei-kou near the southeastern end of the shear zone. There are several parallel veins here which are joined together in part. Generally they are narrow, about 0.5 m, at the west side. But to the east the deposit occupies the silicified zone itself and has a thickness of 8 m and a gold content of 5–12 gm per ton. This prominent portion extends for a distance of 200–250 m. The thickness tends to decrease towards the north and downward. However, an extension of the vein is found at Lao-niu-kou, which is about one km northwest of Hsiao-pei-kou, and the vein extends discontinuously within the shear zone from there through Ta-chin-niu and farther to the north-northwest.

The vein gradually becomes smaller, and near the end the mean thickness is 0.6–0.7 m. The ore grade is also less in this portion.

Siderite is found at the ends of the ore vein at Ta-chin-niu and Hsiao-pei-kou, and injection calcite occurs along the schistosity of the schist at the tapering point of the quartz vein. Along the cleavage planes siderite is injected with fine crystals of magnetite.

The fissures and walls of the vein frequently contain chlorite. The mineral composition of the ore is generally simple and so the ore is well suited to processing by the flotation method.

The principal ore minerals are pyrite and chalcopyrite; no galena and zincblende are visible. The veinstone consists mainly of quartz but also contains calcite and chlorite. Magnetite and siderite are considered gangue minerals, and the sheared schist that is intermingled with the ore of Hsiao-pei-kou is also gangue.

The gold content of the ore varies from 5 to 30 gm per ton; the average of the ore feeding to the milling plant is around 6 gm per ton for a monthly feed of 5,000 tons.

3. *Conclusion*

The deposit of Lao-chin-chang is believed to have been formed by the injection of mineral solution into the shear zone which was formed along with hornfels by the intrusion of quartz monzonite. Fine grains of pyrite and chalcopyrite are the principal indices of the gold ore, as a rule.

The gold content of the crude ore is 6 gm per ton, but the ore-bearing zone extends for a very long distance, nearly 5 km, and trends northwest. In addition, there are many old placer gold mines and old gold-quartz mines in the adjacent areas. Therefore, the mine is worthy of notice in conjunction with the Chia-pi-kou Gold Mine.

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Banded Iron Ore Deposits of An-shan and Other Districts

Goro Asano

1. An-shan iron ore deposits

A. Location and distribution

The An-shan iron ore deposits is a collective term used to designate the banded iron deposits and associated rich ore deposits widely distributed in an area between An-shan Station and Tang-kang-tzu Station to the south. They occur mainly on the east side of the main line of the South Manchuria Railway. Most of the ores are of low grade, yet these deposits rank as the largest iron deposits in the Far East in size and amount of reserves.

The principal localities of the ore deposits are as follows:

(1) Ying-tao-yuan—Wang-chia-pu-tzu—I-tan-shan area.
(2) Kuan-men-shan—Yen-chien-shan area.
(3) Ta-ku-shan area.
(4) Tung-an-shan—Hsi-an-shan area.
(5) Tieh-shih-shan area.
(6) Hsiao-ling-tzu area.

Of the above six areas, the poor ore (or banded iron ore) of Ta-ku-shan has been worked most widely, but the poor ores of Hsi-an-shan, Tung-an-shan and Yen-chien-shan have also been worked extensively. Rich ore has also been worked at Ying-tao-yuan, Wang-chia-pu-tzu, and Hsiao-ling-tzu.

B. Geology

The iron deposits occur in Pre-Cambrian beds, the larger portion of them in Proterozoic rocks. Since they closely resemble the Huronian iron deposits of the United States in mode of occurrence, age, and properties, they are thought to be Proterozoic at least.

The Proterozoic beds in the An-shan district can be roughly divided into two series; (1) the An-shan series consisting of slightly metamorphosed sedimentary rocks containing iron deposits and (2) the Sinian series resting unconformably upon the former.

The Sinian series has been renamed the Hsi-ho series by Rinji Saito. Its lowermost member, the Tiao-yu-tai quartzite, has been found in many places directly overlying the An-shan series with unconformity.

In addition to the sedimentary and metasedimentary rocks, the An-shan and the Hsi-ho series contain granite which was injected into them during two different periods of the Pre-Cambrian era. The older of these may be the oldest in Manchuria. At Tui-mien-shan of Hsi-an-shan, it is unconformably overlain by metamorphic rocks of the An-shan series and was named the Tui-mien-shan granite by R. Saito.

Since such a relationship exists, there is a strong possibility that the granite is of the same age as the Laurentian granite of North America.

The granite injected in the second period cuts through the An-shan series, and in many cases has captured or enclosed the An-shan beds in large blocks; the peneplain-like degraded surfaces of these rocks is covered by the Tiao-yu-tai quartzite of the Hsi-ho series.

This granite has been named the Kung-chang-ling granite and may be of the same age as the Killarney granite of North America.

(1) Tui-mien-shan granite

At Hsi-an-shan the Tui-mien-shan granite, a gray granite, is overlain unconformably by the An-shan series upon a plane of degradation. By an increase in sericite the granite here grades upwards into a sericite-rich, fine-grained metamorphic rock. This rock, about 10 m thick, is overlain by a thin conglomerate of the An-shan series, which consists mainly of rounded quartz pebbles. Above that, sericite phyllite is generally present. Such a transition of granite indicates that a weathered portion of the granite was metamorphosed. The quartz pebbles within the basal conglomerate consist mainly of vein quartz and may have been derived from the Tui-mien-shan granite itself.

The Tui-mien-shan granite is a grayish, leucocratic rock, a fairly large amount of which has a cataclastic structure. The component minerals are albite or oligoclase and quartz. Microcline is almost completely absent and no mafic minerals are present. It can be classed either as leuco-sodaclase-tonalite or leuco-granodiorite.

A crystalline schist is found within the Tui-mien-shan granite, indicating that there is a still older crystalline schist system. There are many unsolved problems concerning Archean rocks in Manchuria.

(2) An-shan series

The An-shan series is a group of crystalline schists containing a banded, or poor iron ore bed. An unconformity at its base can be observed in some parts and indicates that nearly complete peneplanation followed the large-scale granite injection of the Pre-Cambrian period. The conglomerate may also represent a regolith.

Owing to faulting or injections of the Kung-chang-ling granite, the An-shan series is generally distributed in segmental areas or blocks, so it is very hard to determine the horizons and sequences of the strata. Outcrops exclusively of iron ore are also found in many cases. Generally, they are either deposits associated with metasedimentary rocks or deposits consisting solely of iron ore within granite.

(a) Banded ore deposits associated with metasedimentary rocks:—Such deposits occur at Tung-an-shan, Hsi-an-shan, Ta-ku-shan, Yen-chien-shan, Ying-tao-yuan, and Wang-chia-pu-tzu. The metasedimentary rocks include sericite phyllite, graphite-sericite phyllite, and other such rocks. At Hsi-an-shan and Tung-an-shan, the western end of the distribution area, the deposit strikes approximately eastwest and dips 20°–40° or more to the north. To the east, at Ta-ku-shan, the strike is NW and the dip is about 60° NE. On the eastern fringe, from Ying-tao-yuan to I-tan-shan, the strike is NNW and the dip is more than 60° E. South of the above location, at Hsin-kuan-men-shan and Yen-chien-shan, the strike is nearly E-W and the dip is more than 30° N. From Hsi-an-shan to Yen-ch'ien-shan, alignment is nearly E-W and the dip is to the north. North of the eastern end of Yen-ch'ien-shan, between I-tan-shan and Ying-tao-yuan, the deposit strikes NNW. Thus the beds form a hook with the southern extension 25 km in length and with the eastern deposit fringe 15 km in length.

At Tung-an-shan and Hsi-an-shan, there are developments of sericite phyllite, chlorite phyllite, and graphite-sericite phyllite above and below the ore deposit; those below the deposit are smaller. The phyllites are fine-grained crystalline schists, the principal constituents of which are quartz, chlorite, graphite, sericite, and green mica. Under the microscope the rocks show many microscopic folds and reverse faults; pseudo-cleavage structure is also noticeable.

At Tung-an-shan, some chlorite schist of volcanic origin is found just below the ore deposit and a gritty chlorite phyllite of psammitic origin has also been found in the upper part of the ore deposit. The bedded iron deposit might be taken as one stratum, but detailed observations disclose that it consists of lenses of ore which do not necessarily lie in a single horizon.

At Ta-ku-shan only granite, presumably the Tui-mien-shan granite, appears to underlie the ore, and the phyllite group mentioned above overlies the ore.

At Hsin-kuan-men-shan and Yen-ch'ien-shan two ore beds have been found, of which the lower and principal deposit is underlain by granite, presumably the Kung-chang-ling.

The interval between the lower and upper deposits is occupied by a phyllite bed 200–300 m thick. Part of the phyllite contains an alternation of schistose grit, schistose and conglomeratic grit, and quartzite. The quartzite in some places includes fine-grained iron oxide minerals and iron chlorite. A thick phyllite bed containing schistose grit is found also above the upper ore bed.

Within the area from Ying-tao-yuan through Wang-chia-pu-tzu to I-tan-shan the deposit consists generally of one ore bed; and around Yang-erh-shan, east of Ying-tao-yuan, there is a second ore bed parallel to this bed. Of this area, the northern part has a large amount of injected granite and contains a poor residue of phyllite both above and below the ore bed; but to the south the ore bed is fairly thick. The iron deposit is continuous except for rare spots where it lenses out. Portions of it, however, vary greatly in thickness. Large developments of iron-chlorite schist, iron chlorite-bearing quartzite, and iron-chlorite grit are to be seen in this area just above and below the ore bed. This indicates that there is a genetic connection between the iron chlorite and the banded iron. Moreover, from this it can be inferred that a similar genetic relationship may exist where iron deposits formed after the An-shan series had been deposited.

As stated above, the greater part of the metamorphosed rocks of the An-shan series is metamorphosed pelitic sediment; the smaller part is metamorphosed psammitic sediment. The principal mineral components of the metamorphosed rocks are sericite, chlorite, quartz, and, in many cases, much graphite. The sedimentary facies resembles the Mesabi iron beds of the United States, and there is almost no volcanic material—a bed of the so-called prasinitic rock consisting of actinolite, epidote, and albite intercalated with the ore is found only around Wang-chia-pu-tzu. This material may have been derived from a basic volcanic rock.

Aside from the banded iron ore intercalated within the metasedimentary rocks, some banded iron ore in Manchuria is found in metamorphosed rocks of volcanic origin such as plagioclase-amphibole schists. Generally the deposits in metasedimentary rocks are larger than those in meta-volcanic rocks, which is also true of the deposits in America.

The iron-bearing complex of An-shan is of one of the lowest grades of metamorphism among the iron-bearing formations in Manchuria. Despite this, it is somewhat more highly metamorphosed than the Mesabi beds; and, in general, Manchurian banded iron ore is more intensely metamorphosed than that of the Mesabi Range. Banded iron ore in Manchuria, other than that of An-shan, resembles banded iron ore of the Scandinavian type.

(b) Banded ore deposits in granite:—This type of banded iron ore is usually intruded by granite. Preservation of the other rocks, phyllites for example, indicates that they were shielded by the iron bed from a granite invasion. Where the action of the granite was extremely strong, the phyllites were entirely assimilated, leaving an iron deposit within the granite. At the same time, the deposit was separated into many massive ore bodies owing to the granite intrusion along fissures. The deposit of Hsiao-ling-tzu may be an example of this. Even in such cases the original orientation of the deposit, which appears to have been a vein, is well preserved. This indicates palingenesis, and it is possible that the resistive power to such action would be stronger in case of iron ore. Yang-erh-shan, Tieh-shih-shan near Tang-kang-tzu, and Hsiao-ling-tzu are examples of this. At Hsiao-ling-tzu, the ore is accompanied by metamorphosed rocks which had undergone various granitizations.

(3) Kung-chang-ling granite

This granite has been injected into the An-shan series and is unconformably overlain by the Tiao-yu-tai quartzite bed of the Hsi-ho series. In the Tieh-ling district, R. SAITO divided this granite into Hsiang-lu-shan and Hsiao-li-kou granite. However, these two types of granite closely resemble each other, and it is difficult to make correlations between districts without additional special data.

The Kung-chang-ling granite is generally pale purple, leucocratic, and gneissic. A sample from Kung-chang-ling was found to contain 27.3 per cent quartz, 23.6 per cent albite, 6.5 per cent perthite, 41.4 per cent microcline, and 1.2 per cent sericite. It is thus a typical leucogranite; and its microcline is remarkably clear and shows a coarse lattice structure.

The banded iron bed is enclosed in and injected by this granite, but the degree of metamorphism is comparatively low. Locally the granite contains epidote, presumably of primary origin, and seems to resemble the so-called helsinkite. At Wang-chia-pu-tzu the iron ore near the contact has much tourmaline, containing in some instances a large amount of boron.

(4) Tiao-yu-tai quartzite

The rocks of the An-shan series, including the iron bed, and the Kung-chang-ling granite are unconformably overlain by the Tiao-yu-tai quartzite, which is the lowermost bed of the Hsi-ho series. In most places a basal conglomerate 2–3 m thick is present on the plane of unconformity; it is best exposed above the iron bed at An-shan. The basal conglomerate here consists chiefly of quartzite pebbles and banded iron ore, like that of the underlying ore bed. This indicates that the metamorphic action terminated before the conglomerate was deposited. Moreover, pebbles of rich ore are found in the conglomerate, so that the rich ore must also have been formed prior to the deposition of the Hsi-ho series.

The quartzite is a type of quartz sandstone consisting mainly of quartz sand. For the most part its cementing material also is quartz, but in many instances it is hematite; locally the rock is a payable iron ore. Most of the sand grains are round, especially those near the basement, but there are also many angular pebbles. In view of these features it is likely that this bed was formed under desert conditions.

C. Ore deposits

1. *Descriptions of the ore deposits*

(1) Tung-an-shan and Hsi-an -shan

These deposits lie about one km south of Chien-shan Station and form an east-trending range which the railway line crosses. The Hsi-an-shan deposit occurs in four separate mounds or hilltops, the most eastern of which is the longest—700 m. The beds in the eastern hill are about 40 m thick, strike N60°–70°W, and dip 40° N. The deposit in the western hilltop has a strike of N 30° W and a dip of 30° N; it is about 70 m thick and about 600 m long. Farther west at a location in the saddle, the deposit lies directly below the Tiao-yu-tai quartzite and is exposed for about 100 m. It strikes east and dips about 40° N.

In the Tung-an-shan deposit, the bed at the western end, which faces the An-shan River, strikes N 30° W and and dips 50°–80° NE. It is 1000 m long and 30–45 m thick; at the eastern hilltop the thickness is 100 m. East of that hill and beyond the saddle, the deposit strikes approximately east and extends for 400 m. After an interval the bed reappears and extends for about 300 m farther east, but the deposit becomes narrow and seems to taper out at the east end.

The deposits at the above two places are poor in magnetite. They are banded ore which consists mainly of hematite and quartz and which has a high iron content in comparison with other An-shan ore deposits. Hence both have been worked to obtain poor ore. The rich ore deposits at the boundary between the banded ore deposit and the underlying phyllite were worked during the initial stages of the An-shan Mine operation, but they have been almost entirely exhausted.

Production of the poor iron ore toward the end of the war was 800,000 tons (33% Fe) at Tung-an-shan and 200,000 tons (38% Fe) at Hsi-an-shan, a yearly total of 1,000,000 tons.

(2) Ta-ku-shan

Ta-ku-shan is located about 12 km southeast of the city of An-shan to which it is connected by a tramway for transportation of the ore. The stratigraphic succession, in descending order, is as follows:

	Tiao-yu-tai quartzite bed	Thickness
	unconformity	
An-shan Series	Coarse-banded, low grade iron bed ———	scores of meters
	Phyllite bed (mainly sericite phyllite) ——	about 300 m
	Phyllitic magnetite-grunerite schist ———	scores of meters
	Fine quality banded iron bed	200–250 m
	unconformity?	
	gray gneissose granite	

Only the iron bed of the lowest horizon is workable. It strikes northwest and dips more than 70° NE; it has a length of about 800 m and forms hills 170 m high. A northeast-trending granodiorite porphyry dike, about 60 m thick, traverses the ore bed at the central part and bisects it.

The ore from the northwestern half belongs to a type consisting primarily of hematite (mainly martite), magnetite, and quartz. The ore from the southeastern half consists mainly of magnetite and quartz but contains a considerable amount of cummingtonite-grunerite amphibole, and often actinolite and calcite. The ore can be readily split into flakes and may be easily crushed.

At Ta-ku-shan there were vein-like or bed-like rich ore bodies traversing the iron ore bed, but they have been exhausted. At present only open-pit mining of the poor ore is being carried on. During the war, 2,000,000 tons averaging 36 per cent iron was produced annually.

(3) Kuan-men-shan, Hsin-kuan-men-shan, and Yen-chien-shan

Kuan-men-shan is located about 7 km east of Ta-ku-shan and the iron deposit extends for about 5 km farther east. The ore beds strike approximately east and dip steeply to the north. The ore deposit consists of two main beds and minor lenses scattered within the interval between the two main beds. The stratigraphical succession, in descending order, is as follows:

		Thickness
	Tiao-yu-tai quartzite bed	
	unconformity	
An-shan Series	Green phyllite Schistose grit, and quartzite (several meters) Green phyllite, sericite phyllite	more than 30 m
	Coarse banded iron ore, and quartzite	
	Green phyllite, sericite phyllite with intercalated quartzite, and banded iron ore bed	200–300 m
	Narrow-banded fine quality iron bed	60–90 m
	unconformity	
	gneissose granite (injection?)	

Of the above, the lowest banded ore bed usually consists of quartz, hematite, and magnetite. However, at Yen-chien-shan this banded iron ore bed contains amphibole, iron chlorite, and ankerite and has been profitably worked because of a high iron content. The amphibole is grunerite or cummingtonite; the chief iron oxide mineral is magnetite.

Annual production of Yen-chien-shan during the war was 150,000 tons (35% Fe).

(4) Ying-tao-yuan, Wang-chia-pu-tzu, Hu-chia-pu-tzu, and I-tan-shan

From I-tan-shan, which is about 3 km north of Kuan-men-shan, to Ying-tao-yuan, which is about 12 km northeast of An-shan Station—a distance of about 12 km—the iron deposit is in continuous exposure. It consists of one iron bed.

At Ying-tao-yuan and Wang-chia-pu-tzu, massive, or bedded, rich iron ore is enclosed within the ore bed or within the iron-chlorite bearing rock close to the ore bed. The iron formation strikes roughly north-northwest, and dips steeply to the east or west. The rocks other than the iron bed are primarily green phyllite and sericite phyllite. East of the iron bed there are numerous quartzite beds, and one or two quartzite beds are found to the west.

The iron formation, both in the east and west, is in contact with the Kung-chang-ling granite, by which it was injected. The granite at the contact becomes gneissose, with jointing generally parallel to the schistosity of the iron formation.

East of Ying-tao-yuan at Yang-erh-shan, there is an isolated banded-iron deposit not associated with phyllite but enclosed in granite. The deposit has a fairly long extension.

The iron ore usually consists of hematite, magnetite, and quartz. The thickness of the ore deposit varies greatly. At Wang-chia-pu-tzu the thickness ranges from 140 to 170 m, which is the prevailing thickness range of the thicker iron deposits of other localities. However, these beds, like those at Ying-tao-yuan, may in part be duplicated by thrust faults.

The iron bed is accompanied by iron-chlorite bearing rock above and below, and at Ying-tao-yuan it is associated with thuringite schist.

The rich ore is being worked mainly at Ying-tao-yuan and Wang-chia-pu-tzu. The rich ore of Ying-tao-yuan forms small lenticular ore bodies within thuringite schist and consists mainly of massive magnetite or martite.

At Wang-chia-pu-tzu the rich ore occurs as a bed-like deposit along the boundary between the banded iron ore and the iron-chlorite bearing rock. The rich ore consists of iron-chlorite, magnetite, quartz, ankerite, etc. According to mineral composition, it is analogous with the banded iron ore of Yen-chien-shan. In some portions, it contains a large amount of schörlite. The thickness of the rich iron deposit ranges between 0.3 and 0.4 m.

A portion of the rich ore at I-tan-shan is a brecciated ore vein which obliquely cuts the banded ore deposit. This may be caused by the leaching of silica by hydrothermal action along the fault zone.

(5) Tieh-shih-shan

At Tieh-shih-shan 1.5 km west of Tang-kang-tzu Station, the iron ore deposit is found within the gneissose granite in a nearly bed-like form. The deposit strikes northeast, and dips from 50° NW to an almost vertical position. The ore bed has a thickness of 15 m and length of about 300 m. The banded iron ore of the bed consists of hematite, magnetite, and quartz. A rich hematite ore occurs sporadically.

(6) Hsiao-ling-tzu

The ore bed of Hsiao-ling-tzu is located 4–6 km southeast of Tang-kang-tzu Station. The ore deposit, of nearly bedded form, is found within the Kung-chang-ling granite. According to underground observations, this granite was injected along the fissures of the ore deposit. However, the Cretaceous Chien-shan granite may have been injected in part along the same course. The ore bed strikes east, and dips 40°–50° N.

The blocks of the separated ore bed are arranged in a series of low hills about 100 m high. West to east these are Ti-tan-shan, Ting-chia-shan, Ta-wai-tzu-shan, Shuang-ling-tzu, Tsai-chia-fen, and Chang-kang-shan. The total length of the bed is 2,600 m and the thickness is 5–30 m. In addition, several other ore beds have been confirmed by prospecting by means of trenches and drill tests.

The ore deposit has been intensively affected by granitization. Above and below the deposit there is friable plagioclase-blue green hornblende-fels. Migmatitic granite is also found in quantity.

In addition to magnetite, hematite, and quartz, the iron ore generally contains blue-green hornblende and actinolite. The composition of ore varies greatly and diopside, or salite, calcite, spinel and other minerals are present in some sections. At Chang-kang-shan there are ores which are in various stages of transition from banded to rich ore (with about 50% Fe), and scattered occurrences of rich ore. The rich ore, other than magnetite, consists predominantly of diopside, iron-rich olivine, and spinel, and some portions contain anthophyllite. It may be considered the thermal metamorphic rock of a rich ore of the Wang-chia-pu-tzu type.

Because of the transportation factor, only rich ore in this deposit was worked extensively. The average grade for annual production was an iron content of 50 per cent, and the reserves of rich ore were said to be about 50,000 tons.

2. *Descriptions of ores*

Like other banded iron ore deposits in Manchuria, the ore of the An-shan deposits can be divided into "poor" and "rich" ores.

The poor ore is an ordinary banded iron ore, generally 20–40 per cent iron, which makes up the larger part of the ore deposit. Characteristically its banding is well-developed, like similar ores in other countries.

Macroscopically, the structure can be classified into various types, and the distribution of the ores can also be separated into zones in accordance with the classification.

First, a classification by the coarseness of the banded structure can be made. An iron ore with hardly any banded structure, or an ore which appears a nearly homogeneous steel-gray, was once named hornfels-like ore by the author. This type is often seen in ores consisting solely of hematite and quartz, and the grain of the iron oxide minerals is fine. However, some banding can be observed under the microscope.

Then there are some finely and regularly banded iron ores, with each thin layer varying in thickness from 0.5 to 2.0 mm. The author named this type finely-banded ore. At Tung-an-shan there is a bed-like deposit of ore about 10 m thick which consists only of this type; the ore shows an unbroken alternation of bands of quartz laminae, and bands of hematite and quartz laminae. However at Ta-ku-shan and, to some extent, at Yen-chien-shan there are variegated alternations of laminae of magnetite, hematite, and quartz; laminae of iron oxide minerals, grunerite and quartz; and laminae of iron oxide minerals together with intercalations of quartz laminae. Such ore is especially predominant in the high grade banded iron ore. In addition, a banded ore formed of an alternation of iron oxide mineral and iron chlorite laminae, quartz laminae and quartz and iron oxide laminae has been found at Ho-shan-chuang-tzu.

The author named banded iron ore with bands as thick as 0.2–1.0 cm, or sometimes 2.0 cm, coarse banded ore. In such ore, most of the quartz laminae are considerably thicker than the laminae of quartz and iron-oxide mineral. Accordingly the grade of iron should be about 21–22 per cent. Banded ore of this type is usually found as a thick bed, either above or below the fine banded ore, or as a single ore bed. Tung-an-shan and Hsi-an-shan are fine examples of the former, and Hsin-kuan-men-shan (or La-tzu-shan) of the latter.

In view of the value of ore, working banded ore which contains amphibole, or cummingtonite-grunerite, should be the most profitable because this ore is easily milled, is of high grade, and has a high magnetite content. Ta-ku-shan and Yen-chien-shan contain ore of this type.

Next in value is the fine-banded ore consisting of hematite and quartz. This has a grade ranging from 33 to 38 per cent iron in contrast to the ore just discussed which contains about 36 per cent iron; the high percentage of hematite makes it necessary to use a reductive roasting process. It has the objectionable quality of stiffness. The poor ore from Tung-an-shan and Hsi-an-shan is an example of this type.

The banded iron ore is a crystalline schist showing stable mineral facies which vary according to the degree of metamorphism. In the An-shan district the degree of metamorphism is generally low and most of the amphibole found there is either fibrous cummingtonite-grunerite or tremolite-actinolite. Iron chlorite and ankerite are also found in it. Among the iron-oxide minerals, ore with amphibole and iron chlorite is high in magnetite content. It has been assumed through petrographic studies that the larger part of magnetite is derived from siderite. If we leave aside the question of origin, the An-shan ore may be analogous to the Mesabi ore because of the degree of metamorphism. However, it contains more calcium oxide and aluminum oxide than the Mesabi ore and the existence of primary grunerite has not been proved. The granular structure common in Mesabi ore was noted in tailings from Yang-erh-shan, near Ying-tao-yuan.

The rich ore may have been derived from various sources. It is worked mainly at Ying-tao-yuan and Wang-chia-pu-tzu; at both of these places the ore reserves are at the one million ton level. The ore is obtained by underground mining. Annual production at the end of the war was 50,000 tons (60% Fe) from Ying-tao-yuan and 50,000 tons (50% Fe) from Wang-chia-pu-tzu.

The rich ore of Ying-tao-yuan is found as lenses and masses within the thuringite schist, which is intercalated between the beds of banded iron ore. The ore consists of either magnetite or martite. Due to the presence of Kung-chang-ling granite, the thuringite schist contains tourmaline and phengite-like muscovite. Nevertheless, the forerunner of granitization by granitic magma should be the presence of silica, alumina, and alkali minerals, and its end phase should be the formation of blue-green hornblende-plagioclase-fels, as in the cases of Hsiao-ling-tzu and Ying-tao-yuan, from the iron ore and thüringite-schist. Neither local migration of iron, nor local leaching of silica can be taken as the origin of the rich ore. The rich ore should be interpreted as an altered form of the lenticular ore bodies of either siderite or ankerite which were primary deposits in the thüringite-schist.

The rich ore of Wang-chia-pu-tzu occurs as a bedded deposit with an iron content of 50 per cent within the iron chlorite-bearing banded iron ore lying at the eastern margin of the banded iron bed. It consists mainly of ore containing ankerite, iron chlorite, magnetite, quartz, and considerable tourmaline. The iron content, 50 per cent, corresponds to that of the black iron-bearing laminae which are found in the banded iron ore, and the mineral composition is also the same as that of some of the black iron-bearing laminae. Therefore, if we assume that such portions could only have been deposited separately, we can possibly explain its origin.

The appearance of tourmaline in the ore should be an indication that the boron of magmatic origin became fixed under a chemical condition most favorable for the combination. The rich ore of Hsiao-ling-tzu could be considered a metamorphosed rock of the type of the rich ore of Wang-chia-pu-tzu.

The rich ores that have been formed at the lower part, or within the iron ore bed at Hsi-an-shan and Tung-an-shan, are probably of secondary origin. They occur as massive deposits in veins and, in some places, are brecciated. The origin of these ores might be attributed to partial migration of iron content, resedimentation, or leaching of silica. These ores are already almost exhausted.

3. *The grade of ore and the ore reserves*

According to an estimate made about 1940, the ore reserves (positive) and the average grade of ore were as follows:

Name of deposit	Positive ore reserves (t)	Average grade of ore (Fe %)	Number of samples
Ta-ku-shan	84,900,000	36.45	440
Tung-an-shan	148,200,000	32.10	799
Hsi-an-shan	46,700,000	26.62	426
Ying-tao-yuan	37,900,000	31.34	453
Wang-chia-pu-tzu	118,200,000	25.74	1,077
Pai-chia-pu-tzu	66,400,000	24.50	1,348
I-tan-shan	93,300,000	25.92	944
Kuan-men-shan	19,500,000	32.32	379
Hsin-kuan-men-shan	30,000,000	30.00	-
Hsiao-ling-tzu	500,000	-	-
Tieh-shih-shan	300,000	-	-
Total:	646,000,000		

Magnetic prospecting has confirmed the supposition that banded iron ore should continue to a considerable depth under the valley level. If an estimate of ore reserves were extended to 50 m below the valley level, the positive and probable ore reserves would be increased at least three times. Because of transportation costs and restrictions on mining, the ores with 35–36 per cent iron and those located above the valley level have been worked primarily. On the other hand, some fairly high grade ores, like those of Ta-ku-shan and Yen-chien-shan, have shown a considerable loss of iron into the tailings. This may be due to the effect of ferrous silicates such as thüringite in the ore; a study of the effective iron in the ore should be carried out in the future.

2. Banded iron deposits of other districts

We have given a detailed description of the iron deposits of An-shan, which we selected as representative of the banded iron deposits in Manchuria. They form one of the largest iron ore deposits in the Far East. There are many similar deposits of various sizes, e.g. Wai-tou-shan, Kung-chang-ling, Miao-erh-kou, Chiao-tou, and Li-shu-shan; but because of transportation and mining costs, only the iron ores of the An-shan deposits are being worked.

Banded iron ore is a crystalline schist, but the ores in other locations are more highly metamorphosed than the An-shan ore. The banded iron ores are classified according to mineral composition and the degree of metamorphism.

They may be divided into two groups according to mineral composition. Group

A consists mainly of quartz and iron oxides like hematite and magnetite. It is found either in association with group B, or grading into B, or as an independent bed; but in all cases, due to the low degree of metamorphism, mineralogical changes are almost lacking.

Group B is found to contain various minerals in addition to those of group A. The majority are iron-rich silicate minerals. Moreover, because of the degree of alteration, the variations of mineral combinations are great, a factor similar to that existing in metamorphosed basic rocks.

The four facies into which banded ores can be classified according to degree of metamorphism are as follows:

Type No. 1 *Iron chlorite banded iron ore.* This facies contains either carbonate minerals or iron chlorite or both. In addition fibrous cummingtonite, or grunerite, is also contained in much of the rock, according to the composition and mode of occurrence. This may be the banded iron ore with the lowest degree of metamorphism in Manchuria, and the grains of the iron oxide minerals are the smallest in size. The ores of Ta-ku-shan and Yen-chien-shan are excellent examples.

Type No. 2 *Amphibole banded ore.* This type ore consists chiefly of quartz, iron oxide minerals, and amphiboles. The amphiboles are not fibrous. The iron-bearing silicates are limited almost entirely to the amphiboles. Some portions of the rock consist entirely of amphiboles. Of the amphiboles, three varieties—the cummingtonite-grunerite system, diopside-actinolite system, and blue-green hornblende—are the most prevalent.

In addition, glaucophanic amphibole and pargasite are found in some parts. Ore of this type can be correlated with the so-called amphibolite facies, comparatively high in degree of metamorphism and found in many localities, e.g. Wai-tou-shan, Li-shu-shan, Kung-chang-ling, and Chiao-tou.

Type No. 3 *Pyroxene banded iron ore.* This type of iron ore consists chiefly of quartz, iron oxide minerals, and pyroxenes. The country rock is the migmatitic gneiss. The pyroxenes include hedenbergite and rhombic pyroxenes. The latter ranges in composition from iron-hypersthene to orthoferrosilite, but the pyroxene with about 90 per cent $FeSiO_3$, eulite, is most common. Generally both varieties of pyroxenes are found in association, but it is not known in what ratio the varieties occur. Occurrences of ore of this type are not common. Ma-ho-ssu in the vicinity of Fu-shun is the best example of this facies.

Type No. 4 *Eulysite.* This type generally shows a chemical composition similar to that of the banded iron ore, but it frequently lacks iron oxide minerals. The principal components are fayalite, iron-hypersthene-orthoferrosilite, and hedenbergite. Minute amounts of quartz are present in some portions. This ore is sometimes found in pyroxene-banded iron ore, and is likely to be enclosed within migmatitic gneiss as small masses. Generally it has a high aluminum oxide content, and feldspar is often found with it. It is formed where the effect of granitization is strong. With greater granitization, fayalite and hedenbergite disappear and almandite appears. In the opinion of the author, eulysite may thus be changed into almandite-eulysite and with further granitization may become lepidomelane-fels. This type is rarely found in Manchuria. The deposits of Ma-ho-ssu, Wang-chang-tzu of Jehol, and Yu-hsi-kou of Antung are among the best examples.

There is no great difference between the genetic condition of the rich ore deposits and that of An-shan.

Important rich deposits are those at Kung-chang-ling, and Miao-erh-kou.

The deposit at Kung-chang-ling is the largest in Manchuria. It is a lenticular deposit found in iron-chlorite schist and forms a shoot of considerable extent along the ore course. The estimated positive ore reserves are about 40,000,000 tons, and the sum of probable and possible reserves may be as much as 170,000,000 tons.

The rich ore deposit of Miao-erh-kou is a lenticular ore bed in the amphibole-banded iron ore. It contains cummingtonite and has a rather low degree of metamorphism. It is a magnetite ore with carbonate minerals, iron chlorite, anthophyllite, mica, and other minerals. The ore reserves have been estimated at more than 2,000,000 tons.

Aluminous Shale

Takao SAKAMOTO

1. Distribution and General Properties of Aluminous Shale

Aluminous shale forms ore beds in the Paleozoic coal-bearing formations of Manchuria, North China, and Korea. It occurs in two beds, commonly called the "A" and "G" beds after the writer's suggestion for the Yen-tai coal field, the first locality where the aluminous shale was discovered. The "A" bed lies in the upper part of the productive coal-bearing formation and is Upper Permian in age, while the "G" bed lies below the "A" bed at the base of the Middle Carboniferous formation and covers the plane of unconformity above the Ordovician limestone or dolomite. The vertical distance from "A" bed to "G" bed is 200–500 m. The "A" bed is best developed in Shan-tung, Chi-tung, South Manchuria, and Korea, and the "G" bed is found in Shan-tung, Ho-pei, Ho-nan, Shan-hsi, Inner Mongolia, Manchuria, and Korea. The area of distribution of "A" bed is smaller than that of "G" bed. The latter is almost always found where there is an Upper Paleozoic coal-bearing formation.

The "A" and "G" beds of each coal field are listed in the Table 1.

Both "A" and "G" beds form a thick bed of kaolinite or flint clay, and are intercalated with lenticular aluminous shale. The flint clay bed is 2–17 m thick, and the outcrops are from several to over 100 km in length in each of the coal fields. A single lens in a bed of aluminous shale is 0.5–6 m thick and several hundred meters in length. The lenses in "A" bed are so flat that they can be called beds, while those in the "G" bed are locally variable in thickness and more irregular in shape.

The flint clay is grayish white, grayish-blue or red, compact, massive, fractures conchoidally, and has a smooth, glassy texture. When exposed to the sun, it breaks down into sandy grains in hours. *Hakusan-roseki*[1] used to be roasted before shipment not only to reduce weight and hence freight costs but also to protect it from rapid disintegration. Its hardness is 3, and its specific gravity 2.7 (apparent s.g. 2.6, sometimes 2.2). Mineral composition: kaolinite and halloysite, with ± 40 per cent alumina, ± 1–20 per cent ferric oxide.

[1] A trade name for the light bluish, compact clay mined and exported from the Po-shan coal field, Shan-tung.

Table 1. List of Occurrences of the "A" and "G" Aluminous Shale Beds in Manchuria.

Coal fields	Beds	Thickness (m)	Length of outcrop (km) Actual (possible)	Remarks
Sung-shu-chien	A	—		
	G	—		
Wan-kou	A	—		
	G	—		
Pa-tao-chiang	A	?		Basal conglomerate with round quartz pebbles
	G	—		
Wu-tao-chiang	A	?		With round quartz pebbles
	G	0 – 1	small	
Tieh-chang	A	1.5 – 3		Gray-white and red flint clay
	G	—		
Tien-shih-fu	A	0.8 – 10	5.2	Coal seam on hanging wall
	G	—		
Hsiao-shih	A	2.5 – 7.5	25.1 (3.3)	
	G	—	very small	
Niu-hsin-tai	A	2.5 – 10.5	4.8	Lenticular coal seam (max. thickness 1.5 m) on hanging wall
	G	3 – 10	10	
Pen-hsi-hu	A	4 – 8	6	
	G	5 – 10	7	
Han-po-ling	A	—		Eroded out
	G	0 – 12	2.4	
Yen-tai	A	8	2.9	
	G	10	2 (12)	
Fu-chou	A	—		Eroded out
	G	5 – 17	3.7 (18.3)	
Chin-chou	A	—		Eroded out
	G	5 – 17	2.5	
Hung-lo-hsien	A	—		
	G	2 – 4	4.5	Flint clay only
Nan-piao	A	3.5	small	Flint clay only
	G	0 – 10	〃	Sandy clay
Hsiao-hei-yu-kou	A	none		
	G	1.4 – 4.2	1.7	
Wu-tao-ling	A	none		
	G	0 – 8.95	0.3	Al_2O_3 46%
Sung-shu-tai	A	none		Flint clay, sandy clay
	G	0 – 1.65	0.7	
Hsing-lung	A	none		Non-deposition?
	G	〃		〃

Aluminous shale is grayish-white, bluish-green, yellowish-green, brown, and red. It is compact, massive or pisolitic, uneven and rough in fracture, and has a hardness measured at 3–7 and a specific gravity of 2.8–3.1 (apparent s.g. 2.6–3.0). It has a mixed composition of flint clay and diaspore (with a small amount of boehmite and sporogelite), with 45–70 per cent alumina and ±2–25 per cent ferric oxide. Diaspore and kaolinite form an aggregate of fine crystal grains with diameters of 1–100 microns. The flint clay is soluble in sulphuric acid, while the high-grade aluminous shale, being composed chiefly of diaspore, is soluble with difficulty both in acids and alkalis.

It is this relative insolubility of diaspore, both in acids and alkalis, under normal pressure that makes the extraction for metallurgical purposes of pure alumina from aluminous shale difficult. However, solution may be possible in a solid phase reaction with concentrated sulphuric acid (sulphuric acid method by Kōemon Hunaki and Yogorō Katō). When roasted with either calcium carbonate (or barium carbonate) or soda ash, it becomes soluble. It is on the basis of this reaction that such combined dry and wet methods as the alkaline earth method (Manchuria Light Metals Manufacturing Co., Inc. and Tsuyoshi Arimori) and similar alkali methods (Shōichirō Nagai, *et al.*) have been established.

Part of the aluminous shale which was called "sporogelite or gelalumino-ferrique" by the writer is amorphous under the microscope. S. Oda of the Continental Research Institute (Tairiku Kagakuin) made X-ray analyses and found it to be boehmite. Ores with sporogelite as their chief constituent are greenish-yellow to gray, compact, and are mixed with chloropal (iron silicate) and halloysite, usually having an alumina content of about 60 per cent. Sporogelite of unusual purity is found in a part of the "A" bed at Po-shan, and the writer thinks that the Bayer process could be applied to these kinds of ore.

The fact that the aluminum hydroxide contained in the aluminous shale occurs not only in the form of diaspore but also in a soluble form is important in connection with its treatment. It is important that this amorphous part was determined mineralogically as boehmite. (The reserves of this type of ore do not amount to much at present, however.)

2. Shape and Profile of the Aluminous Shale Ore Bodies

The aluminous shale forms flat lenses with a maximum thickness of 3 m and a maximum length of several hundred meters along the outcrop, which are intercalated in a thick bed of flint clay. The lenticular aluminous shale, fully developed in "A" bed, shows distinct symmetrical banding along a vertical profile, i.e., with green and grayish-blue aluminous shale at the center and yellowish-blue and reddish-purple flint clay bands both above and below, with the yellowish-blue bands nearest the center. The "A" bed is 3.5–10 m thick, and may be over 100 km long along the outcrop. White quartzose sandstone, cemented by blue to white kaolinite and having an appearance similar to *gairome*,[2] is found on the footwall. The kaolinite often forms small lenticles within the sandstone. A celadon (green) flint clay bed is found near the footwall and consists of pure, bluish flint clay which is quite similar in color and texture to the kaolinite cement of the sandstone, showing both of these beds to be sediments of continuous deposition. An alternation of thin sandstone and variegated shale occurs on the hanging wall of the "A" bed; a thin coal seam is found covering "A" bed in only a few places.

The lower part of "G" bed is reddish or purplish and ferruginous, and the middle and upper parts are grayish-green and grayish-white. Banding is seldom as regular as in "A" bed. Nodular hematite or turgite is found in the lowest part of the "G" bed, popularly known as *lao-kuang*[3] in Shan-hsi. Similar ores were once prospected in Niu-hsin-tai, Manchuria. High grade ores of aluminous shale form irregular lenses in the middle and upper parts. The "G" bed is 2.5–17 m thick, several hundred km in aggregate length along the outcrop, and is as persistent laterally as the "A" bed.

Ordovician limestone or dolomite occurs on the footwall, and sandstone and shale on the hanging wall. The formation on the hanging wall together with "G" bed is in disconformable relationship to the Ordovician limestone or dolomite below. Although projections and depressions due to solution are occasionally met with on the surface of the limestone bed on the footwall, the surface is usually smooth, with thin layers of yellow and brown marl interbedded with thin sandstone and sandy shale, and lacks large engulfing pockets or vein-formed downward protuberances. This is rather a unique feature when compared with the footwall limestone of the *Bohnerz* in Europe, showing serrate depressions, or with the footwall of the terra rossa bauxite, showing similar and sometimes sinkhole shaped pockets.

The "G" bed in the hanging wall is conformably covered by sandstone and sandy shale. The sandy shale is reddish-purple and brown and is intercalated with limestone beds which contain fossil marine fauna. A lenticular coal seam is occasionally found covering the "G" bed. Grayish flint clay with a similar appearance is found about 5–20 m above "G" bed. It is more easily decomposed into "soft" clay than the "G" flint clay, and is utilized as china clay. (Examples are in Yen-t'ai and Kai-lan. The so-called *honso nendo*[4] from Fu-chou is situated above in a different horizon).

The color and macroscopic texture of the aluminous shale and flint clay are shown in the following table:

[2] Completely kaolinized arkosic sandstone in Japan, which can be separated into kaolinite and quartz sand for glass making.

[3] *Lao-kuang* (meaning "old iron ore") is an iron ore used in the domestic smelters in Shan-hsi Province, North China.

[4] *Honso nendo* is refractory clay exported to Japan in large quantities, averaging at 300,000 metric tons a year.

Table 2. Color and Texture of Aluminous Shale and Flint Clay.

Bed	Ores	Color	Texture
"A"	Aluminous shale	Yellowish-green or grayish-green	Pisolitic, compact amorphous
		Grayish-blue or gray	Compact crystalline
	Flint clay	Celadon or light purple	Compact, disintegrates into angular hexahedron
		Yellow, light brown or cream white	Compact or porous, soft
		Pink or reddish-purple	Compact or porous, disintegrates into prisms
"G"	Aluminous shale	Grayish-white, grayish-green or red	Pisolitic, compact crystalline
	Flint clay	Gray, pink or red	Compact, disintegrates into prisms

3. Chemical Composition of the Aluminous Shale Ores

The alumina content of the aluminous shale varies from 45 to 70 per cent (silica: alumina mol ratio, 1.8–0). The chief component minerals are diaspore, sporogelite (boehmite), kaolinite, and halloysite. The alumina content of the flint clay is 40 per cent=(silica:alumina mol ratio, $2.0\pm$), consisting almost entirely of kaolinite and halloysite. The aluminous shale occurs as lenses in the flint clay, and the transition between them is gradual, but is only 20–30 cm or narrower in width. The change in mineral composition is also gradual; where it consists only of minerals of the kaolinite series it is called flint clay and where it consists of aluminous hydroxide minerals together with kaolinite minerals it is called aluminous shale. The chemical compositions of aluminous shale and flint clay, as shown by the analyses of ores from different localities, are shown in Table 3.

One thing that attracts our attention in the above analyses is that the ignition loss is almost constant at 12–14 per cent, notwithstanding the fact that a considerable amount of amorphous matter is contained in all the ores except crystalline kaolinite and diaspore. The iron is shown as ferric iron, but as has already been stated, a fairly large amount of ferrous iron is included in it, especially in the green and bluish-gray ores.

4. Mineral Components of Aluminous Shale and Flint Clay

Some of the aluminous shale ores show a scintillating reflection of light upon fresh fractures, indicating the presence of visible, though fine-grained, crystals. But in the majority of the ores such crystal grains can hardly be discerned by the naked

Table 3. Chemical Analyses of the Aluminous Shale in Manchuria.

		Locality	Ore	Ig. 1.	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Alkalis	TiO_2	Analyst*
"A" Bed	Aluminous shale	Pan-tao-ling, Yen-tai	Diaspore nodule (gray)	11.04	1.48	69.95	11.94	0.38	0.57	1.47	3.65	Mita
		,, ,,	Diaspore pisolite	14.52	7.05	68.82	6.00	0.44	0.50	1.26	2.61	,,
		,, ,,	High grade ore (green, pisolitic)	15.55	15.90	60.14	7.98	0.08	0.11	-	-	,,
		,, ,,	Medium grade ore (green, pisolitic)	12.97	18.80	53.52	15.76	tr.	0.18	-	-	Cent. Lab.
		Chang-chia-kou, Hsiao-shih	Low grade ore (bluish-gray, pisolitic)	-	25.08	45.50	15.87	-	-	-	2.08	,,
		Pen-hsi-hu	Low grade ore (bluish-gray, pisolitic)	-	29.84	43.65	13.52	-	-	-	0.95	,,
	Flint clay	Tsu-erh-shan, Yen-tai	High grade ore (celadon)	14.02	45.71	39.19	1.62	0.21	0.17	-	-	Mita
		Pen-hsi-hu	Low grade ore (yellow)	-	39.82	33.80	8.41	-	-	-	1.74	Cent. Lab.
		Pan-tao-ling, Yen-tai	Low grade ore (purple red)	13.58	40.24	36.68	9.45	0.22	0.34	-	-	Mita
"G" Bed	Aluminous shale	San-leng-shan, Fu-chou	Diaspore (compact, massive, gray)	-	3.28	71.60	3.14	-	-	-	3.26	Cent. Lab.
		Yen-tai	High grade ore (white, pisolitic)	14.75	21.64	57.72	1.98	0.58	0.70	1.28	3.05	Mita
		Niu-hsin-tai	Low grade ore (red)	-	25.08	43.60	17.44	-	-	-	-	Cent. Lab.
		,,	Low grade ore (dark green)	-	23.98	28.22	35.28	-	-	-	1.50	,,
	Flint clay	Niu-hsin-tai	High grade ore (gray)	-	42.70	40.53	1.90	-	-	-	1.70	,,

* Analyst: Mita—Masaaki Mita, Research Section, formerly Showa Iron & Steel Works, An-shan; Cent. Lab.—Central Laboratory, South Manchuria Railway Co., Dairen.

Table 4. Mineral Components and Crystal Grain Size of the Aluminous Shale and Flint Clay.

	Minerals	Pisolitic ores		Compact massive ore	Remarks
		Pisolite	Matrix		
Chiefly microcrystalline	Diaspore: α–Al 0 (0H)	Macro-Micro	Micro-crypto	Crypto	Macrocrystalline: 50–200 microns
	Kaolinite: $Al_2Si_20_5$ $(0H)_4$	Micro	Micro	Crypto-Micro	Microcrystalline: 5–50 microns
	Chamosite: $(Al, Fe^{3+}, Fe^{2+})_6$, $(Al, Si)_4$ 0_{10} $(0H)_8$	Macro (rare)-Micro	Macro (rare)-Micro	Crypto	Cryptocrystalline: 1–5 microns
	Nontronite: $(Fe^{3+}{}_2)$ $(Al_{.33}Si_{3.67})0_{10}(0H)_2$. n H_20	Macro-Micro	Micro-Crypto	Crypto	Cryptocrystalline: <1 microns
	Rutile: $Ti0_2$	Micro	Micro	Crypto	
	Turgite: $2Fe_20_3$ $2H_20$	Powdery or filmy			
Gel-like or cryptocrystalline	Boehmite: α–Al0 (0H)		Crypto		
	Halloysite: $Al_2Si_20_5$ $(0H)_4$		Crypto	Crypto	
	Chamosite: $(Al, Fe^{3+}, Fe^{2+})_6$ Al, $Si)_40_{10}$ $(0H)_8$		Crypto	Crypto	
	Doelterite: $Ti0_2$ $2H_20$		Crypto?	Crypto?	
	Limonite: Fe0 (0H) nH_20		Stain	Stain	

Table 5. Mineral Components of the Aluminous Shale in Manchuria.

Beds	Localities	Fu-chou	Chemical analysis				Mineral components							
			SiO_2	Al_2O_3	Fe_2O_3	TiO_2	Diaspore (grain size: dia. microns)		Sporogelite, Boehmite	Halloysite, Kaolinite	Chamosite	Chloropal, Nontronite	Hematite, Turgite	Doelterite Rutile
"A"	Pan-tao-ling, Yen-tai	Grayish-brown, compact, hard	9.93	63.85	9.40	2.80	○	2–30	○	+	+	△		+
〃	〃	Yellowish-brown, compact	18.15	54.86	11.30	1.95	◦	2–10	○	△	+	◦		+
〃	Niu-hsin-tai	Gray, pisolitic	17.38	65.92	1.74	1.03	◎	3–50		○				+
"G"	〃	Dark grayish-brown, hard	9.86	58.90	17.65	-	◎	10–25		◦		+	△	−
〃	Fu-chou	Gray, compact	22.36	58.10	2.63	-	◎	2– 5		○				R+
〃		Grayish-white, compact, hard	16.18	65.87	1.81	2.79	◎	2–10		○				R+

Weight %: ◎ 50–75 ○ 25–50 ◦ 15–25 △ 5–15 +<5

eye. All of the minerals are extremely fine-grained or under 100 μ in diameter. Under the microscope the compact and apparently opaque portion is seen to be an aggregate of fine, dusty crystal grains; the individual grains can be first observed with a magnification of over 200. These grains are 1–3 μ in diameter. At first glance under the microscope the compact translucent part which appears to be amorphous is also present in a fairly large amount. With a magnification of 200 or more and by inserting a condenser under the crossed nicols, minute grains show slight double refraction which suggests that they are crystalline. The mineral components of this part can be inferred on the basis of the degree of recrystallization as well as chemical analyses. Besides, by means of X-ray and differential thermal analyses, the components have been nearly determined.

Grain size and distribution of each mineral are shown in Table 4.

In the table the flint clay corresponds to the compact massive ores which consist of kaolinite and halloysite. Microscopical examinations of thin sections of ores from different localities are summarized in Table 5.

By means of differential thermal analyses, heating aluminous shale and flint clay and measuring the dehydration and inversion temperatures, it was established that flint clay consists of kaolinite and halloysite, and aluminous shale of a mixture of kaolinite, halloysite, and diaspore.

It has been stated that the outcrop of the rich ore body of the "A" bed at Pan-tao-ling, Yen-tai, shows a symmetrical banding in a profile perpendicular to the bedding, that is, with green aluminous shale in the middle, and yellowish-brown to purple flint clay both above and below. The chemical analyses of each band by M. Mita are shown in the following table:

Table 6. Chemical Analyses of Aluminous Shale and Flint Clay, taken along the Profile of an Outcrop of the Rich Ore Body in the "A" Bed at Yen-tai (M. Mita).

Samples	Ig. l.	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Color
E-No. 11	13.25	43.82	40.30	1.46	0.46	0.23	Celadon
10	15.42	43.90	39.58	2.24	0.24	0.11	Gray
9	13.58	40.24	36.68	9.45	0.22	0.34	Reddish-purple
8	14.39	42.30	38.33	4.83	0.27	0.15	Purplish-gray
7	16.24	39.92	39.27	4.43	0.05	0.13	Grayish-yellow
6	16.54	33.55	37.66	12.38	0.04	0.26	Grayish-brown
5	16.00	25.15	45.88	14.41	0.14	0.14	Green
4	15.55	15.90	60.14	7.98	0.08	0.11	〃
3	13.60	25.72	47.92	9.88	0.07	0.25	Grayish brown
2	15.18	37.70	41.40	5.72	0.09	0.13	Brown
1	14.55	42.77	36.88	4.98	0.16	0.23	Grayish-purple

Sample numbers: 11 at footwall; 1 at hanging wall; others intermediate.

M. Mita analyzed these samples by the differential thermal method. Green aluminous shale in Table 6 exhibits a diaspore curve which grades successively upward and downward into a kaolinite curve. This sequence is perfectly in accordance with optical observations and chemical analyses, showing a typical profile of the "A" bed.

Yasuo TANAKA discovered through thermal analyses and measurement of vapor tension that the aluminous shale from Chin-chou consists of a mixture of diaspore and kaolinite (*Jour. Chem. Soc. Japan,* v. 58, p. 176–181).

Shōichirō NAGAI *et al.* made a comparative study by thermal analyses of bauxite, aluminous shale, and diaspore from different localities.

The X-ray analyses performed at the Continental Research Institute revealed the presence of boehmite in some of the ores as well as diaspore and kaolinite. From optical observation the writer suspected the presence of boehmite in some ores from Shan-tung Province. Boehmite is the chief constituent of the terra rossa type bauxite in France and elsewhere and is soluble in soda. The ores with a large amount of boehmite may be economically utilized by the Bayer process.

The results of ODA's X-ray analyses are shown in the following table (Saburo ODA, X-ray studies on clays from Manchuria, Report No. 1; On the boehmite in the aluminous shale in Manchuria: *Report of the Continental Research Institute,* v. 5, no. 10, p. 293–308, 1940).

Table 7. Chemical Components of the Aluminous Shale and its Mineral Composition as Determined by X-ray Analyses (S. Oda).

Localities	Al_2O_3	SiO_2	Fe_2O_3	TiO_2	MgO	CaO	Ig. l.	Minerals det. by X-ray*
Ku-yeh	77.67	2.46	1.96	2.49	–	–	14.89	D. K
Sho-ko-zan	69.50	7.12	4.51	2.76	–	0.21	14.98	D. K
N. China	72.59	8.86	1.41	2.60	–	–	14.55	D. K
Fu-chou	69.60	10.70	1.76	3.43	–	–	14.30	D. K
Yen-tai	57.06	15.28	12.15	1.99	–	–	13.24	D. K. B
〃	54.51	17.98	12.24	1.92	–	–	13.40	D. K. B
〃	52.70	18.66	13.40	1.70	–	–	13.43	D. K. B
Niu-hsin-tai	52.98	18.92	12.66	1.96	–	–	13.34	B. K. D
Yen-tai	53.31	20.00	9.63	2.36	–	–	14.21	B. K

* D—Diaspore, K—Kaolinite, B—Boehmite

Observations, both by the naked eye and under the microscope, are not discussed in detail by ODA, but the last-mentioned sample from Yen-tai is said to be "greenish-yellow" to the naked eye. Therefore, it is almost certain to be a compact, massive, rich aluminous shale ore containing pisolites. The ores of this class appear to be amorphous under the microscope, and from both observations under the microscope and chemical analyses, have been supposed to consist of a mixture of halloysite with either sporogelite or gel-alumino-ferrique. Judging from results obtained by S. ODA, however, the sporogelite may be cryptocrystalline boehmite.

Nonmetallic Deposits in Manchuria

Takao Sakamoto

(1) Coal[1]

Coal is by far the most important mineral product in Manchuria. Out of the total annual production of coal—nearly 23 million tons in 1944— 58 per cent comes from the Mesozoic coal fields, 29 per cent from the Cenozoic, and only 13 per cent from the Palaeozoic fields. In total world production, 81 per cent is contributed by the Palaeozoic fields, only 2 per cent by the Mesozoic and 17 per cent (including lignite) by the Cenozoic fields. The predominance of Mesozoic instead of Palaeozoic coal fields is a unique feature of Manchuria. This applies to the Russian Far East, too, as was pointed out by Prigorovsky[2] in 1937. Prigorovsky denoted this as the Pacific type of coal genesis as distinguished from that of other parts of the world.

The Mesozoic and the Cenozoic coal fields are distributed more or less uniformly throughout Manchuria, whereas the Palaeozoic coal fields are developed only in South Manchuria, *i.e.*, south of the great east-west tectonic line. The Mesozoic fields are nothing but a southern extension of those of Siberia, and the Palaeozoic ones an eastern extension of those of North China, the former overlapping the latter in South Manchuria.

The Mesozoic and Cenozoic fields are of an intermontane or a limnic type, and both the coal-bearing formations and the coal seams themselves often attain a great thickness, one to several thousand meters for the coal-bearing formations and from fifteen to more than one hundred meters for a single coal seam. But the area of the fields is limited and the thickness of both the coal-bearing formations and the coal seams variable within a short distance. Each of these fields originated as an isolated basin in a tectonic depression, so the sequence of coal seams in one field is usually different from that of the neighboring fields. The Mesozoic strata are characterized by arkose and tuffaceous materials and in many places contain thick volcanic lava and agglomerates both in the lower and upper portions, and also a conglomerate with huge boulders up to several meters in diameter.

1) The production quantities mentioned in this article are a rough estimate of the maximum outputs immediately before and during world War II.

2) A lecture given at the XVIIth International Geological Congress in Moscow, 1937, which the writer attended.

The Palaeozoic fields are of a littoral type, with the thickness of the coal-bearing formations only 200–450 m. The thickness and lithologic character are remarkably constant over a wide area, and one may naturally infer that Palaeozoic coal fields were once great continuous fields which, by later tectonic movements, were divided into the smaller, separate fields of the present.

The sequence of the strata and coal seams are stikingly similar among neighboring fields, not only in South Manchuria but also in North Korea and North China. The sandstones are quartzose and the shales kaolinitic.

Such differences in the mode of genesis of the Mesozoic and Palaeozoic coal basins account for differences in mining methods as well as in the properties of the coal. Difficulties in mining thick seams (15–100 m) and in protecting weak tunnel walls and working faces (due to the weakness of bentonitic beds) are drawbacks of the Mesozoic fields. Coal ashes of the Mesozoic coal are often bentonitic and consequently have a low melting point (1,100°–1,200°C), whereas those of the Palaeozoic are kaolinitic and highly refractory. Sometimes the low refractoriness of the Mesozoic coal ashes prevents their use for making coke, in spite of the strongly caking nature of the coal itself (like the coal from some seams in Pei-piao fields) or in an extreme case, even for boiler heating (like the coal from Lin-kou west of Mi-shan), because the ashes easily melt into clinkers which choke the grate openings.

Table 1. Coal Ratios in Important Coal Fields in Manchuria.

Coal fields	Coal ratios (%)
Fu-shun (T)	0.7–10
Hao-kang (M)	4.2
Sung-shu-chen and Wan-kou (P)	3.0
Pen-hsi-hu (P)	2.8
Hsi-an (M)	2.5
Pa-tao-hao (M)	1.8
Yen-tai (P)	1.3
Hsiao-shih (P)	1.2
Fu-hsin (M)	1 – 2
Pei-piao (M)	1.0
Mi-shan (M)	1.0
Fu-chou (P)	1.0
Chiao-ho (M)	0.6

(P)—Palaeozoic coal fields
(M)—Mesozoic ,,
(T)—Tertiary ,,

The coal ratios (a percentage ratio of the thickness of the coal seams to the total thickness of the coal-bearing formations) of more important fields are listed in Table I.

The coal from the Palaeozoic fields is either high-grade bituminous or anthracite. The high-grade bituminous coal always cakes and is used for making coke. The coal from Mesozoic fields comprises all grades ranging from lignite to anthracite. A large field of Jurassic lignite is found in the Cha-lai-no-erh coal fields.

The Fu-hsin, Hsi-an, and most of the other smaller fields in central Manchuria of Jurassic or Jura-Cretaceous age produce bituminous coal, which is good for steam coal and also for cement and other ceramic industries. But they usually contain a rather large amount of water (7–10 per cent), and accordingly are of low calorific value.

Mesozoic fields in northeastern Manchuria, *e.g.*, Hao-kang, Fu-chin, Mi-shan, produce good caking coal. Other Mesozoic fields, distributed more or less erratically in central Manchuria, produce caking coal (Pei-piao, Wa-fang-tien), or anthracite (Tien-shih-fu-kou).

Table 2. Coal Reserves of Important Coal Fields in South and North Manchuria—Surveyed and Revised in 1943 by the Government Committee.

Age	Coal field	Province	Coal properties & fuel ratio	Reserves (mil. m. tons)	Area of coal field (km²)
M	Ai-hun	Hei-ho	L 1.0	3.9	—
M	Cha-lai-no-erh	Hsing-an	L 0.9	404.7	500
M	Hao-kang	(Eastern Manchuria)	B 1.6	1,762.0	180
M	Fu-chin	(Eastern Manchuria)	B 1.8	50.4	350
T	San-hsing	(Eastern Manchuria)	B 1.0–1.2	162.3	40
M	Mi-shan	(Eastern Manchuria)	B 1.6	370.4	1,500
M	Mu-leng	(Eastern Manchuria)	B 1.4	16.9	35
M	Tung-ning	(Eastern Manchuria)	(B) 1.0	5.4	350
M	Lao-hei-shan	(Eastern Manchuria)	(B) 0.9	114.3	—
T	Hun-chun	Chien-tao	L 0.8	10.1	200
M	Lao-tou-kou	Chien-tao	B 1.1	14.3	5
M	San-tao-kou	Chien-tao	B 1.2	28.6	100
M	Tu-shan-tzu	Chien-tao	B 1.2	114.3	—
M	Huo-shih-ling	Chi-lin	B 1.0	11.9	20
M	Ssu-mi-kou	Chi-lin	B 1.0	0.8	—
M	Chiao-ho	Chi-lin	B 1.3	37.8	500
T	Shu-lan	Ssu-ping	L 0.8	(200.0)	200
M	Hsi-an	Ssu-ping	B 1.1	224.0	25
M	Ya-tzu-Chuan	Ssu-ping	A 7.0	4.1	—
T	Fu-shun	Feng-tien	B 1.1–1.8	582.9	40

P	Pen-hsi-hu	Feng-tien	B 3.2	225.2	40
P	Tien-shih-fu	Feng-tien	B 3.2	20.9	60
M	Tien-shih-fu	Feng-tien	A 6.1	57.9	
P	Niu-hsin-tai	Feng-tien	A 6.8–11.6	53.2	20
P	Yen-tai	Feng-tien	A 6.0	29.8	20
M	Wa-fang-tien	Feng-tien	B 2.5	0.3	5
M	Wa-fang-tien	Feng-tien	A 8.0		
P	Fu-chou	Feng-tien	A 7.0	4.5	10
M	Sai-ma-chi	Feng-tien	B 2.9	56.9	180
			A 6.5		
P	Tieh-chang	Tung-hua	B 2.9	(58.5)	—
P	Wu-tao-chiang	Tung-hua	B 3.3	(155.2)	17
M	Lin-tzu-tou	Tung-hua	B 1.8	10.5	20
P	Sung-shu-chien	Tung-hua	B 2.3	88.8	30
P	Wan-kou	Tung-hua	B 2.0	25.3	8
M	Shan-sung-kang	Tung-hua	B 1.6–2.3	25.6	—
M	Fu-hsin	Chin-chou	B 1.2–1.6	1,423.0	1,100
M	Pa-tao-hao	Chin-chou	B 1.2	59.1	20
M	Pei-piao	Chin-chou	B 1.5–2.0	173.3	65
P	Nan-piao	Chin-chou	B 4.5	191.7	60
M	Hsi-yuan-pao-shan	Jehol	L 1.0	106.3	—
M	Tung-yuan-pao-shan	Jehol	L 1.0	35.0	—
P	Hsing-lung	Jehol	B 2.3	18.6	20
	Total:			6,941.2	

P: Palaeozoic M: Mesozoic T: Tertiary
A: Anthracite B: Bituminous L: Lignite

Tertiary coals are usually black lignite, but in Fu-shun bituminous coal of very good quality, some of it caking, is produced. This coal is used for gas production, locomotives, coke ovens, ceramic kilns, and for other industrial purposes. It was also used for experiments on artificial liquefaction of coal in Fu-shun.

In 1935, the total coal reserves of Manchuria were estimated at 4,600,000,000 metric tons. The estimates of reserves in Hao-kang and Fu-shin were revised following a recent survey and increased. The reserves in Hao-kang are now believed to be 1,700,000,000 metric tons or three times those of Fu-shun and to constitute the largest coal field in Manchuria. The total coal reserves of all Manchuria are estimated at 7,500,000,000 metric tons, immediately before the war. The coal reserves of all seams, 1,000 m or less in depth and 70 cm or more in thickness, of the important fields are listed in Table 2.

Total reserves of all the fields, inclusive of new fields discovered near Mi-shan (*e.g.*, Kuang-i) and all other minor deposits amount to a total of 7,500,000,000 metric tons.

The proportion among the fields of the various periods, of both coal reserves and area of fields, are shown in Table 3.

Table 3. Geologic Age Distribution of Coal Reserves and of Area of Coal Fields.

Age	Coal reserves (metric tons)	Per cent	Area of coal field (Square Kilometers)	Per cent
Palaeozoic	700,000,000	9	500	7
Mesozoic	5,800,000,000	78	5,800	85
Tertiary	1,000,000,000	13	520	8
Total	7,500,000,000	100	6,820	100

The predominance of the Mesozoic fields is clearly shown in the above list.

(2) **Oil shale and natural oil indications**

Both Mesozoic and Tertiary coal-bearing formations are intercalated with oil shale beds. The Mesozoic oil shale beds are usually thinner and of a poorer grade, but occasionally rich shales, such as those in Hua-tien and Lo-tzu-kou, are found. The Tertiary oil shale is represented by a thick bed in Fu-shun with a thickness of 120 meters, directly overlying the main coal seam. It can be traced for 16 km along its outcrop, rather a short distance for its great thickness. Another example of a Tertiary oil shale bed is the 20-meters-thick bed at San-hsing which, like the bed of Fu-shun, overlies a bituminous coal seam.

The Hua-tien shale is yellowish-brown and the richest part, about one meter thick, yielded as much as 23 per cent crude oil in a laboratory distillation test. There are a few other seams, but with shale of greatly inferior quality. The construction of a small-scale distillation plant was planned in Hua-tien during the war.

The Lo-tzu-kou shale is brownish-black with a finely banded texture just like the "mahogany shale" or the richer portion of the oil shale beds in the Green River formation of Utah and Colorado. The oil yield of the richer beds obtained by laboratory tests is about 10–12 per cent. The total reserve is larger than that of Hua-tien and is believed to be several million metric tons, but the richer shale is limited both in area and reserves.

The Mesozoic coal seams in Tung-ning and Lao-hei-shan contains partings of oil shale beds. It burns easily with an unusually large amount of smoke, and upon proximate analysis, gives low fuel ratios such as 0.9–1.0. These are due to the presence of oil shale partings. The coal itself is bituminous.

Oil shale in Fu-shun has been known since 1909. After twenty years of extensive experimentation both in laboratories and in pilot plants, a big distillation plant was erected. It incorporates a series of vertical retorts with an internal heating system which was Fu-shun's own device. The total reserve of the oil shale amounts to over five billion metric tons. The crude ore used in the distillation plant is only the richer portion of the shale and has to be stripped in open pit mining of the coal. The average crude-oil yield is 5.5 per cent. Although the oil yield is very low, the cost of the crude ore is kept extremely low by means of large-scale mechnization of mining and transportation. It can be said that economic success in the industry depends upon this mechanization in the handling of bulky and cheap materials. For example, the Scottish shale treated by the Anglo-Persian Oil Company in Lothians, Scotland, yields 8 per cent and the Esthonian shale treated by the government plant averages 18 per cent. Ores in both countries are mined underground.

Natural oil indications are known from the Fu-hsin and Cha-lai-no-erh coal fields. In Fu-hsin, traces of crude oil were first found in 1935. They consisted of oil stains in cores and drops of oil floating on the drilling fluid. A deep boring (planned depth 1,000 m) was begun in 1937 and oil indications were found at several horizons from a depth of 644 to 780 m, and a total of about 70 liters of crude oil was recovered from the circulating water. The formation is part of the Mesozoic Fu-hsin coal-bearing formation, situated below the horizon of the main coal seams. It is 500 m thick and consists of tuffaceous sandstone and agglomerate.

Asphalt was found in 1930 in Cha-lai-no-erh. It occurs either as seepage in porous sandstones or as amygdaloidal cavities in trachytic lava. In 1935, one deep boring (planned depth 1,000 m) and fourteen shallow borings (depth 200–300 m) were finished. One of the shallow holes encountered an oil sand 3 m thick. Next year, the deep boring reached a depth of 1,114 m. In 1937 and 1938, gravitational and seismic prospecting methods were used in examining the underground structures. Further prospecting with both diamond and rotary drilling was planned but not carried out owing to political conditions.

(3) Graphite

The most important graphite deposit is the Liu-mao deposit near the Mi-shan coal field. The rocks are crystalline limestone, paragneiss, graphite schist, and intrusive biotite granite and pegmatite.

The graphite deposits are of two types: one consists of a flaky graphite in an irregular vein form and is associated with such skarn minerals as diopside, scapolite, andradite, anorthite and titanite; the other consists of an "ore bed" of a graphite schist. The second type forms very large deposits.

The average of the values obtained by analysis of the ore treated in the flotation mill shows 18 per cent carbon. In 1944, about 500 metric tons of carbon for crucibles and 4,200 metric tons for electrodes were produced. Production capacity can be greatly enlarged in the future.

(4) Pyrite

Practically all the pyrite produced in Manchuria comes from two sources: one source is the flotation plants of metal mines, especially lead and zinc mines, and the other is the dressing plants of coal mines. In both cases, the pyrite is a by-product of other minerals. The normal demands for this mineral as raw material for sulphuric acid plants (Fu-shun, An-shan, Pen-hsi-hu, and Kan-ching-tzu in Kuantung Territory) amounted to over 200,000 metric tons, whereas production from all sources in Manchuria resulted in a grand total of only 30,000 metric tons. When shipment from Japan was interrupted, every effort was made to increase domestic production. But since most of the pyrite was obtained as a by-product, production could not be increased in a short time. Thus, the sulphuric acid plants (Manchuria Chemical Co., Kan-ching-tzu) were compelled to curtail or stop operations.

A new deposit of pyrite was discovered near the Wu-ta-lien-chih volcanoes, north of Chi-chi-har. The deposit is in a loose Cretaceous sandstone bed impregnated with pyrite nodules. The impregnation was traced for a wide area, but the nodules are scattered and sparse, and after many months of examination by means of test pits (10–30 m deep) the work was given up.

(5) **Aluminous shale and fire-clay**

Aluminous shale, or *Bando-ketugan,* occurs in two beds parallel to the coal seams in Palaeozoic coal fields, one ("A" bed) above and the other ("G" bed) below the coal seams. The bulk of the material of both the "A" and "G" beds is a kaolinitic fire clay or a flint-clay with a thickness of 2.5–10 m or more; the rich ores of the *bando-ketugan* with an alumina content of 55–70 per cent occur in flat lenses within this clay bed. The *bando-ketugan* lenses are nearly one meter thick and several scores and occasionally several hundreds of meters long. In the "G" bed the *bando-ketugan* is thicker but relatively limited in area.

The vertical distance between the "A" and "G" beds, the thickness of the productive coal-bearing formations, ranges from 250 to 450 m in different fields. Between these two *bando-ketugan* beds are several kaolinitic fire-caly beds. The total thickness of all these clay beds is over 20 m in most of the Palaeozoic coal fields. This is the largest development of kaolinitic clay and aluminous shale in the world. This is due to the fact that these coal basins are typical paralic basins and were subjected only to epeirogenic movements during their formation.

The flint fire-clay is made up of practically pure kaolinite (and halloysite), whereas the *bando-ketugan* is a mixture of kaolinite with varying amounts of aluminum hydroxide, usually as α-Al_2O_3 H_2O, or a diaspore. Upon analysis, the flint fire-clay, when pure, has an alumina content of 40–42 per cent, that is, a little more than that of a pure kaolinite, whose alumina content theoretically is 39.5 per cent. This excess, according to the writer's study, is accounted for by the presence of pholerite, an atomic isomorph of kaolinite which has a higher content of alumina. So the writer suggests placing the boundary of the flint clay and *bando-ketugan* at 45 per cent alumina in the proximate analysis, on a titanic acid and ferric oxide free basis, *i.e.*, on a SiO_2, Al_2O_3 and H_2O basis.

Only the "G" bed is found in Fu-chou, because the "A" bed has been removed by erosion. The "G" bed yielded high-grade ore, containing 60–70 per cent alumina, which was used for refractory materials such as Corhart, electrically melted and cast bricks.

In Yen-tai, Niu-hsin-tai and Hsiao-shih both the "A" and "G" beds occur; from these beds richer "ores" (averaging 55 per cent alumina and 10 per cent ferric oxide) were shipped to the Manchuria Light Metals Co. at Fu-shun for the production of aluminum. The production capacity of this company was about 15,000 metric tons per year. The metal produced was used for high-tension transmission lines from the water power plants at the Feng-man and Shui-feng dams to big cities in Manchuria.

(6) Magnesite

Magnesite is found in metamorphic rocks of the Ta-shih-chiao series of the Eo-Proterozoic Liao-ho system. It is coarsely-crystalline, white, pink, and grayish, and is associated with crystalline dolomite. The ore bodies are found in a zone extending from east of Ta-shih-chiao to east of Hai-cheng, a distance of over 40 km. A single ore body ranges in thickness from a few score to a few hundred meters and is 200–1,000 m long—large enough to permit modern large scale mechanized quarrying. The magnesite is secondary magnesite which was derived from dolomite by hydrothermal metasomatism.

The total reserves of magnesite are said to amount to several billion tons, and the reserves of rich ore—with less than 2 per cent SiO_2—to nearly 500 million metric tons. In Hamgyong-pukto, North Korea, there is the same type of deposit, with a nearly equal amount of ore reserves. So the combined area of South Manchuria and North Korea will be one of the leading sources in future of crystalline magnesite.

Calcined magnesite was produced in Ta-shih-chiao in vertical kilns, burned with anthracite; about 300,000 tons of magnesite clinkers were exported to Japan, the United States, and elsewhere in one year.

(7) Dolomite

Dolomite beds are found in many sedimentary formations of Pre-Cambrian and Palaeozoic age:—gray crystalline dolomite associated with magnesite, bluish-gray compact dolomite in the Kuan-tung series of the Sinian system, and bluish-gray compact dolomite in the Lower Ordovician series (the Wan-wan series). Of these, the second type is the most important. It is very well developed in the Kuan-tung Territory and is quarried for the manufacture of refractory materials and white paint dolomite plaster for walls.

The dolomite is believed to be a shallow sea replacement product of limestone, formed during or immediately after deposition by sea water containing magnesium ion. It occupies definite stratigraphic horizons over a wide area and there are enormous reserves.

(8) Limestone

Limestone is found in thick beds and is distributed in more stratigraphic horizons than dolomite in Manchuria.

The reserves are abundant. They are, as a rule, more or less magnesian and if more than 2 per cent magnesia is present, they are unsuitable for portland cement manufacture. But if proper horizons are selected for quarries, limestones of any of the periods listed in Table IV could be used for this purpose. Of these, the Neo-

Table 4. Geologic and Geographic Distribution of Limestone Beds in Manchuria.

Age		Type	Main localities
Eo-Proterozoic		Crystalline limestone associated with crystalline magnesite, dolomite	Ta-shih-chiao, Hai-cheng, Lien-shan-kuan, Wei-sha-ho, Mi-shan, Hao-kang
Neo-Proterozoic (Sinian)		Grayish-blue compact limestone associated with dolomite	Kuan-tung Leased Territory, Chuan-tou
Palaeozoic	Cambrian	Gray compact limestone	Kuan-tung Leased Territory, Huo-lien-chai Kang-ta-jen-tun
	Ordovician	Grayish-blue compact limestone associated with dolomite	Liao-yang (Shuang-miao-tzu), Pen-hsi-hu, Chuan-tou, Kuan-tung Leased Territory
	Carboniferous	Grayish-white crystalline limestone	Ming-cheng, Chi-lin, Erh-tseng-tien-tzu, Kuan-tung Leased Territory

Proterozoic and Ordovician in South Manchuria and the Carboniferous in Chi-lin Province are the purest and have the largest reserve.

The Showa Iron and Steel Works previously used the Cambrian limestone in Huo-lien-sai, but as the quarrying, proceeded SiO_2 in the limestone increased to more than 3 per cent and the quarry was abandoned. In recent years they used the neo-Proterozoic limestone in Kan-ching-tzu, Kuan-tung territory with about one per cent SiO_2. This difference of 2 per cent in SiO_2 content was said to justify the far longer haulage by rail. The Pen-hsi-hu Iron and Steel Works uses the Ordovician limestone in Pen-hsi-hu.

The Carboniferous limestone in Ming-cheng, south of Chi-lin, along the Mukden—Chi-lin Railway line is extremely low in SiO_2 (0.5–1.0%) and MgO (0.5–2.0%). This is the best quality in all Manchuria, and was to be used by the new Manchuria Electro-Chemical Co. at Chi-lin for the manufacture of carbide, etc.

(9) Talc

Talc is found in hydrothermal metasomatic deposits in crystalline dolomites, associated with the big magnesite deposit in the Ta-shih-chiao —Hai-cheng region.

The ore bodies are irregular in shape. The largest is in Ta-ling, 30 km southeast of Hai-cheng. The talc is white to rosy and very pure; thin slabs are often semitransparent.

The annual production amounted to 40,000 metric tons, nearly all of which was shipped to Japan.

(10) Asbestos

Asbestos is found in contact metasomatic deposits of two types: one in magnesian limestone, intruded by gabbro dikes (Ho-shang-tun, Kuan-tung leased territory, Tai-ping-fang, Jehol, and elsewhere), and the other in serpentinized limestone blocks caught by intrusive granites (Li-shu-kou, Ta-huang-kou, and elsewhere).

In the deposit of Ho-shang-tun, the asbestos is found in parallel veinlets in a zone one to two meters thick and 500 meters long of nephrite, which is contact metamorphosed limestone.

The content of asbestos varies from one to 3 per cent or, rarely, 4 per cent of the nephrite. The fibers are less than 3 cm long and are arranged perpendicular to the walls of the veinlets. The asbestos is a chrysotile of good quality.

At Tai-ping-fang, there are seven small deposits in a dolomitic limestone of Sinian age intruded by a gabbro. Small veinlets of asbestos are found in the mineralized zones, which are 0.5–2 m thick and 110–550 m long. The content of asbestos in the mineralized zone ranges from 1.1 to 3.6 per cent. The asbestos is a chrysotile with fibers 1–3 cm long.

The deposits of the second type are more irregular. They also produce a chrysotile with fibers 1–3 cm long. At Ta-huang-kou, a rare mineral, szaibelyite magnesium borate, was discovered in the asbestos deposit.

Asbestos was one of the most eagerly sought minerals during the war period. Although ore of as fine a quality as the ore produced in the Urals or in Canada was not discovered, the annual production of second grade ore (shorter fibers) amounted to 5,000–6,000 metric tons of refined products.

(11) Mica

Muscovite is found in pegmatites in the Pre-Cambrian mica schist and gneiss, and is generally associated with tourmaline; phlogopite is found among skarn minerals in Pre-Cambrian limestone in contact with intrusive granite or gneiss.

The pegmatite-type deposits are smaller and so are the dimensions of the muscovite crystals; as a rule, the contact-type deposits are more promising. Near Pa-wang-chao, the contact-type ore deposits are distributed within an area 20 by 15 km where a series of metamorphic rocks with dolomite are engulfed in gneiss. The dolomite is intruded by aplite and pegmatite dikes, and phlogopite and diopside are present along the area of contact. This area has recently been discovered and is worth further prospecting. It promises to be one of the largest phlogopite deposits in East Asia.

(12) Fluorite

Fluorite is usually found in quartz veins in granite, gneiss and quartz porphyry, and other rocks, and in rare cases in a contact metamorphic deposit (Ma-lu-kou).

Fluorite-bearing quartz veins are known from twenty or more localities and have been exhaustively prospected. Deposits near Lung-hua, Jehol Province, and Na-lo-mu-to, north of Hailar, are larger and more promising.

The ores as mined are mixed with quartz and sometimes with barite and need dressing in order to raise the CaF_2 content. We heard recently that an oil-flotation process had been successfully applied. In 1943 the production of ores with more than 93 per cent CaF_2 was 11,000 metric tons; with less than 93 per cent, it was 26,400 metric tons, for a total of 37,400 metric tons.

(13) Boron minerals

Ludwigite ($3MgO.B_2O_3.(Fe,Mg)O.Fe_2O_3$) was first found in the Hua-tung-kou copper mine. The mineral is in a dense, felt-like aggregate of dark bluish-black acicular crystals, in the skarn zone of the contact metasomatic copper deposit of the mine. Richer ores analyze at 15 per cent B_2O_3, the reserve of which is estimated to be only 1,000 metric tons, whereas reserves of ores containing about 10 per cent B_2O_3 are believed to amount to 4,000–5,000 metric tons. Several hundred tons of the richer ores were shipped to Japan for the manufacture of a boron glass (a special hard glass used for ampoules, etc.), as a substitute for imported borax.

Another rare mineral called szaibelyite ($10MgO.4B_2O_3.3H_2O$) was found in the Ta-huang-kou asbestos deposit in 1942. This mineral occurs in spots or irregular vein-like masses and is associated with asbestos, ludwigite, humite, and magnetite. Rich ores give 8–11 per cent B_2O_3. The amount of reserves of rich ore is calculated to be only several hundred tons, but that of poorer grades is very large—27,000 metric tons of ores with 4–5 per cent B_2O_3 and 200,000 metric tons with 2 per cent.

A tourmaline schist which contains an unusually large number of tourmaline crystals was found to the east of Ta-shih-chiao. The schist gives 6–9 per cent B_2O_3 on analysis. It is said that utilization of this schist was considered, but details are not known.

(14) Vein-quartz and feldspar

Vein-quartz is found either in pegmatites in association with feldspar or in quartz veins. Pegmatites are found abundantly in gneiss regions in the Kuan-tung leased territory and near Hai-cheng.

Among the larger pegmatites in Hai-cheng region are those with a zonal structure. The outer zones consist of smaller crystals of quartz and feldspars in an intimate graphic intergrowth, whereas the inner zones consist of an aggregate of the same minerals but with larger (20–30 cm in diameter) separate crystals. Only the inner zones are quarried for quartz and feldspar, because the minerals are easily separated by hand picking.

Feldspars in the outer zones are richer in potash and in this respect, better suited for glass manufacture than those in the inner zones, which contain less potash (6–7 %) and a greater amount of soda.

The vein-quartz in Kuan-tung leased territory was used for the manufacture of the gauge glass and cut glassware in the Nanman Glass Works in Ta-lien.

Feldspars with a high content of potash (11 %) were found in orthophyre dikes northeast of Tsao-ho-kou, Mukden—An-tung Line but were not utilized because of inconvenience of transportation.

(**15**) **Quartzite**

Quartzite occurs in thick beds in the Ta-ho-shang-shan series of the Neo-Proterozoic, or Sinian system in Kuan-tung leased territory, and elsewhere. When pure, it contains 99 per cent SiO_2 and 0.2 per cent iron and is good enough for window glass.

Quartzite in Lu-shun (Port Arthur) and in Ta-lien was extensively quarried and shipped to Japan for the manufacture of dinas (silica) bricks for coke ovens, etc.

(**16**) **Natural soda**

Natural soda, together with salt, occurs in saline lakes near Hailar and Tao-nan. Both are utilized by the natives. Beside Na_2CO_3, soda minerals occur in many forms; among them is a rare mineral, gaylussite ($CaCO_3.Na_2CO_3.5H_2O$).

CHINA

Upper Paleozoic Formations of Coal Fields in North China

Yoshio ONUKI

Introduction

The author was engaged in the investigation of coal fields in North China from 1937 to 1945 and has reported, at least in outline, the results of every investigation completed. As he submitted all data and specimens to the Chinese Government following Japan's surrender in 1945, this paper has been prepared on the basis of the author's memories and papers, reports by the North China Development Company which had previously been sent to Japan, and also the data presented to Japanese scholars visiting North China.

In the coal fields of North China, there are coal seams of the Upper Paleozoic, Mesozoic and Cenozoic eras. Most of them belong to the Upper Paleozoic era; those of the Mesozoic era succeed them and are developed regionally, but those of the Cenozoic era are rare. The coal fields of the Upper Paleozoic era are widely distributed and contain coal seams of superior quality, so these have been exploited for a long time, and have been investigated and studied geologically and paleontologically by many researchers. The author examined the stratigraphic order of the Upper Paleozoic formations and their interrelations, in order to consider sedimentation facies and crustal movements. He attempted to correlate these findings with the Upper Paleozoic formations in Central and South China and those in Korea, and he will present this data as a contribution to the synthetic study of the Upper Paleozoic formations in North China.

In connection with the preparation of this paper, the author expresses his grateful thanks to Takao SAKAMOTO, Fujio HOMMA and Nobuo YAMANOUCHI, for their kind guidance rendered to the author while he was in service at the South Manchuria Railway Company and later in the North China Development Company, surveying the geology of coal fields in North China. The author is indebted also to all persons who presented data and cooperated in his investigation.

1. Upper Paleozoic Formations and Coal Field Geology

I. Correlation of Upper Paleozoic formations in the coal fields of North China

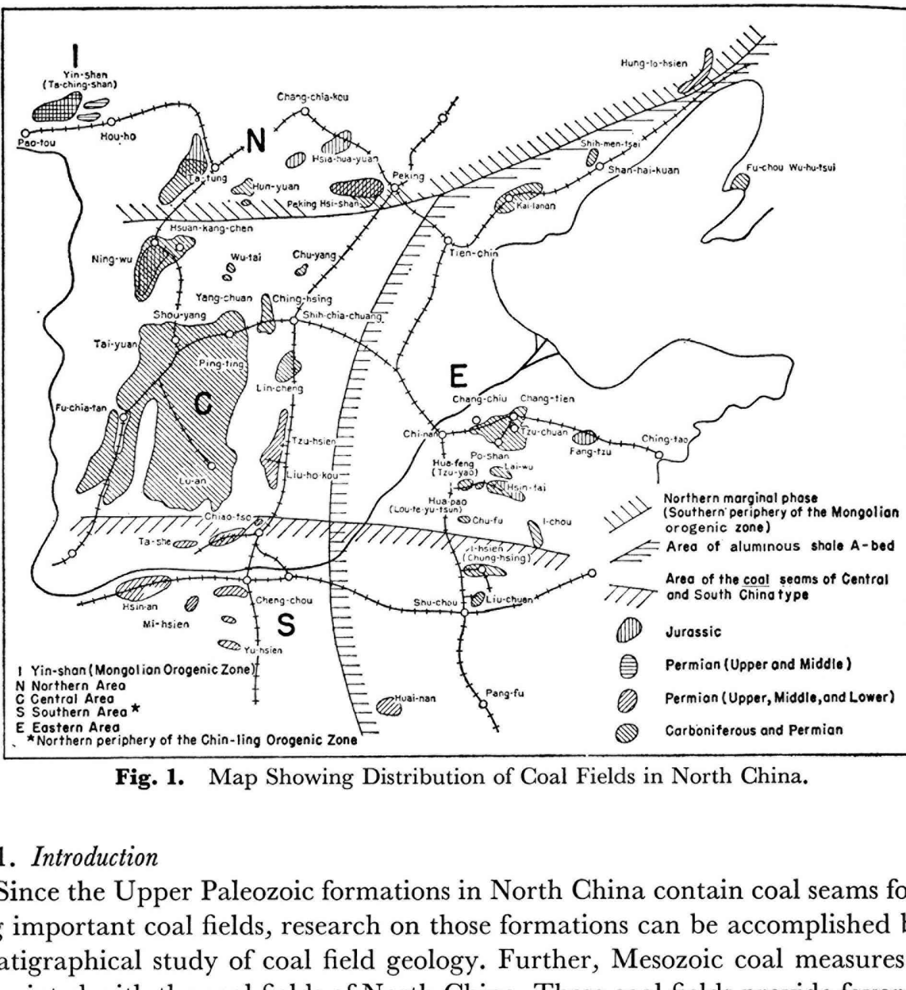


Fig. 1. Map Showing Distribution of Coal Fields in North China.

1. *Introduction*

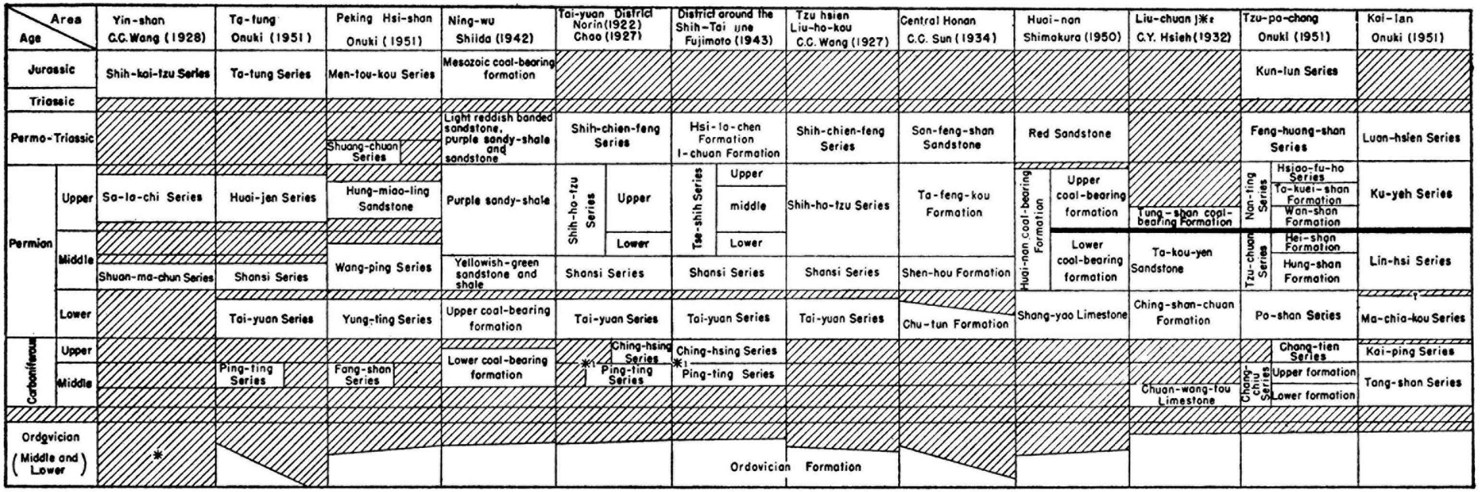
Since the Upper Paleozoic formations in North China contain coal seams forming important coal fields, research on those formations can be accomplished by a stratigraphical study of coal field geology. Further, Mesozoic coal measures are associated with the coal fields of North China. These coal fields provide favorable conditions for a stratigraphical study of the complex, from the Paleozoic to the Mesozoic eras.

The distribution of coal fields in North China is as follows:

1) Eastern provinces: Chi-tung (Shih-men-chai and Kai-lan); Shan-tung (Tze-Po-Chang, Lai-wu, Ta-wen-kou, Hsin-tai, I-chou, Chiu-fu, Y-hsien); and Northern Chiang-su (Liu-chuan).

2) Northern provinces: Hsi-shan in the suburb of Peking; Hun-yuan; Ta-tung.

3) Northernmost provinces: Yin-shan (Ta-tsing-shan).



※ Sinian limestone and quartzite ※1 Subdivision was made by the author for the so-called "Pen-chi Series" ※2 The author will use the division of Tzu-chuan—Po-shan—Chang-chiu ▬ Aluminous shale A-bed

Fig. 2. Correlation of Upper Palaeozoic Formations in North China.

4) Central provinces: Ning-wu; Wu-tai; Southern Shan-hsi (Tai-yuan district, the area along the Shih-Tai Railway Line, the marginal portion of the Tsin plateau); and the eastern side of the Tai-hang mountain range (Tzu-hsien—Liu-ho-kou).

5) Southern provinces: Southern side of the Tai-hang mountain range; the Yellow River basin; Central Honan; and Huai-nan.

I will outline the stratigraphic order of each coal field in North China. The constituent formations are correlated synthetically in Fig. 2, and each bed will be explained.

2. *Carboniferous formation*

In the Upper Paleozoic areas of North China, the Moscovian of the Middle Carboniferous period is well developed, but the Uralian complex of the Upper Carboniferous period is lacking, and unconformity is present between the Middle Carboniferous formation and the Lower Permian formation in most places. Mitsuo NODA (1950) stated that this relation holds true for North China and Manchuria.

The Late Carboniferous formation is commonly called the Pen-hsi (or Pen-chi) series in North China and Manchuria, but after a detailed survey of all coal fields in North China, the author recognized the necessity of dividing the series into the Chang-chiu series and Chang-tien series in the Tze-Po-Chang coal field, and the Ping-ting series and Ching-hsing series in the region along the Shih-Tai Railway Line. Their interrelations are shown in Table 1.

Table 1. Relation between Late Carboniferous and Lower Permian formations.

<table>
<tr><th>Age</th><th>Area along the Shih-Tai line</th><th colspan="2">Tze-po-chang</th><th>Division in the past</th></tr>
<tr><td>Lower Permian (Sakmarian)</td><td>Tai-yuan series</td><td colspan="2">Po-shan series</td><td>Tai-yuan series</td></tr>
<tr><td>Upper Carboniferous (Uralian)</td><td>Ching-hsing series</td><td colspan="2">Chang-tien series</td><td rowspan="3">Pen-chi series</td></tr>
<tr><td rowspan="2">Middle Carboniferous (Moscovian)</td><td rowspan="2">Ping-ting series</td><td rowspan="2">Chang-chiu series</td><td>Upper beds</td></tr>
<tr><td>Lower beds</td></tr>
</table>

The formations, recently distinguished by the author from the Ping-ting series or the upper beds of the Chang-chiu series as stated above, are intercalated with flint-bearing limestone, commonly varying from 4 m to 10 m in thickness. This limestone is given different names in different places: Tang-shan limestone in Kai-lan; Hsu-chia-chuang limestone in Chang-chiu; Feng-shui limestone in Tze-chuan and Po-shan; Lin-cheng limestone in Ping-ting and Yang-chuan; Pan-kou limestone in Tai-yuan; Kou-chuan limestone in Ta-tung; and Fang-shan limestone in Hsi-shan in the suburbs of Peking.

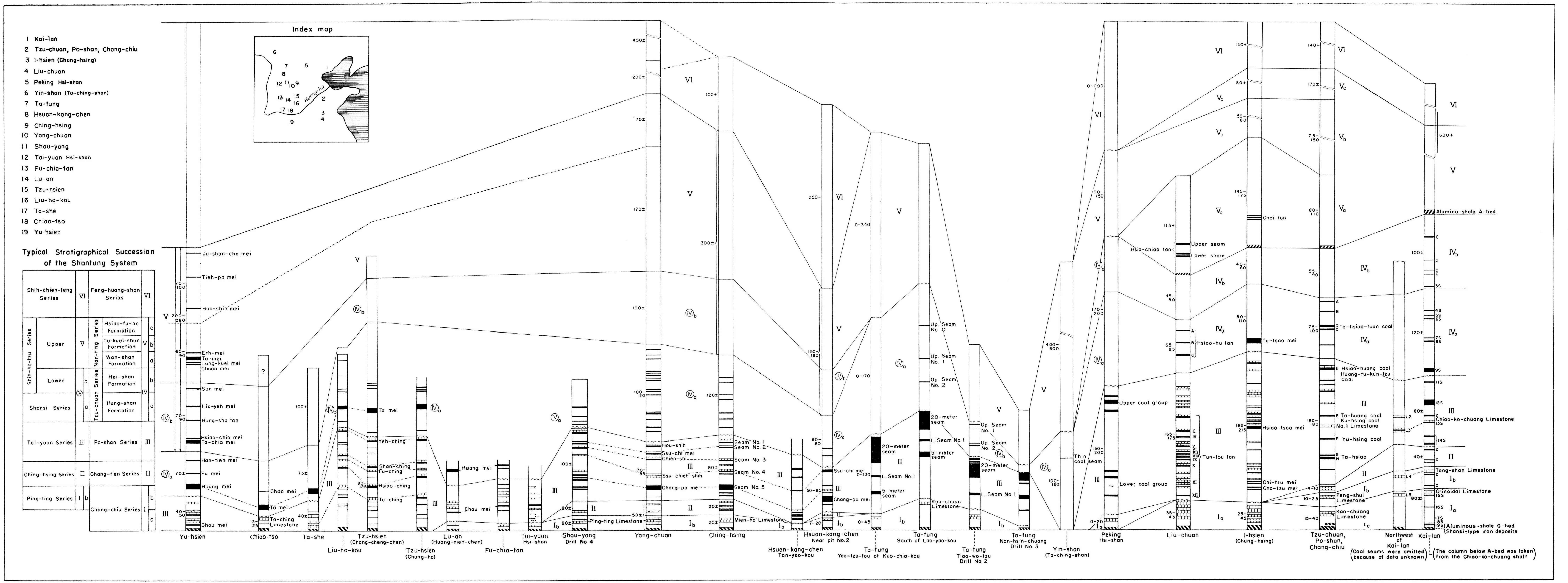


Fig. 3 Columnar Sections of the Upper Palaeozoic (Shantung System) of Coal Fields in North China

In the Tze-Po-Chang, Chung-hsing, Liu-chuan and Kai-lan regions, the lower beds of the Chang-chiu series are developed beneath them, indicating that these regions were affected by transgression earlier than other regions. The Ping-ting series and Ching-hsing series cannot be seen in Liu-ho kou in Tze-hsien (prefecture) in Ho-nan Province, which suggests that this area was affected by transgression later than other regions. This feature shall be regarded as overlapping by transgression, which advanced from the east.

As stated above, in the North China coal fields there are two cases for the Ching-hsing series or Chang-tien series, corresponding to the Uralian, i.e. Upper Carboniferous period. In one case, these series grade into the Permian formation conformably. In the other, these are not developed, and there is an unconformity between the Middle Carboniferous formation and the Permian formation. Their relations are as follows:

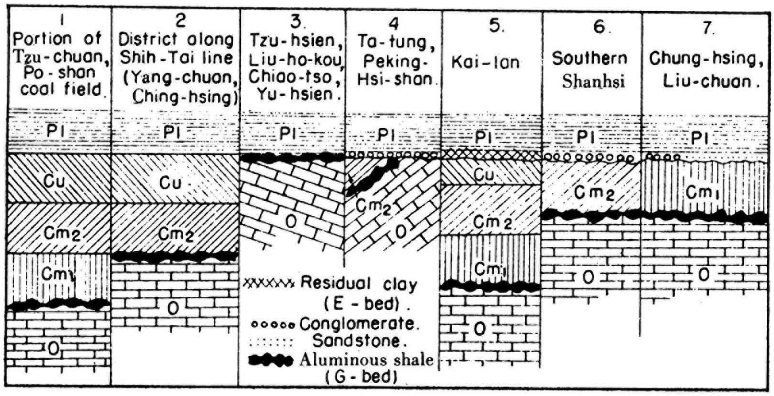


Fig. 4. Boundary between Permian and Carboniferous.

1, 2	Cases of Conformity	Pl. Permian (Lower)	Tai-yuan Series, Po-shan Series.
3, 4, 5, 6, 7	Cases of Unconformity	Cu. Carboniferous (Upper)	Ching-hsing Series, Chang-tien Series.
		Cm_2. Carboniferous (Middle)	Ping-ting Series, Upper Chang-chiu Series.
		Cm_1. Carboniferous (Lower)	Lower Chang-chiu Series.
		O. Ordovician	

(a) Cases of conformity

Regions along the Shih-Tai Railway Line, including Ching-hsing, Yang-chuan and Shou-yang, and Tze-po-chang district (exception: part of Tze-Po-Chang).

(b) Cases of unconformity

(i) Regions where the Ching-hsing series is lacking:—Ta-tung, Hun-yuan, part of Tai-yuan, southern Shan-hsi, Hsi-shan in the suburbs of Peking, and Lai-wu.

(ii) Regions where the Chang-tien series and the upper beds of Chang-chiu series are lacking:—Chung-hsing and Liu-chuan.

(iii) Regions where the Chang-tien series or the upper part of Ching-hsing series are lacking:—part of Tze-Po-Chang, Hsien-kang-chen, Kai-lan, and part of Tai-yuan district.

(iv) Regions where the Carboniferous formation is wholly lacking (Lower Permian formation covers Cambro-Ordovician formation directly):—Ho-nan district, Huai-nan district, part of Ta-tung, most of Hsi-shan in the suburbs of Peking, and part of Lai-wu.

3. *Permian formation*

The Permian formation is divided into marginal-facies and central-facies types by the rock facies of sediments and the stratigraphical conditions of unconformity. The marginal facies is further divided into Yin-shan and Tsin-pei types, and the central facies into Tsin-nan and Shan-tung types. On the other hand, the Permian formation can be stratigraphically divided into three, i.e., upper, middle and lower beds. The names of strata belonging to the Permian period differ according to district as shown in Fig. 2, but are classified on the basis of sedimentation facies as shown in Table 2.

In relation to the table, it should be noted that in the central facies, (1) the gap of sedimentation is small, (2) the rock facies is fine-grained and the Tai-yuan series includes limestone, and (3) "A" bed of aluminous shale (Shan-tung type) or clay (Tsin-nan type) is contained in the base of the upper beds. On the other hand, in the marginal facies, (1) the gap of sedimentation is big, as seen in the table, and unconformity is often seen, (2) the rock facies is coarse-grained and the Tai-yuan series contains no limestone, and (3) the horizon of "A" bed of aluminous shale is lacking, with apparent unconformity.

In the central facies, the Tsin-nan type shows unconformity between the Tai-yuan series and the Shan-hsi series, but the Shan-tung type involves almost no unconformity. The Yin-shan type of marginal facies lacks the Tai-yuan series, but the Tai-pei type contains the series although it varies in thickness.

(a) Lower Permian formation

It consists of marine deposits, which are named Tai-yuan series, Po-shan series, Ma-chia-kou series, Ching-shan-chuan series, Shang-yao limestone, Chu-tun beds and Yung-ting series.

(b) Middle Permian formation

The strata deposited after this formation are terrigenous in North China, and parallel unconformity is often found between them and Lower Permian strata that are marine deposits. This relation is the most remarkable in the Yin-shan mountain range, and the Shuan-ma-chun series rests upon the Sinian formation directly. In the Shan-tung type coal fields, the complex, ranging from the lower limit of "A" bed of aluminous shale to the upper limit of the marine Po-shan series, is distinguished by the name of Tze-chuan series in Shan-tung, Ma-chia-kou series in Chi-tung and Lower coal measure in Huai-nan, and "A" bed of aluminous shale has an important significance stratigraphically, as has already been stated. The terrigenous formation is called the Shan-hsi series in the Tsin-nan type coal fields,

Table 2. Representative Names.

Facies		Marginal facies		Central facies				Fossils	
Type		Yin-shan type	Tsin-pei type	Tsin-nan type		Shan-tung type			
Permo-Trias				Shih-chien-feng series		Feng-huang-shan series		*Lepidodendron**	
Permian	Upper	Sa-la-tsi series	Huai-jen series	Shih-ho-tzu series	Upper	Nan-ting series		*Gigantopteris*	*G. nicotianaefolia*
	Middle				Lower	Tze-chuan series	Hei-shan bed		*G. whitei*
		Shuan-ma-chun series	Shan-hsi series	Shan-hsi series			Humg-shan bed		
	Lower		Tai-yuan series	Tai-yuan series		Po-shan series		*Pseudoschwagerina princeps*	

* Quarry at Hsi-luo-chen in the west of Yang-chuan along the Shi-Tai Railway Line. Collected by Haruyoshi Fujimoto (1946). "A" bed of aluminous shale.

and the corresponding formations are named the Shen-hou beds in Ho-nan and the Shuan-ma-chuan series in Yin-shan. In both the Shan-hsi series and the Shen-hou beds, the higher the horizon, the rarer the intercalation of coal seams, and rocks with yellowish-green and red coloration appear. This red-rock complex is called the Shih-ho-tzu series in the Tsin-nan coal field, and is divided into upper and lower parts, with the "A" bed of aluminous shale taken for the key bed of division. In the regions of the marginal facies, such as Ta-tung, Yin-shan and Hsi-shan of Peking, an unconformity (a good-sized gap) is found between the complex corresponding to the Upper Shih-ho-tzu series (that is, the Huai-jen series, the Sa-la-tsi series and the Hung-miao-ling sandstone bed) and the underlying complex (Shan-hsi series and corresponding formations). Accordingly, the "A" bed of aluminous shale is supposed to have formed in the coal fields of Shan-tung type during the erosion period of this gap.

The Shan-hsi series passes gradually into the Shih-ho-tzu series, so the boundary between the two can hardly be determined and evidence of unconformity is not seen in the Shih-ho-tzu series. Therefore, the Shih-ho-tzu series is regarded as Middle Permian or Upper Permian in age.

(c) Upper Permian formation

"A" bed of aluminous shale occurs at the base in the Shan-tung type coal fields. This formation has long been known as the Ku-yeh formation in Kai-lan, which corresponds to the Nan-ting series in Tze-Po-Chang and the upper coal measure of Huai-nan. It is also represented by the Upper Shih-ho-tzu series in Tsin-nan and other regions and the upper part of the Ta-feng-kou formation in Ho-nan, in the coal fields of the Tsin-nan type. In the regions of marginal facies, the Huai-jen series of Ta-tung, the Sa-la-tsi series of Yin-shan, and the Hung-mioa-ling sandstone of Hsi-shan, Peking correspond to this, and all contain *Gigantopteris nicotinaefolia* flora.

(d) Permo-Triassic formation

A complex consisting of red sandstone is better developed in the upper horizon than the Shih-ho-tzu series, and it is named the Feng-huang-shan series in Tze-Po-Chang, the Shuang-chuan series in Hsi-shan, Peking, and the Shih-chien-feng series in Shan-hsi district. The formation distributed along the Shih-Tai Railway Line was divided by Haruyoshi FUJIMOTO (1943) into the Chin-chuan formation and the Hsi-lo-chen formation, in ascending order. FUJIMOTO (1946) collected many plant fossils, including *Lepidodendron* and *Calamites,* from a quarry in the vicinity of Hsi-luo-chen hamlet west of Yang-chuan along the Shih-Tai Railway Line. This red sandstone complex was regarded as Triassic in the past, but, as these fossils suggest Paleozoic in age, the author provisionally assigns its age to the Permo-Triassic period. This problem involves the serious questions that the determination of geologic ages necessiates further more investigations and researches in detail.

II. Correlation of Upper Paleozoic formations in North, Central and South China

1. *Stratigraphic succession in coal fields of Central and South China*

It is necessary to refer to the stratigraphic succession in coal fields of Central and South China for both the stratigraphic correlation and the consideration of the geologic age of North China coal fields. The stratigraphic succession in the central district of Hu-nan Province, in the mountainous district of Nanking, and in the Chang-hsing coal field of Che-kiang Province is shown in Table 3 to provide an outline.

Table 3. Outline of Stratigraphic Succession in Coal Fields of Central China.

Age		Central district, Hu-nan district	Nanking mountainland	Chang-hsing coal field, Che-kiang Province
Permian	Upper	Thinly bedded muddy limestone	Tung-yang-kang system (120 m)	Chang-hsing limestone (20 m)
		Tou-ling coal measure*	Lung-tan coal measure* (80 m)	Lung-tan coal measure* (300 m)
	Middle	*Doliolina* limestone	Ku-feng formation (0–10 m)	Ku-feng limestone (10 m)
		Yuan-chia-chung coal measure**	Chi-hsia formation (150 m)	Chi-hsia limestone (140 m)
	Lower	Tzu-men-chiao limestone (upper)	Chuan-shan limestone (20 m)	Chuan-shan limestone (30 m)
Carboniferous	Middle	Tzu-men-chiao limestone (middle)	Huang-lung limestone (100 m)	Huang-lung limestone (30 m)
	Lower	Tzu-men-chiao limestone (lower)	Ho-chou limestone (10 m)	
		Tzu-shui system**	Kao-li formation** (15–50 m)	Kao-li shale** (40 m)
			Chin-ling limestone (4–6 m)	
		Chiu-chin-chung manganiferous system	Wu-tung formation** (200–300 m)	Wu-tung quartzite** (270+ m)

* Principal coal measure. ** Thin coal seam is intercalated.

As the table shows, the Lower Carboniferous formation and Middle Permian formation are locally intercalated with thin seams of coal, but the principal coal-bearing formations are the Lung-tan coal measure and corresponding strata. The Lung-tan coal measure is composed of terrigenous marine deposits and yields *Lyttonia* fauna and *Gigantopteris* flora. The fact that the Lung-tan coal measure yields animal and plant fossils and is intercalated with workable coal seams is especially important for the correlation of coal measures between North China and Central to South China. Table 4 shows the stratigraphic succession and index fossils of the Paleozoic coal fields in Central and South China.

The Lung-tan coal measure is the principal coal producer in Central and South China, as already stated. According to C. T. HUANG (1932), the formations to be correlated with the Lung-tan coal measure are as shown in Table 5.

Thus, the principal coal measure in Central and South China corresponds to the

Lung-tan coal measure of the Le-ping system. It is intercalated with limestone and presents a terrigenous marine facies characteristically yielding *Gigantopteris nicotinaefolia*. It is also important as a formation containing the so-called Le-ping paleofauna represented by *Lyttonia*.

Table 4. Stratigraphic Succession and Index Fossils of Coal Fields in Central and South China.

Age		System	Western C. China & western S. China		Eastern C. China	Fossils
Permian	Upper	Le-ping system	Chang-hsing limestone		Chang-hsing limestone	*Lyttonia* fauna *Oldhamina* *Gigantopteris*
			Chu-tang system (marine)	Lai-pa-kou system (terrigenous)	Lung-tan coal measure	
			O-mei-shan basalt			
	Middle	Yang-hsin system	Mao-kou limestone		Ku-feng formation	*Neoschwagerina* fauna
			Chi-hsia limestone		Chi-hsia limestone	*Tetrapora* fauna
	Lower	Chuan-shan system	Chuan-shan limestone		Chuan-shan limestone	*Pseudoschwagerina princeps*
Carboniferous	Middle	Wei-ning	Wei-ning limestone		Huang-lung limestone	*Fusulinella bocki, Staffella sphaeroidea*

Table 5. Contemporaneous Coal Measures in Central and South China.

Name of formation	Area	Corresponding formation	Author
Lung-tan coal measure	South Kiang-su	Le-ping system	L.C. LIU, J.C. CHAO
Li-hsien coal measure	West Che-kiang	Le-ping system	L.C. LIU, A.T. CHAO
Fang-chung coal measure	S. Kiang-su	Le-ping system	C. J. HSIEH
Yen-wa coal measure	S. Kiang-su	Le-ping system	L.C. LIU
Chu-tang system	S. An-hwei	Chu-tang formation	L.F. YEH, C. LI
Hsuan-ching coal measure	S. An-hwei	Le-ping system	L.F. YEH, C. LI
Tao-chung coal measure	S. An-hwei	Chu-tang fm. (Lai-pa-kou series)	Ichiro HAYASAKA

Ku-feng system	S. An-hwei	*Gastrioceras zitteri* horizon	S. CHU
Feng-tien coal measure	W. Kiang-si	Le-ping system	C.C. WANG
Chin-hsien c. m.	C. Kiang-si	Le-ping system	H.C. TAN, S.W. WANG
Lao-hu-shan c. m.	W. An-hwei NW. Kiang-si	Le-ping system	C.C. WANG
Tan-shan-wan c. m.	SE. Hu-pei	Le-ping system	C.J. HSIEH
Pao-an shale	SE. Hu-pei	*Gastrioceras zitteri* horizon	C.J. HSIEH
Mao-chuang c. m.	SW. Hu-pei	Le-ping system	C. J.HSIEH, L.C. LIU
Chung-tzo-shan limestone	W. Hu-pei	Le-ping system + Mao-kou limestone	S.K. LI
Tou-ling system	C. Hu-nan	Le-ping system	C.C. TIEN
Lai-pa-kou formation	C. Hu-nan	Lai-pa-kou fm.	RICHTHOFEN
Chiao-tzu-shan c. m.	W. Kwei-chow	Le-ping system	S.H. LO
Hsuan-chia-ping c. m.	S. Kwei-chow	Le-ping system	S.H. LO
Hu-kou shale	S. Fu-kien	Le-ping system (?)	S.W. WANG
Huang-kang-ling c. m.	N. Canton (Kuang-tung)	Lai-pa-kou series or Le-ping system (?)	C.T. FENG

2. *Correlation*

The stratigraphic succession in Paleozoic coal fields in North China and Central and South China is correlated as shown in Fig. 5. The basis for correlation is explained as follows:

(a) Chang-chiu series

The Chang-chiu series yields *Fusulinella bocki, Staffella sphaeroidea, Spirifer mosquensis* and others. Its age is regarded as Middle Carboniferous (Moscovian), and it is correlated with the Huang-lung limestone and the Wei-ning limestone.

(b) Chang-tien series

Upper Paleozoic formations are lacking in Central and South China, and an unconformity is believed to exist between Middle Carboniferous and Lower Permian formations. Although an unconformity is recognized in most places of North China, too, the central portion of the sedimentary basin, including most of the Tze-Po-Chang coal field and the area along the Shih-Tai Railway Line, is supposed to have been covered by sea water continuously during the Middle Carboniferous to Upper Carboniferous period, as has already been stated.

(c) Po-shan series

Many fossils of Fusulinidae including *Pseudoschwagerina princeps* are found in the

Po-shan series, and the series is paleontologically correlated with the Chuan-shan limestone in Central and South China.

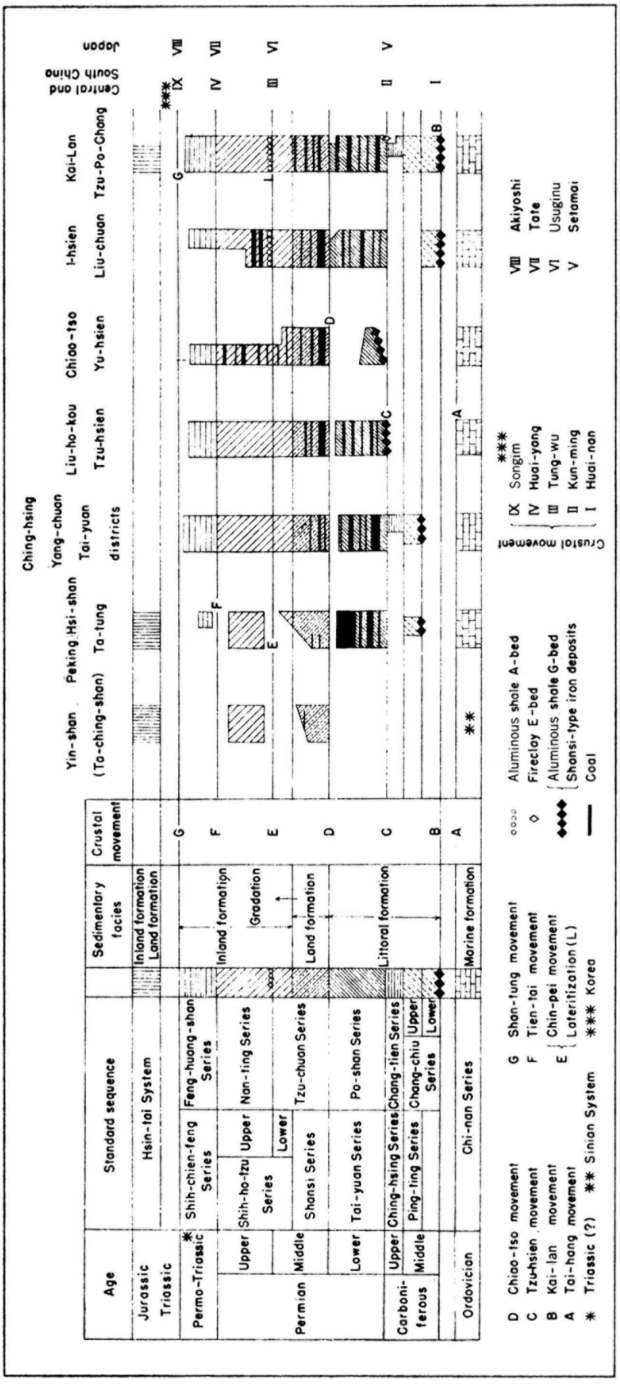


Fig. 5. Correlation of the Stratigraphical Successions of the Coal Fields of North China, Central and South China.

(d) Tze-chuan series

In North China the Tze-chuan series and younger strata show a terrestrial or inland facies, so that it is difficult to correlate them with the contemporaneous formations in Central and South China which show a marine facies. However, on the basis of the locally correlatable horizons, their stratigraphic positions and their unconformable relations, we may be able to make the following correlation.

We can see throughout North China that the relation between the Tze-chuan series and the Po-shan series, or between the Shan-si series and the Tai-yuan series, is disconformable. On the other hand, in Central and South China the Chi-hsia limestone and the Chuan-shan limestone are almost always conformable, though it is true that, in Fu-kien Province, the Chi-hsia limestone rests unconformably on the Lower Carboniferous Wu-tung formation (Hou, 1935), so it cannot be denied that there was a partial unconformity or an extensive transgression between them. Consequently, it may not be unreasonable to correlate stratigraphically the Chi-hsia limestone with the Tze-chuan series or the Shan-hsi series. The "A" bed of aluminous shale is developed upon the Tze-chuan series, and in this horizon in the region showing the marginal facies of North China an unconformity is seen, which is regarded as contemporaneous with the unconformity after the Yang-shin system. Therefore, if a correlation is made for the crustal movement after the deposition of the Chuan-shan system, Po-shan series or Tai-yuan series, and for the succeeding crustal movement after the deposition of the Tze-chuan series and the Yang-hsin system, it may become possible to regard the Tze-chuan series as nearly contemporaneous with the Yang-hsin system of Central and South China. According to C. C. Tien, a coal measure named Yuan-chia-chung occurs below *Doliolina* limestone in the central district of Hu-nan Province, but this is a littoral deposit to be correlated with the Chi-hsia limestone.

(e) Nan-ting series

As often stated, it is almost certain that the Nan-ting series of Shan-tung, upper part of the Shih-ho-tzu series of Shan-hsi, and the Huai-jen series of Ta-tung are all in the same horizon. From the fact that these formations yield *Gigantopteris* flora and that the Nan-ting series in the Y-hsien and Liu-chuan coal fields contain coal seams which correspond to the principal coal seams in Central and South China, the Nan-ting series of North China can be correlated with the Lung-tan coal measure of the Le-ping system of Central and South China.

The Lung-tan coal measure and corresponding formations in Central and South China are littoral deposits characteristically yielding *Lyttonia* and plant fossils such as *Gigantopteris nicotinaefolia.*

In this connection, *Lyttonia* is found in all Permian formations in Japan (Sakamotosawa series, Kanokura series, Toyoma series). It serves as an important fossil of Le-ping fauna, facilitating correlation of the Le-ping system of the Upper Permian period in Central and South China with the Toyoma series of Japan. This fossil is yielded from the Chi-hsia limestone (Middle Permian) of China and also from the A-tang series of Manchuria (to be correlated with the Tai-yuan series and the Po-shan series of North China, and with the Sakamotosawa series of Japan) yielding *Pseudoschwagerina* at Yang-shu-kou in the Wu-hu-tsui coal field.

(f) Feng-huang-shan series

The Feng-huang-shan series in Shan-tung is a red sandstone, lying conformably upon the Nan-ting series, which corresponds to the Shih-chien-feng series (NORIN, 1922) in Shan-hsi, the Chin-chuan formation and the Hsi-lo-chen formation (FUJIMOTO, 1943, 1946) along the Shih-Tai Railway Line. FUJIMOTO collected important Permian plant fossils, including *Lepidodendron* and *Calamites*, from the Hsi-lo-chen formation, thus raising a question important for determining the age of the Shih-chien-feng series, which was regarded as Triassic in the past. However, the author has no data for judging the geologic age of this series, and so tentatively treats it as Permo-Triassic.

In Central and South China, the formation covering the Lung-tan coal measure is the Chang-hsing limestone, containing *Oldhamina* of the *Lyttonia* fauna. On it lies the Triassic Ching-lung limestone or corresponding Ta-yeh limestone, and these are all marine deposits. These rocks are quite different from the red formation of the Feng-huang-shan series of North China in sedimentary environment and it is impossible to connect them paleontologically.

(g) Correlation of coal seams

The correlation among coal measures in North China was not complete in the past. In North China, those containing workable coal seams are the Po-shan series (Tai-yuan series) and the Hung-shan formation of the Tze-chuan series (Shan-si series), but in the area covering southern Shan-tung Province and central Ho-nan Province, including Huai-nan, the Nan-ting series (Upper Shih-ho-tzu series), too, is intercalated with workable coal seams (ONUKI 1945a, 1946). In Central and South China important workable coal seams are contained only in the Lung-tan coal measure, which is in the same horizon as the Nan-ting series.

III. Correlation of Upper Paleozoic formations between North China, Manchuria and Korea

1. *General remarks*

The Upper Paleozoic formations in South Manchuria and North Korea, contiguous to North China, are well represented by the Tai-tzu-ho system in the former and by the Pyongan (Heian) system in the latter. The stratigraphic succession of the Upper Paleozoic formations in these regions closely resembles that of the Shan-tung system, named by the author (ONUKI, 1944a, b), in Chi-tung and Shan-tung districts in the eastern part of North China. On the other hand, it also resembles the sequence in the Jehol district and in the area of Ta-tung to Hsi-shan in the suburbs of Peking, where the strata show a marginal facies of a vast depositional basin. The relation is indicated in Fig. 6.

2. *Relation between the eastern region of North China, South Manchuria and North Korea*

The close resemblance of stratigraphic succession between the eastern part of

North China, namely Chi-tung and Shan-tung, and South Manchuria and North Korea is unanimously accepted according to previous studies, so only two or three problems will be considered here.

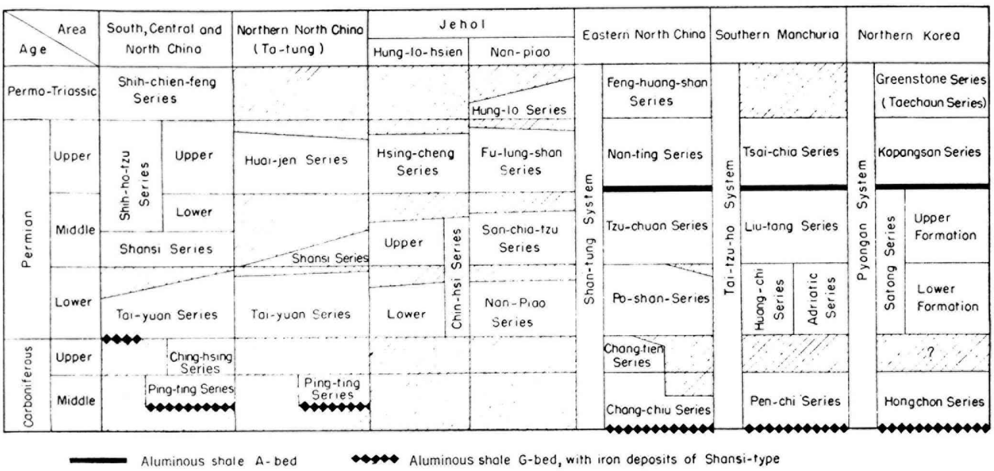


Fig. 6. Correlation between North China, Manchuria and Korea.

a. Pen-hsi (or Pen-chi) series[1)]

The Carboniferous formation in North China was treated in the past as the Pen-hsi series, as it was in Manchuria. But the author, after investigation of the Tze-Po-Chang coal field, divided the formation into the Chang-chiu series and the Chang-tien series, and the formation along the Shih-Tai Railway Line into the Ping-ting series and the Ching-hsing series. The Chang-chiu and Ping-ting series were assigned to the Middle Carboniferous, and the Chang-tien and Ching-hsing series to the Upper Carboniferous period. The lack of Upper Carboniferous in Manchuria was studied in detail by Mitsuo Noda (1950). In North China, too, an unconformity is recognized over a wide area, at the base of the Permian formation though a conformity seems to occur in limited areas, where the Chang-tien series of the Upper Carboniferous period was deposited.

b. Relation of the formations correlatable with the Po-shan series or Tai-yuan series

The formations corresponding to the Po-shan series or the Tai-yuan series of North China are intercalated with limestone and terrigenous marine sediments. The A-tang series (Hanzawa, 1941) in the Wu-hu-tsui coal field, Fu-chou, Manchuria, is located east of the Kai-lan coal field, China, across the Gulf of Pechili, and is intercalated with limestone as in North China. However, the Huang-chi

[1)] The transgression in Manchuria is supposed to have started earlier than in North China, so it is possible that the lower limit of the Pen-hsi series in Manchuria is somewhat older than that in North China.

series, distributed over the Tai-tzu-ho basin in Manchuria, has no limestone intercalations, and the A-tang series in Wu-hu-tsui, Fu-chou, was once regarded to be absent between the Pen-hsi series and the Huang-chi series (CHAO, 1926). But NODA collected marine animal fossils from the Huang-chi series in 1939 and made it clear that the A-tang series and the Huang-chi series are equivalent and occur in the same horizon. The Tai-yuan series in Ta-tung and Hun-yuan coal fields and the Yung-ting series in Hsi-shan in Peking contain lenses of limestone, or calcareous shale or calcareous sandstone locally but almost no limestone beds are intercalated as in the case of the Huang-chi series. This sedimentation facies is limited to regions showing the marginal facies, but this feature is similarly observed in the Tai-tzu-ho region of Manchuria.

c. "A" bed of aluminous shale

"A" bed of aluminous shale occurs in the Tai-tzu-ho region of Manchuria and in the eastern region of North China, so persistent geophysical conditions seem to have prevailed over the wide area extending from the eastern part of North China to South Manchuria and North Korea at that time. However, "A" bed of aluminous shale is entirely absent in the depositional area of the marginal facies type in the northern part of North China, and this area seems to have been subjected to erosion at the time of formation of the aluminous shale.

3. *Relation between the northern region of North China and the Jehol region of Manchuria*

a. Formations correlatable with the Ping-ting series

The Ping-ting series of the Ta-tung coal field and the Fang-shan series of Hsi-shan, Peking, are present but not developed throughout the region. The Tai-yuan series of the Ta-tung coal field and the Yung-ting series of Hsi-shan, Peking, were directly deposited upon the Cambro-Ordovician formation, with basal conglomerate. Similarly, no formation corresponding to the Ping-ting series is found in the Hung-lo-hsien coal field in Jehol surveyed by Nenji TAKAHASHI (1944a) or in the Nan-piao coal field in the same region surveyed by Li-shu CHANG (1944). The lower beds of the Chin-hsi series at Hung-lo-hsien and the Nan-piao series at Nan-piao cover the Cambro-Ordovician formation with basal conglomerate. These phenomena suggest that the northern marginal region of the North China coal fields is strikingly different from the central region in geologic structure, and was affected by crustal disturbance far more intensely than the central region in, at least, Upper Paleozoic.

b. Formations correlatable with the Tai-yuan series, Shan-si series and Huai-jen series

Formations to be correlated with the Tai-yuan series may be the lower beds of the Chin-hsi series in Hung-lo-hsien and the Nan-piao series in Nan-piao. Those to be correlated with the Shan-si series are the upper beds of the Chin-hsi series in Hung-lo-hsien and the San-chia-tzu series in Nan-piao, and those to be correlated with the Huai-jen series are the Hsing-cheng series in Hung-lo-hsien and the Fu-lung-shan series in Nan-piao.

It is not exactly known with which formation in North China the Hung-la series is to be correlated, but it seems to be comparable to the Shuang-chuan series and the Shih-chien feng series.

The Tai-yuan series, Shan-si series and Huai-jen series in Ta-tung are unconformable with each other. Likewise, three groups in Hung-lo-hsien, namely the lower Chin-hsi series, the upper Chin-hsi series and the Hsing-cheng series, and four groups in Nan-piao, namely the Nan-piao series, San-chia-tzu series, Fu-lung-shan series and Hung-la series, are all in unconformable relation. These formations all presents the marginal facies of the great basin of North China.

c. Coal seams

As the Tai-yuan series in Ta-tung and the Yung-ting series in Hsi-shan, Peking form the principal coal measures, the lower beds of the Chin-hsi series and the Nan-piao series form the coal measures.

d. Coal seams occurring in the same horizon as the Nan-ting series

The principal coal measures in North China correspond to the Po-shan series and the Tze-chuan series, but in the southern part of North China the formations corresponding to the Nan-ting series sometimes form the principal coal measure. The principal coal measures in Manchuria are the Huang-chi series and the Liu-tang series, and those in Korea are the lower beds and the upper beds of the Jido series. The Tsai-chia series in Manchuria and the Kopangsan series in Korea, which are correlatable with the Nan-ting series, contain almost no coal. However, Nobuhiro Hatae reported recently that a coal seam was intercalated in the Kopangsan series. This fact is important for consideration of the relation of the coal-bearing formations in the southern part of North China to those in Central and South China and also those in North Korea.

2. Sedimentary Environment of Upper Paleozoic Formations

I. Sedimentary basin and cycle of sedimentation

1. *Introduction*

The Cambro-Ordovician formation is distributed widely in mountains throughout North China. Above this lie the Upper Paleozoic formations with unconformity, forming coal fields everywhere. The Cambro-Ordovician formation is a marine deposit, consisting of thick beds of limestone and dolomite, whereas the formations younger than Upper Paleozoic are composed of terrigenous-marine, terrestrial and inland deposits. The Upper Ordovician formation, Gotlandian formation, Devonian formation and Lower Carboniferous formation are lacking between the Cambro-Ordovician and the Upper Paleozoic formations. The Middle Ordovician formation is overlain directly by the Middle Carboniferous formation or Lower Permian formation, thus revealing the transgression overlap and the changes in sedimentary facies, as well as a great time gap due to erosion. However, in spite of the great erosion gap and the facies changes in Middle Paleozoic, the Lower and Upper Paleozoic formations are generally in a disconformable relation, and their sedimentary basins were not at all deformed. The sedimentary environments of the

Upper Paleozoic formations in North China will be examined in the following paragraphs.

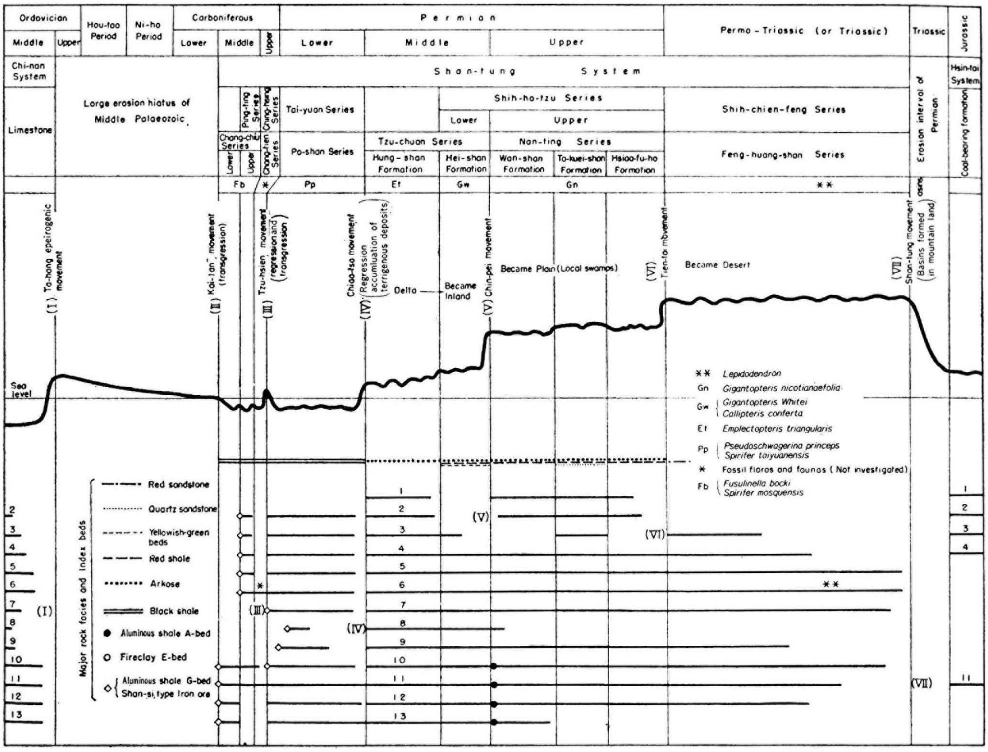


Fig. 7. Cycle of Sedimentation of the Shan-tung System.

1 Yin-shan (Ta-ching-shan)
2 Ta-tung
3 Peking Hsi-shan
4 Ning-wu
5 Tai-yuan District
6 Yang-chuan, Ching-hsing
7 Tzu-hsien, Liu-ho-kou
8 Chiao-tso, Ta-she
9 Central Honan (Yu-hsien)
10 Kai-lan
11 Tzu-chuan, Po-shan, Chang-chiu
12 I-hsien (Chung-hsing)
13 Liu-chuan

2. *Sedimentary basin and cycle of sedimentation*

Upper Paleozoic formations in North China extend over a wide area from the Yin-shan mountain range (Mongolian orogenic zone) in the north to the area in the south bounded by the so-called Chin-ling—Seoul line, running southeastward from the northern foot of the Chin-ling mountain range, and their eastern extension is widely distributed from South Manchuria to North Korea (Fig. 1). Judging from this distribution, the sedimentary basin of the Upper Paleozoic formations seems to be nearly the same as that of the Lower Paleozoic. This sedimentary basin was formed between the Mongolian orogenic zone named by Teiichi Kobayashi and the Chin-ling—Seoul line, and is divided into several basins. The northern one is the Ping-an—Liao-tung basin, the southern one is the

Shan-kiang-an basin, with the Yellow River basin (a plain in North China at present) connecting the two, and the western one is the Shan-hsi basin. Further, the Tai-tzuiho basin is connected with the Ping-an—Liao-tung basin in Kai-lan region, and with the Jehol—Hsi-shan, Peking—Tsin-pei region, and forms a sedimentary basin between the Mongolian orogenic zone in the north and the Wu-tai mountainland in the south. The author named it the Peking—Tsin-pei basin, although it is connected with the Shan-hsi basin through the Ning-wu region.

The state of strata in this wide sedimentary basin shows that these were not products of the sedimentary environments characterized by intense crustal displacements due to an orogenic movement, but the mode of their deposition indicates essential features of Kratogen ascribed to a slow epeirogenetic movement, presenting a cycle of sedimentation from marine to terrigenous deposition and then to inland deposition.

The Upper Paleozoic formations in Central and South China are distributed generally to the south of the Yang-tze River, and their deposition continued intermittently from the time of the Lower Paleozoic formation, showing the marine sedimentary facies. The sedimentary facies of the Upper Paleozoic formations in North China is strikingly different from those in Central and South China, but considering the relations among marine animal fossils there is continuity from the middle part of the Carboniferous period to the lower part of the Permian period. The strata later than the Middle Permian period in North China grade into terrigenous or inland facies. But, considering the mode of occurrence of coal, in connection with coal measures of Central and South China, and the relations among the strata yielding *Gigantopteris* flora, the relationship between North China and Central to South China is supposed to be a close one.

II. Sedimentary facies

1. *General remarks*

Looking over the sedimentary facies of the Upper Paleozoic formations in North China, the strata ranging in age from Middle Carboniferous to Lower Permian present a terrigenous marine facies, while those from Middle to Upper Permian show a continental or inland facies. The terrigenous marine deposits are divided into three series, i.e., the Chang-chiu, Chang-tien and Po-shan, and the continental deposits are divided into the Tzu-chuan series, Nan-ting series and Feng-huang-shan series. The stratigraphical division of the Upper Paleozoic formations in North China varies more or less with area, as shown in Fig. 2. On the whole, the Upper Paleozoic deposits are roughly grouped into marine and continental facies, with an unconformity in between, as evidenced in many places. Thus, it is reasonably inferred that the continental deposits came to cover North China, keeping pace with the marine regression.

2. *Shallow marine deposits*

The deposits are mainly primarily consist of black shale, which contains pyrite

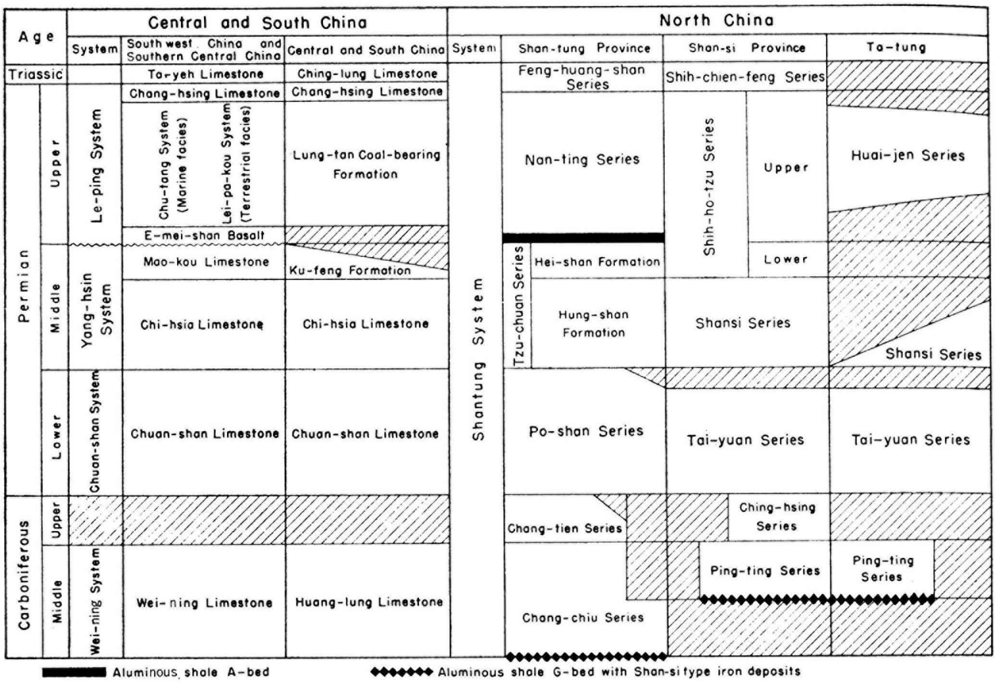


Fig. 8. Sedimentary Facies, Crustal Movement and Coal Seams of the Shan-tung System.

and is intercalated with limestone and coal seams. The coal seams also contain pyrite in masses or in bedded form. Although the sulphur content is rather high[2] the coal seams are generally uniform in thickness in each coal field. Further, soft clay and hard clay occur everywhere, providing a rich source of refractory and ceramic raw materials.

3. *Terrigenous deposits*

The terrigenous deposits are characterized by dominance of sandstone which is marked with false or irregular bedding. The sandstone constitutes a massive or thick platy formation and often makes cliffs. The formation covered the marine deposits under a deltaic environment during regression, and an unconformity is observed between the two in many places. The unconformable relation is often hardly recognized in areas that were supposedly deeper parts of the sedimentary basin, in spite of the conspicuous changes in lithology and strata from the marine facies to the terrigenous facies. However, the coal seams in the terrigenous deposits vary remarkably in thickness even within a single coal field. For example, the Ta-tsao coal of the Chung-hsing colliery varies in thickness from 10 m at its maximum to nearly zero. The coal seams intercalated in the terrigenous deposits are low in sulphur content and are excellent in terms of coal quality.

[2] The sulphur content of the coal seams intercalated in the marine deposits varies between one and 5%, and the coal is named a "stink coal". The sulphur content of the coal seams in the terrigenous deposits, on the contrary, is usually less than one percent, and the coal is named a "fragrant coal".

4. *Inland facies*

The facies gradually changes from terrigenous to inland, and red rocks become predominant. From the standpoint of age, the deposits gradually changed to an inland facies since the end of the Middle Permian period and the red rocks were added, but these rocks increased more in the Triassic than in the Upper Permian period until entire deposits came to be composed of red rocks in the last stage, and sometimes contain a gypsum layer. As stated above, conditions are supposed to have been tropical, with high temperature and dryness, from the end of Middle Permian through the early stage of the Triassic period. There was also a special condition which caused lateritization and the formation of the "A" bed aluminous shale over an extensive area from Chi-tung to South Manchuria and North Korea. Namely, that the northern region of North China was subjected to erosion during that period—a condition deduced from the unconformity in the Pre-Huai-jen series. The "A" bed aluminous shale was formed due to weathering under special topographic and climatic conditions in this period. The reason that the aluminous shale is rarely developed in the west of the Peking—Han-kou Railway may be ascribed to the influence of topography, even though the climatic conditions of the two regions were identical.

This inland formation contains coal seams in the southern regions of North China, namely, in the south of the line extending east-west at the southern margin of the Ta-hang mountain range, north of the Yellow River. In Shan-hsi, on the contrary, almost no coal has been developed, although abundant plant fossils (fossil flora of the Shih-ho-tzu series) are found in the contemporaneous formations. This suggests that the condition of the lake basin was not favorable for the formation of coal.

In the Permo-Triassic period, that is, the age of deposition of the Shih-chien-feng series and Feng-huang-shan series, the climate became warmer and drier, the land became a desert, gypsum was locally accumulated in the Shan-hsi district, and red rocks, sometimes mixed with green rocks, became dominant. The Shuang-chuan series, occurring at Hsi-shan in the suburbs of Peking, may possibly be correlated with those formations, but the plant fossils from this series contain Mesozoic elements besides the plants of the Nan-ting series or Upper Shih-ho-tzu series. This series is intercalated with several coal seams, and is supposed to have been deposited under the topographic conditions of an intermontane basin. Paleobotanically it is very interesting that Carboniferous and Permian plants, such as *Lepidodendron*, have remained in the strata corresponding to the Shih-chien-feng series.

III. Sedimentary ore deposits

Introduction

The ore deposits in the Upper Paleozoic formations include coal, aluminous shale, hard clay, soft clay, iron ores and pyrite. The mode of occurrence of these deposits will be stated to facilitate the study of the sedimentary environments.

Also, an outline of the status of limestones will be given to consider the relationship between marine and terrigenous facies.

A. Coal

1. *General remarks on coal seams*

The workable coal seams in the Paleozoic coal fields in North China are intercalated in the Po-shan series, Tze-chuan series and corresponding strata, but they are also intercalated in the Nan-ting series and corresponding strata in Chung-hsing, in the south of Liu-chuan, in central Ho-nan and in the Huai-nan coal field.

Looking over the thickness of coal seams, the coal of the Po-shan series is thicker toward the north and thinner toward the south, and is rarely developed in the central Ho-nan and Huai-nan regions. The coal of the Tze-chuan series is thicker in the south and thinner in the north, and there is almost no workable seam in the Ta-tung and Yin-shan districts in the north. The coal seams are from 6 m to 10 m thick in Chung-hsing, Tzu-hsien—Liu-ho-kou, Chiao-tso and central Ho-nan, in the southern region. The coal of the Nan-ting series is developed in Chung-hsing, Liu-chuan, central Ho-nan in the south of the southern margin of the Tai-hang mountain range, but is rarely found in most of North China, and the number of coal seams is one in Chung-hsing, two in Liu-chuan and over 10 in the Yu-hsien coal field in central Ho-nan.

2. *Coal seams of different coal fields*

Regarding the vertical mode of occurrence of coal seams, those of the lower horizons are better developed in coal fields in the north, while those of the upper horizons in coal fields in the south. This feature is specially important in considering the relationship between the coal fields of North China and those of Central and South China. The relationship is numerically shown as follows (total thickness of more than one meter):

(i) Coal seams in Po-shan series (Tai-yuan series)

Ta-tung and Hun-yuan	20 m
Ning-wu	11 m
Central Shan-hsi, Ching-hsing, Yang-chuan, Shou-yang and Tai-yuan—Hsi-shan along the Shi-Tai Railway Line	7.8 m
South of the line connecting Fu-chia-tan along the South Ta-tung—Pu-chou Railway Line and Lu-an in southern Shan-hsi	less than 2 m
South of Tse-chou	less than 1 m
Kai-lan	more than 10 m
Tze-po-chang	4 m±
Hsin-tai	more than 5 m
Tzu-hsien—Liu-ho-kou	4 m±
Chung-hsing	1.5 m
Liu-chuan	1 m
Chiao-tso—Ta-she	0 m

Central Ho-nan	0 m
(ii) Coal seams in Tze-chuan series (Hung-shan formation) or Shanhsi series	
Yin-shan, Ta-tung, Hun-yuan, Ning-wu and Hsi-shan of Peking	0 m
Kai-lan	2 m±(?)
Tze-po-chang	less than 3 m
Ta-wen-kou	less than 6 m
Chung-hsing	9 m
Fu-chia-tan	1.5 m
Liao-chou	1.8 m
Yang-chuan	1.7 m
Tze-hsien—Liu-ho-kou	6 m
Chiao-tso, Ta-she	6 m
Central Ho-nan	11 m
(iii) Coal seams in Shih-ho-tzu series North of Yellow River (the greater part of North China)	0 m
Liu-chuan	3.2 m
Central Ho-nan	more than 7 m five seams or more)

B. Aluminous shale

1. *Introduction*

There are two layers of aluminous shale, "A" bed and "G" bed. According to Takao SAKAMOTO, the former occurs at the base of the Nan-ting series and the latter at the base of the Upper Paleozoic strata.

2. *"A" bed*

The "A" bed of aluminous shale occupies the base of the Nan-ting series, and extends over Chi-tung, Shan-tung, northern Kiang-su and northern An-hwei, but is rarely developed to the west of Peking—Han-kou Railway. As SAKAMOTO determined, the "A" bed is a result of lateritization due to chemical weathering in the regions of warm and arid climate. It was formed in the eastern half of North China but not in the western half. Taking into consideration the fact that the period of its formation corresponds to the age of erosion in the northern half, it is supposed that an important topographic factor, being influenced by crustal movements, combined with the climatic factor in the process of formation. (The lower Shih-ho-tzu series and the Shan-hsi series were partly eroded in this weathering period.)

3. *"G" bed (with iron ore of Shan-hsi type)*

The "G" bed of aluminous shale is distributed widely at the base of the Upper Paleozoic formations, but its thickness and quality vary remarkably from place to place. It occurs as lenses or masses, locally as thick as 10 m or so, but sometimes pinches out suddenly. In general, it is bedded and better ores are developed in two separate beds with an interval of several meters. Iron ores are intercalated in the "G" bed, and are commonly known as Shan-hsi type iron ores, although it is very rare that rich aluminous shale and rich iron ores occur together. Generally, an aluminous bed occurs in the upper part and an iron ore bed in the lower. If the former forms a rich ore the latter is not at all developed, while if the latter is a rich ore the former does not deserve to be treated for aluminous shale, and sometimes both are too poor to be treated for an ore, and are very thin.

A clay, named Shan-tung brown clay, thinly covers the limestone in Shan-tung and Ho-pei Provinces. This is a *terra rossa*. It is not difficult to suppose that the Ordovician limestone was affected by weathering for a long time up to the deposition of the Upper Paleozoic, and insoluble matters were left behind, to become *terra rossa*. Considering that the complex containing a "G" bed is composed of red rocks, the climate seems to have been warm and humid at that time. According to soil-chemical experiments for clay containing free alumina and iron, it is known that if the pH is 8 or higher, the colloidal alumina congeals, while if pH is 7 or slightly lower, the iron congeals. Therefore, iron ore is formed in neutral ground water and aluminous shale is formed in alkaline ground water.

The horizons, in which the "G" bed of aluminous shale and Shan-hsi type iron ores occur, are three, according to the stratigraphical succession in different areas:

a. Base of the Po-shan series on top of the Ordovician limestone.
b. Base of the Ping-ting series on top of the Ordovician limestone.
c. Base of the Chang-chiu series on top of the Ordovician limestone.

Since the Upper Paleozoic formations are the great deposits formed by a regional overlapping due to transgression, the "G" bed is developed at the base of the Chang-chiu series in Shan-tung and Chi-tung districts; at the base of the Ping-ting series in Ta-tung, Shan-hsi Province and in part of Hsi-shan of Peking; and at the base of strata corresponding to the Po-shan series in Tzu-hsien—Liu-ho-kou, Chiao-tso, Ta-she and in central Ho-nan. Therefore, at the contact with the Ordovician limestone, the stratigraphical horizons of the Ordovician formation as well as of the Upper Paleozoic formations are widely variable and accordingly the amount of time gap differs remarkably.

4. *Hard clay*

The horizons in which hard clay occurs are quite different from those of "A" and "G" beds of aluminous shale. The clay is mostly hard clay of excellent quality, being kaolin, and is associated with coal seams. Two or three examples will be given below.

i. Kaolin of Ta-tung and Hun-yuan coal fields. This forms thick "partings" alternating with such coal seams as "20 m seam" and "5 m seam", of the Tai-yuan series. Alternating beds of coal and kaolin are more than 30 m thick on the outcrops at Kou-chuan-kou and Chin-shan-ssu and even the thickness of kaolin alone amounts to 12 m or so.

ii. Kaolin of Ching-hsing and Yang-chuan coal fields. Seam No. 2 of the Ching-hsing coal field is intercalated with a kaolin bed, 0.10–0.30 m thick, which serves as an important key for the determination of stratigraphic order. This applies to the Yang-chuan coal field, too.

iii. Kaolin of Tze-Po-Chang coal field. In the Tze-Po-Chang coal field, a kaolin bed 0.6–2 m thick occurs all over the coal field beneath the Ta-hsiao coal seam (GH bed) of the Po-shan series, and it is an index bed for the investigation of this coal field. The author named this the Li-chia-ling hard clay (ONUKI, 1951–1945).

In this coal field, the "Ao" bed of hard clay, associated with iron ore, occurs also in the upper part of the Wan-shan formation of the Nan-ting series, although the clay is sometimes absent and the bed consists only of iron ore.

5. *Soft clay*

This clay, being important as ceramic raw material, occurs in many horizons, chiefly in the Chang-chiu, Chang-tien and Po-shan series and corresponding strata, but sometimes also in the Nan-ting series and corresponding strata. Especially, the clays associated with "G" bed are of excellent quality and are often utilized.

C. Pyrite

Pyrite is abundantly contained in marine units of the Upper Paleozoic formations, and occurs in bedded form or masses in coal seams. Sometimes it forms a thick bed at the base of the Upper Paleozoic formations.

Pyrite in the Po-shan coal field (called the Po-shan type pyrite) has been known for a long time. It forms a bed having a thickness of over 0.10 m in the Po-shan series coal seams, or occurs as scattered lenses or nodules. It is contained in such coal seams as E, E' and F of the Tze-chuan colliery, and also in the Huang-tu-tun-tzu coal, Ta-huang coal and Hsiao-huang coal of the Po-shan and Hsi-po collieries. A good example of its mode of occurrence is seen in the Hsiao-tsao coal of the Chung-hsing colliery.

Pyrite which forms a thick bed at the base of the Upper Paleozoic formations (Hsin-po type pyrite) is found in Chiao-tso and Yang-chuan. At the time of investigation of the Chiao-tso coal field in 1942, a pyrite bed of about 1.2 m in thickness was being mined in the tableland west of Ping-hsin in the western extremity of this coal field. In the Yang-chuan and Hun-yuan coal fields, pyrite is similarly developed, and especially in the former the ore reserves were known to be great, according to KO SHIIDA.

IV. Transgression and limestone

1. *Carboniferous period*

In the middle stage of the Carboniferous period of North China, the transgression started in the east and gradually advanced westward. As a result, the lower beds of the Chang-chiu series are developed in the Shan-tung and Chi-tung regions, but are not found in the area west of the Peking—Han-kou Railway. As the transgression advanced farther west, the upper beds of the Chang-chiu series and their equivalent Ping-ting series were deposited, while the Ho-nan district was not yet covered with sea water.

In the later stage of the Carboniferous period, a regression took place, and the marginal portion of the depositional basin became land. However, the central portion of the basin, corresponding to the location of today's Shin-Tai Railway Line, was still under sea water. This is the reason the relation between the Carboniferous formation and the succeeding Early Permian formation deposited by a new transgression is sometimes unconformable and sometimes conformable. And, even in the case of unconformity, some areas are covered with the basal conglomerate or basal sandstone of the Permian formation, while other areas are covered with residual clay (e.g. E bed at Kai-lan and the main-bed clay at Fu-chou). These features may be ascribed to the topographic changes caused by the crustal movement.

2. *Permian period*

In the beginning of the Permian period, transgression took place again and most of North China, except the Yin-shan region, was inundated with sea water, and the Po-shan series and corresponding strata (Tai-yuan series) were deposited. The Po-shan series and its equivalents are composed chiefly of black shale intercalated with limestone. The total thickness of limestones occurring in the Po-shan series was estimated by Shiida (1944) as follows:

Liu-chuan	40 m
Chung-hsing	30 m
Tze-hsien	12 m
Ta-wen-kou	10 m
Tze-Po-Chang	46 m
Fu-chia-tan	12.4 m
Lu-an	9 m
Hsi-shan of Tai-yuan	7.5 m
Hsien-kang-chen	1 m
Ning-wu	0.8 m
Hsi-shan of Peking	0 m
Ta-tung	0 m
Hun-yuan	1.5 m

From the above list, it may be seen that the thickness is greater in the southeastern regions and is thin in the west or entirely disappears toward the north. The number of limestone beds shows a similar tendency; there are more than 10 in Chung-hsing, 5 in Tze-hsien, 3 or 4 in Tze-Po-Chang, 3 in the region along the Shin-Tai Railway, one or 2 in Ning-wu, and almost none in Hsi-shan of Peking, and in Ta-tung.

3. Crustal Movements of Upper Paleozoic Era

Introduction

The Upper Paleozoic formation, covering the Lower Paleozoic formation with parallel unconformity in North China, grades from littoral to terrigenous deposits and then to inland deposits, and finally becomes desert deposits, but several unconformities may be seen. Judging from them, erosion gaps and crustal movements seem to have occurred, so consideration will be given to them in this chapter.

I. Tai-hang epeirogenic movement and Pre-Shan-tung unconformity

After the Ordovician limestone had been deposited, the Cambro-Ordovician sedimentary basin, between the Mongolian orogenic zone and the Chin-ling—Seoul line, was upheaved by an epeirogenic movement and became land. This movement is named the Tai-hang epeirogenic movement, from the Tai-hang mountain range lying in the central portion of this basin and consisting of the Cambro-Ordovician strata. As a result, the Cambro-Ordovician formation in North China was affected by erosion for a long period, until the Middle Paleozoic and Lower Carboniferous. A wide area was lowered to a peneplain or a level land surface, close to sea level. But, in the Middle Carboniferous period (Moscovian), the ground began to subside and to be gradually covered with sea water, and the Shan-tung system was deposited. Because of this great erosion gap in the Middle Paleozoic era, residual clays occur at the base of the Shan-tung system, indicating the unconformity of the pre-Shan-tung system. This unconformity is a parallel unconformity in spite of the great erosion gap caused by the Tai-hang epeirogenic movement, and the sedimentary basin has undergone almost no deformation from the Lower Paleozoic through the Upper Paleozoic era, thus presenting a distinct geological division of North China, Manchuria and Korea. In this respect, the role played by the Tai-hang movement is quite significant.

II. Kai-lan movement (Huai-nan movement)

In the Middle Carboniferous period, the land subsided gradually, to be covered with sea water. The regions of Kai-lan and Shan-tung were flooded first, and the lower beds of the Chang-chiu series, the oldest formation of the Upper Paleozoic era in North China, were deposited there. Thereafter, transgression gradually advanced into the interior of North China, and almost all of North China except the southern part of Ho-pei Province, central and northern portions of Ho-nan Province, northern portion of An-hwei Province and the Yin-shan district of Mongolia, were submerged below the sea, and the upper beds of the Chang-chiu series and the Ping-ting series were deposited in the same horizon.

This subsidence, or transgression movement, continued from Moscovian to Uralian. The transgression age of the Huai-nan movement in Central and South China coincides with the deposition stage of the Chang-chiu series, and the author gave the name of Kai-lan movement to this transgression movement in North China.

III. Tze-hsien movement (Kun-ming movement)

1. Unconformity at the base of Permian formation

After the transgression, which ranged in age from Middle Carboniferous to Upper Carboniferous (Uralian), a regression again took place in North China, following an upheaval of land at the end of the Upper Carboniferous period. The deeper portion of the sedimentary basin was still under water but the marginal and shallow portions were raised above the sea and were subjected to erosion. Thereafter in the Lower Permian period (Sakmarian), a wide area submerged below the sea again, and the Po-shan series, or the corresponding Tai-yuan series, was deposited. This upheaval of land is reflected by various states of unconformity between Carboniferous and Lower Permian formations, such as the lack of all strata or part of the Ching-hsing series between the Ping-ting series and the Tai-yuan series, the lack of all strata or part of the Chang-tien series between the Chang-chiu series and the Po-shan series, the lack of upper beds of the Chang-chiu series and the whole Chang-tien series; in one extreme case the Tai-yuan series rests directly upon the Cambro-Ordovician formation. Thus, the gap due to the erosion before the Lower Permian period is observable in various states of stratigraphic relation everywhere in North China.

2. State of the base of Permian formation in coal fields of North China

Several examples will be given as explanation.

a) In the Ta-tung coal field, the Tai-yuan series overlies the Ping-ting series with basal conglomerate and the Ching-hsing series is lacking. However, in the northern area of this coal field, the Tai-yuan series directly covers the Cambrian formation.

b) In Hsi-shan of Peking, the Middle Carboniferous formation is seen only in the vicinity of Fang-shan, and the Lower Permian Yung-ting series covers the Cambro-Ordovician formation directly.

c) In the southwestern region of North China, extending over much of Tzu-hsien—Liu-ho-kou, central Ho-nan, and Chiao-tso and Ta-she coal fields, the Carboniferous formation is rarely developed and the Lower Permian formation rests directly upon the Ordovician formation. The Tai-yuan series in this region contains several beds of limestone, the lowermost of which is named Ta-ching limestone and serves as an index bed in many coal fields. The strata between the Ta-ching limestone and the underlying Ordovician formation are 50 m thick at Liu-ho-kou, 40 m at Peng-cheng-chen, 10 m at Ai-kou-tsun in An-yang-hsien, and only 2 m or so in the Ta-she coal field.

d) Mitsuo Noda (1944) observed similar unconformity in the Lai-wu coal field.

3. Tze-hsien (Kun-ming) movement

The distribution of the Po-shan series or the Tai-yuan series is wider by far than that of the Carboniferous formation. The author gave the name of Tze-hsien movement to the movement of upheaval and subsidence near the end of the Upper Carboniferous period. This seems to be contemporaneous with the Kun-ming movement in Central and South China and also with the Setamai movement in Japan. In Manchuria, the boundary between the Carboniferous period and the Permian period was placed between the Pen-hsi series (Moscovian) and the Huang-chi series by Noda (1950) who attached importance to the lack of Uralian. In North China, too, similar unconformity is found, as already stated. However, the two series are not always in contact unconformably; in some areas the deposition was continuous from the Carboniferous period to the Permian period.

IV. Chiao-tso movement (*Fig.* 8)

1. Difference of sedimentary facies between Tai-yuan series and Shan-hsi series

The period from the Tai-yuan series through the Shan-hsi series is that of transition from marine to terrigenous deposition. That is, the Tai-yuan series is composed of black shale intercalated with limestone, whereas the Shan-hsi series consists mainly of sandstone.

In the past, little attention was paid to the unconformity between the two, but this unconformity is seen in districts to be mentioned later, and in other districts of North China, and when considered together with the lithological difference between the two series, comes to have more importance than was hitherto assumed.

2. Base of Shan-hsi series

a) In the Yin-shan mountain range in the Ho-ho district, the Shuan-ma-chun series, corresponding to the Shan-hsi series, directly overlies the quartzite or the limestone of the Sinian system and the strata corresponding to the Tai-yuan series cannot be found.

b) The author discovered an unconformity between the Shan-hsi series and the Tai-yuan series in 1941, and estimated this erosion gap at 5 m to 10 m.

c) Ko SHIIDA observed similar unconformity in the Ning-wu coal field and estimated the erosion gap as more than 15 meters.

d) SHIIDA observed an unconformity between the Tai-yuan series and the Shan-hsi series in the vicinity of Tai-yuan and in the Yang-chuan coal field and emphasized the geological significance of this unconformity because the former is marine and the latter is terrigenous.

e) Haruyoshi FUJIMOTO found similar unconformity in the Yang-chuan coal field along the Shin-Tai Railway. The erosion gap exceeds ten meters in the area extending from the Tai-yuan district to the Shin-Tai Railway.

f) The author observed this unconformity in the Ching-hsing coal field in 1942.

g) C. C. WANG observed this unconformity in the Lin-cheng and the Tze-hsien—Liu-ho-kou coal fields.

h) T. F. HOU found this unconformity in the Chiao-tso coal field and reported it in 1930. The author observed this relation in the northern mountains of Chiao-tso during his exploration of the Chiao-tso coal field in 1941, and also postulated its presence by boring logs. As already stated, five layers of limestone are intercalated in the Tai-yuan series in the Tze-hsien—Liu-ho-kou coal fields, and a complex, 70 m to 100 m thick, is developed upon the Ta-ching limestone, which is the lowermost layer. In the Chao-tso coal field, however, about 50 m to 75 m of this complex has been eroded away, and the basal conglomerate of the Shen-hou series, corresponding to the Shan-hsi series, sometimes rests directly on the Ta-ching limestone which occurs in the same horizon as the Chu-tan series and the Tai-yuan series. In the central region of Ho-nan Province, the Chu-tan series is eroded to the extent of 35 m to 50 m.

i) According to the results of boring at the Ching-hsing colliery, more than 10 meters is sometimes lacking in the uppermost part of the Po-shan series.

j) In the Wang-ping-kou district of Wang-ping-hsien, west of Peking, a basal conglomerate is developed in the Wang-ping series and its relation to the Yung-ting series is of parallel unconformity.

3. Nature of Chiao-tso movement

The time gap represented by the above-mentioned unconformity is larger in the areas along the Yellow River, and is greatest in the Chiao-tso coal field, and this feature can be explained only by assuming a regional upwarping. In this connection, the lack of the Lower Cambrian formation in the Vicinity of Tsi-shan of southern Shan-shi, as studied by Teiichii KOBAYASHI, the clino-unconformity between the Sinian system and the Cambrian formation in Yui-ho in the southern end of the Tai-hang mountain range, as observed by Shinji YAMANE, and the change of coaly material into anthracite in Chao-tso—Ta-she region are all significant.

The sea, which had covered much of North China in the Lower Permian period, retreated completely by the end of the period, and the terrigenous deposits again covered the former with parallel unconformity in the Middle Permian period. The regression of this period is called the Chiao-tso movement. The boundary between the Chuan-shan limestone and the Chi-hsia limestone in Central and South China corresponds to this age. The two are mostly conformable, but in the Fu-kien district (HOU, 1935) the Chi-hsia limestone directly covers the Lower Carboniferous Wu-tung formation with distinct unconformity. The boundary between the Sakamotosawa series and the Kanokura series in Japan seems to correspond to this, but no unconformity has been found as yet between the two.

V. Tsin-pei movement (Tung-wu movement)

1. An example of crustal movement after the deposition of Shan-hsi series

In the Ta-tung coal field, after deposition of the Shan-hsi series, the land upheaved and was eroded; the amount of erosion is more than 170m, and is greatest toward the north, so that the Huai-jen series came to cover the Tai-yuan series toward the north, and covers even the Cambrian formation on the northern margin. This clearly shows a remarkable movement of the ground prior to the deposition of the Huai-jen series.

In Hsi-shan, Peking, the contemporaneous movement is inferred from the unconformity between the Hung-miao-ling sandstone, which is supposedly of the same horizon as part of the Huai-jen series, and the Wang-ping series that constitutes the basement.

In the region of the Yin-shan mountain range north of Ho-ho and Pao-tou, the Sa-la-tsi series, regarded as of the same horizon as the Huai-jen series, covers the Shuan-ma-chun series and the Sinian system with unconformity.

2. Nature of Tsin-pei movement (Tung-wu movement)

In the northern region of North China, that is, the Peking—Tsin-pei basin to the south of the Mongolian orogenic zone, an unconformity before the deposition of the Huai-jen series is recognized, and similar relations are reported by Nenji TAKAHASHI from Hung-lo-hsien of Chin-hsi district, Jehol, and by L. H. CHANG from the Nan-piao coal field. Accordingly, this movement shall be regarded as a large scale crustal movement extending over a wide area from the northern region of North China to the Jehol district. The author gave the name of Tsin-pei movement to this movement, after a conventional name of the Ta-tung district. In the period of this movement, however, the Shin-ho-tzu series was being deposited in the area extending from the central part of Shan-hsi Province to the central part of Ho-nan Province, and judging from the sedimentary facies an inland deposition seems to have been carried on continuously with repeated advances and retreats.

In an extensive area stretching from South Manchuria and North Korea to Chi-tung, Shan-tung, northern Kiang-su and Huai-nan, the "A" bed of aluminous shale occurs at the base of the author's Nan-ting series. This is a special horizon of the red complex to be correlated with the Shih-ho-tzu series. According to T. SAKAMOTO, the aluminous shale is a product of climatic and topographic conditions which prevailed then, so this horizon can be regarded as an unconformity plane of this age.

3. Paleontological views of the Tsin-pei movement

The Huai-jen series of the Ta-tung coal field has been proved by Hikoji MORITA to be correlated with the Upper Shih-ho-tzu series in Shan-hsi Province. This series characteristically yields *Gigantopteris* flora. In the area from the southern part of Shan-tung Province to the northern part of Kiang-su Province and the northern part of An-hwei Province, there is a complex intercalated with coal above the "A" bed of aluminous shale which contains *Gigantopteris* flora. This complex is the author's Nan-ting series and is supposed to correspond to the Upper Shih-ho-tzu series and the Huai-jen series. Therefore, from a paleontological viewpoint, the age of the unconformity, or erosion period, below the Huai-jen series can be assigned to the age of formation of the "A" bed of aluminous shale, and the period when the materials for aluminous shale were completely lateritized and redeposited may be assigned to the period preceeding the partial erosion of the Lower Shih-ho-tzu series and the Shan-hsi-series.

4. Contemporaneous movements in Central and South China and Japan

In Central and South China, a distinct unconformity is found between the Lung-tan coal measure, yielding *Gigantopteris* flora, and the Ku-feng formation and corresponding beds, yielding *Neoschwagerina*, and the deposition of the Lung-tan coal measure was preceded by a period of volcanic activity of O-mei-shan basalt. J. S. LEE called the movement in Central and South China at that time the Tung-wu movement, which seems to be contemporaneous with the author's Tsin-pei movement. The age of the particular sedimentary facies containing the Usuginu conglomerate, which is transitional between the Kanokura series and the Toyoma series in Japan may correspond to this, although the state of deposition has remarkably changed since that time.

VI. Tien-tai movement (Huai-nan movement)

The Shuang-chuan series in Peking—Hsi-shan covers the Hung-miao-ling sandstone with unconformity and, according to Misaburo SHIMAKURA, the red sandstone bed overlies the Huai-nan coal measure with unconformity in the Huai-nan coal field. Therefore, this unconformity is important geologically from the viewpoint of the change of the sedimentary facies. Presuming a period of crustal movement prior to the deposition of the Shuang-chuan series, this movement was named Tien-tai movement after the name of Tien-tai-shan where the Shuang-chuan series is typically developed. This seems to be correlated with the Huai-yang movement in Central and South China and also with the movement of the Tate stage in Japan.

VII. Shan-tung movement

1. Crustal movement before the deposition of Ta-tung series

Taking the Ta-tung coal field as an example, the coal measure of the Ta-tung series of Triassic to Jurassic period rests upon the Huai-jen series with unconformity. This unconformity is observed distinctly in the upper reaches of E-mo-kou in Huai-jen-hsien, and upon examining the boring logs and outcrops in the northern and northernmost parts of the Ta-tung coal field, it is known that the Ta-tung series overlies directly whole complexes ranging from the Huai-jen series to Cambrian formation and then to the Sang-kan gneiss. As to the coal measures, only Paleozoic coal measures are developed in the central and southern parts of the Ta-tung coal field, whereas in the northern part the Tai-yuan series, which is Paleozoic coal-bearing formation, coexists with the Mesozoic coal-bearing Ta-tung series. On the other hand, in the northernmost part of this coal field, the coal measures of the Ta-tung series are widely distributed, resting directly upon the Cambrian formation and the gneiss. From this fact it is clear that there was a crustal movement before the deposition of the Ta-tung series, and the amount of upheaval was greater toward the north. Erosion accompanied the upheaval, and the Ta-tung series was deposited with a gradual northward overlapping. Similar relations are seen in the Yin-shan area where the Shih-kai-tzu series rests unconformably on the Sa-la-tsi series, and in the Peking—Hsi-shan area where the Men-tou-kou series overlies the Shuang-chuan series with unconformity.

2. Importance of Shan-tung movement

In the Tze-po-chang coal field, Shan-tung Province, the Kun-lun series that constitutes the lower beds of the Hsin-tai system covers the Feng-huang-shan series with unconformity. The author previously called the Upper Paleozoic formations in the Shan-tung district by the name of Shan-tung system, so the movement represented by this unconformity below the Hsin-tai system shall be called Shan-tung movement. This movement caused drastic changes in the sedimentary facies and the shape of sedimentary basin of the Shan-tung system, which had graded from marine deposits to terrigenous deposits and then to inland deposits, and started an entirely new cycle of sedimentation. The Shan-tung movement may be contemporaneous with the Akiyoshi orogenic movement in Japan and the Songnim stage in Korea. Taking these features into consideration, it may be concluded that the Upper Paleozoic crustal movements in North China, ranging from the Kai-lan movement to the Tien-tai movement, were minor movements in the course of the cycle of sedimentation of the Shan-tung system, while the Shan-tung movement which took place last is by far the most important from the viewpoint of structural geology.

Summary

1. Before the Middle Carboniferous sedimentation

The whole of North China was upheaved uniformly to become land by the Tai-hang epeirogenic movement after the deposition of the Ordovician formation, but was affected by erosion over a long period of time—from Middle Paleozoic to Lower Carboniferous—and was degraded nearly to the base level plane. The Ordovician limestone produced residual clay on the surface as a result of weathering during the erosion of the Middle Paleozoic era. In this clay, alumina and iron were concentrated to form high-grade ores as a consequence of lateritization under a tropical climate. These ores are known as the "G" bed aluminous shale and the iron ores of the Shan-hsi type, and occur at the base of the Upper Paleozoic formations all over North China.

2. Nature of Kai-lan transgression

After the Middle Carboniferous period, the land subsided and gradual transgression occurred first in the east and then in the west, and the deposition of the Upper Paleozoic formation was started. This sedimentary basin is regarded as the same as that of the Lower Paleozoic era, as has been already stated. The deposition during the period from Middle Carboniferous to Upper Carboniferous was carried out in the form of overlapping due to transgression, and this movement was named the Kai-lan movement.

All area was submerged below the sea by this movement, but not equally, and the states of overlapping are different, partly resulting from the relief of the surface of the Ordovician formation and partly due to the degree of subsidence of the land, varying with region. As a result, there is a rather wide difference among the lower limits of the Shan-tung system. In this sedimentary basin, the area that first went under water includes Kai-lan on the western margin of the Pyongan—Liao-tung basin of T. KOBAYASHI, and Shan-tung Province, as well as northern Kiang-su in the northeastern part of the Shan-kiang-an basin, and the lower beds of the Chang-chiu series and corresponding strata were deposited there. These two basins were connected with the Yellow River basin of KOBAYASHI. The transgression advanced farther and reached the Shan-hsi basin and the Peking—Tsin-pei basin, there depositing the Upper Chang-chiu series and its equivalent Ping-ting series. The southern limit of the transgression during the Kai-lan movement did not go as far as the southern part of the Shan-kiang-an basin (central Ho-nan and northern An-hwei), and its northern limit failed to reach the Yin-shan region.

3. Characteristics of Tze-hsien movement

At the end of the Carboniferous period, ground upheaval and regression took place, and most of the area formerly covered by sea owing to the Kai-lan movement became land, later eroded. However, deposition continued in some portions of the basin, namely, the area along the Shih-Tai Railway and the Tze-Po-Chang and Kai-lan region. Later, a large scale transgression occurred again, inundating the whole area of the Kai-lan transgression and even the southern portion of the Shan-kiang-an basin, which had survived the earlier transgression. This movement of upheaval and subsidence is named the Tze-hsien movement, as has been stated already. The deposits produced by this movement are the Po-shan series and corresponding Tai-yuan series. At the base of these deposits, a basal conglomerate or basal sandstone is developed, occasionally forming a bed of residual clay (E bed in Kai-lan). In the southern part of the Shan-kiang-an basin, which was covered with sea water for the first time, the deposits have the "G" bed of aluminous shale and the Shan-hsi type iron ores at the base. The Tse-hsien movement is thus represented by the so-called Pre-Sakmarian unconformity, and is correlated with the Setamai movement in Japan, the Kun-ming movement in Central and South China, and the movement of the Nan-piao stage in Manchuria.

The formations deposited as a result of the Tze-hsien movement have already been described; they are composed mainly of black shale, abound in limestone and iron sulphides, and are intercalated with the type of coal named stink coal. There are more than 10 layers of limestone in the southern region, amounting to 40 m in total thickness, but these decrease toward the north, where only three or five layers are found in the area along the Shih-Tai Railway and in the Tai-yuan district and none in the Ta-tung and Peking—Hsi-shan region. On the other hand, coal seams become thicker northward, thinner southward, and almost nonexistent in the area extending from central Ho-nan to Huai-nan.

4. Chao-tso movement and land of North China

The complete regression of the sea, which once covered virtually all of North China at the end of the Lower Permian period, is clearly indicated by the unconformity at the base of the Tze-chuan and the Shan-hsi series of the Middle Permian period. The Tze-chuan and Shan-hsi series are composed mainly of thick platy sandstone, false-bedded or irregularly bedded, or gravelly rocks, and belong to terrigenous deposits, showing a facies of wide deltaic deposition. The amount of erosion of the Po-shan series, Tai-yuan series and corresponding formations by the unconformity at the base of the Tze-chuan series or Shan-hsi series is greater in the southern region than in the northern region, being 5 m to 10 m in Ta-tung, more than 15 m in Hsien-kang-chen, over 10 m in Tai-yuan and the area along the Shih-Tai Railway, 50 m to 75 m in Chao-tso—Ta-she, and 35 m to 50 m in Yu-hsien. In the Yin-shan region, the northernmost part of North China, the Middle Permian formation (Shuan-ma-chun series) covers the Sinian system with unconformity, and the deposition of the Upper Paleozoic formation seems to have started for the first time in this period. The unconformity dividing the marine deposits and the terrigenous deposits of the Upper Paleozoic strata in North China has a special significance, and the author named the movement of that time the Chaotso movement, as has been stated.

The total thickness of coal seams of the Hung-shan formation of the Tzu-chuan series or Shan-hsi series increases to the south and decreases to the north, and almost no coal seam is developed in the northern region. It is noteworthy also that the thickness of a coal seam varies even within one and the same coal field.

5. Paleogeographical significance of red formations

The afore-said deltaic deposits passed gradually into an inland basin facies from the latter half of the Middle Permian period, and as the climate became higher in temperature and more arid the red rocks increased. The boundaries between the Shan-hsi series and the Shih-ho-tzu series in the Shan-hsi district, and between the Hung-shan formation and the Hei-shan formation of the Tzu-chuan series in the Shan-tung district, are placed at the lower limit of the introduction of red rocks.

The red-rock complex in the eastern part of North China, South Manchuria and North Korea contains the "A" bed of aluminous shale in a nearly equal horizon. Immediately above this horizon lies the Nan-ting series yielding *Gigantopteris* flora. This series is correlated with the Upper Shih-ho-tzu series of the Shan-hsi district and the Huai-jen series of the Ta-tung coal field, and is supposed to be contemporaneous with the Lung-tan coal measure of Central and South China. The unconformity plane at the base of the Lung-tan coal measure is contemporaneous with the unconformity plane at the base of the Huai-jen series and also with the unconformity plane indicated by the "A" bed of aluminous shale. The crustal movement represented by this unconformity is called the Tsin-pei movement which the author regarded as contemporaneous with the Tung-wu movement of Central and South China and the movement of the Usuginu stage of Japan.

In the inland basin of the Upper Permian period, where the Upper Shih-ho-tzu series, Huai-jen series and Nan-ting series were deposited, the climate was remarkably arid, with the landform of a plain, so that the growth of plants seems to have been hindered. However, in the southern region, a lake basin or swamps formed which favored the formation of coal seams. Such coal seams are found in the I-hsien coal field in the southeastern part of Shan-tung Province, the Liu-chuan coal field in northern Kiang-su Province, the coal fields of Yu-hsien and Mi-hsien in central Ho-nan Province, and the Huai-nan coal field in northern An-hwei Province. During this period, the Lung-tan coal measure, an important coal producer, was being deposited in Central and South China.

6. Paleogeographic significance of dark-red complex

The Shih-chien-feng series is developed upon the Shih-ho-tzu series, while the Feng-huang-shan series is upon the Nan-ting series. The Shih-chien-feng series is composed mainly of dark-red sandstone, and is several hundred meters thick, sometimes containing gypsum beds. These features indicate that the depositional environments were strikingly different from those of the underlying formations. Namely, the formations beneath the Shih-chien-feng or Nan-ting series had been deposited in a plain where lakes or swamps developed in favor of coal formation, but with the changing climatic conditions the environment turned to those of a desert. In the past the Shih-chien-feng series and corresponding formations were regarded as Triassic in age, but since Fujimoto collected *Lepidodendron*, *Calamites* and other plants of supposedly Paleozoic age at Hsi-lo-chen along the Shih-Tai Railway, the question of the age of this series needs further examination.

The author considers the Shuang-chuan series developed in Peking—Hsi-shan to correspond nearly to the lower part of the Shih-chien-feng series, but the latter is unconformable with the underlying Hung-miao-ling sandstone on the southern slope of Tien-tai-shan, which is the type locality of this series, so the crustal movement responsible for this unconformity was named the Tien-tai movement. Shimakura regards the red sandstone above the Huai-nan coal measure as Triassic and the relation between the two to be unconformable. Thus, even when no unconformity is recognized between the Shih-chien-feng series and the Shih-ho-tzu series or its equivalents in various parts of North China, a crustal movement is reasonably inferred from the striking change in the rock facies. The relation between the Kopangsan series and the Green-rock series in Korea is comparable to this, and the Huai-yang movement in Central and South China and the movement of the Tate stage in Japan also seem to correspond to the Tien-tai movement.

7. Shan-tung cycle of sedimentation and Shan-tung movement

Considering the above, the continuous deposition from the marine deposits of the Middle Carboniferous period to the terrigenous and then to inland deposits of probably Permo-Triassic age can be regarded as that of one great cycle, so the author named it the Shan-tung cycle of sedimentation, all deposits being grouped in the Shan-tung system. The crustal movement interrupting this cycle is very important in North China, and is called the Shan-tung movement by the author. The Shan-tung movement seems to be contemporaneous with the Akiyoshi orogenic movement in Japan and the movement of the Songnim stage in Korea. After this movement, no such extensive regional deposition as that in Paleozoic era has taken place in North China up to the present. However, intermontane basins formed in the various places where deposition of coal began at the end of the Triassic period and continued to the Jurassic period, as exemplified by the Men-tou-kou series of the Men-tou-kou coal field, the Ta-tung formation which is the upper coal-bearing formation in the Ta-tung coal field, and the Fang-tzu series of the Fang-tzu coal field.

It may be appropriate to end this paper with the following remark: the sedimentary environments in North China, as indicated by the cycle of sedimentation of the Shan-tung system, were not associated with orogenic movements but resulted from very slow movements of the Kratogen-type ground.

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The Huangtu Formation and the Loess of North China

Eigo SAKAI

1. Introduction

F. VON RICHTHOFEN introduced the Huangtu of North China as a loess in 1877. Its wide area of distribution, its thickness and the question of its origin attracted the attention of geologists all over the world. After RICHTHOFEN, the WILLIS and BLACKWELDER (1907) paper was an epoch-making one. The origin of the Huangtu is not yet known, even though many studies have been made. The geological study of the Huangtu formation is connected with primeval man in the Far East and also with the relation of the Far East continent and Japanese islands. It is also an important and interesting geological problem of the Cenozoic Era in North China. This paper includes the results of my observations of the Huangtu formation in South Cha-har, Ho-pei, Shan-hsi, and Shan-tung.[1] It is my contribution to the study of the origin of the Huangtu and I hope it will attract new attention to that formation.

I gratefully acknowledge the help of Prof. T. TOMITA, who kindly directed me and gave me many important suggestions. Next, I express my hearty thanks to Messrs. T. TAKEYAMA, N. KURATA, S. SHOJI, T. YAMAZAKI, and T. KAMIYAMA, who helped my field survey; to Mr. S. NAITO and T. KAWANO, who took charge of the topographic survey; and to K. KUWAHARA and C. C. WANG, who took charge of the mechanical analysis. I would also like to acknowledge the kind encouragement of the late Dr. T. KATO, Dr. S. YAMANE, and Dr. H. FUMIMOTO.

2. The Loess, the Huangtu, and the Huangtu Formation

The Loess

According to F. VON RICHTHOFEN, loess has the following properties:

(1) It is a yellowish-brown soft soil, and is easily crushed by crumbling with the fingers.

[1] The area surveyed by the author is very small compared with the estimated distribution area of the Huangtu, 1,324,000 square km (T. WAKIMIZU, Loess of China: Sekai Chiri, vol. 3, China 1, North China, pp. 83–100). However, the area studied is well exposed and contains much data for the study of the origin of the Huangtu.

(2) It gets into the skin folds of one's finger, and it is a fine soil having no rough feel.

(3) It is rich in calcium carbonate.

(4) It is sometimes coarse.

(5) Slender tubes are developed vertically.

(6) Voids are frequently present.

(7) It has the property of breaking and forming vertical walls in cliffs.

(8) Particles are fresh and angular.

Generally, loess is a silt-rich soil, a brownish-yellow color, porous, coarse, and contains calcium carbonate.

The Huangtu

The Huangtu (a general term which can refer to certain component parts of the Huangtu formation) has many properties of the above-mentioned loess, and in addition has the following properties:

(1) In some places it is almost completely composed of sand, and may contain pebbles.

(2) The results of mechanical analysis differ by region, by deposits in the same region, and by direction (vertical and horizontal) in the same deposit.[2)]

More than seventy years have elapsed since the Huangtu was introduced as a loess, but the two do not always have the same properties. The author proposes that the term loess and Huangtu should be used as they are. A distinction between the two will be made in this paper.

The Huangtu formation

B. Willis named the deposits consisting of loess, sand and gravel the Huangtu formation. Tomita and I used the same term for deposits of loess, sand and gravel.[3)]

3. The Huangtu Formation of North China

Distribution and thickness

The Huangtu formation extends over the Yin-shan mountain range and the Jehol mountains in the north, and the Tsin-ling and Fu-niu mountain range in the south. The location of deposition is from several meters to 1,000 m above sea

2) Even if an outcrop looks like a thick Huangtu formation of identical properties, the granularity of specimens differ. Accordingly, the fineness of one specimen does not represent that of the outcrop.

One important fact made clear about the vertical distribution of fineness is the discontinuous plane, supposedly in the primary deposit of the Fan-shan-pu region. It is clear that the granularity differs horizontally in the primary deposit in the Cheng-ho village region.

3) According to the geological map of the Chang-hsia district, Province of Shan-tung (Willis and Blackwelder, 1907), the Huangtu formation (chiefly loess with notable amounts of sand and gravel) is a terrace deposit. As seen in Fig. 6, the Huangtu formation is clearly a terrace deposit cropping out on the right bank of Sha-ho, 2.5 km NNW of Chang-hsia station (Tomita and Sakai, 1941).

level, and is rarely as high as 1,500 m. The topographical distribution of the Huangtu formation is (1) the present and old valleys, which are the widest, (2) the periphery of valleys, (3) broad plains, and (4) higher mountain areas.

The distribution of the Huangtu formation shows a characteristic common to both the Tertiary formation and the Diluvial deposits. TOMITA and MASUBUCHI (1943) discovered that its thickness is greatest in the following two regions: from east of Lan-chow to the southeast, and from Ching-yuan to the Shen-pei basin. The thickness varies from 40 to 50 m and is sometimes more than that in the first region. The third region is the Pu-te, Wu-pu and Kung districts on the banks of the Huang-ho (more than 40 m).

The literature of the past tell us that the thickness varies from 100 to 500 m, but it includes the lower Diluvial deposits and the Tertiary deposits.[4] (see distribution map by CRESSEY). I have observed that the actual maximum thickness seems to be from 50 to 60 m. The thickness of the Huangtu varies from 16 m to 17 m, as at Cheng-ho village, Fan-shan-pu and Chang-hsia (see Table 1).

Classification of the Huangtu formation

TOMITA and I divided the deposition layers in ascending order of first, second, and third deposits, etc. for every surveyed area.[5] The division of the Huangtu formation in North China is given in Table 1.[6]

State of deposition[7]

The NW district of Ping-men, Kalgan

Deposit (I) covers the 15 m gravel bed unconformably. The loam of (I–l) has many vertical platy joints, conchoidal fractures and pseudostratification; it contains Huangtu spherulites which are more than 12.5 m thick. The loam of (I-m) is remarkably false-bedded, has vertical joints on its surface exposures, and contains Huangtu concretion and Huangtu spherulites. Deposit (I-u) is a light-yellowish-brown or yellowish-brown Huangtu; it is lighter-colored than (I-l) and (I-m), and is noteworthy because of its vertical joints. Deposit (II) is composed of Huangtu sand and gravel and forms river terraces. Vertical joints are also developed. Deposit (III) forms talus deposits or fan deposits in some places, and is com-

[4] Pliocene red clay is included.

[5] Cliff exposure is convenient for the geological exploration of the Huangtu, and it is desirable to divide outcrops into deposition layers by character.

Terms such as "plateau loess" or "primary loess" were used in the past. The purpose of the geological study of the Huangtu formation is to find the origin of the Huangtu, in other words, to determine which is the primary Huangtu. Thus, it is not proper to use the term "primary loess" indiscriminately.

[6] In order to simplify the classification of the deposits, the terms valley-filling "Huangtu formation," the first deposits, the second deposits, the third deposits, and the aeolian Huangtu formation are denoted by Vh, (I), (II), (III), and Ah respectively. The lower, the middle and the upper members of (I) are denoted by l, m, and u. Vh and Ah do not have a stratigraphic notation of upper or lower.

[7] See also Table 1 in connection with the paragraphs on state of deposition.

posed of gravel, sand, and Huangtu. The gravel is the weathered product of bed rocks (Chang-chia-kou series). Sometimes vertical joints are developed. The first and second, and second and third deposits are clearly related geologically by unconformities. Further, (I-l), (I-m) and (I-u) are not stratigraphic divisions.

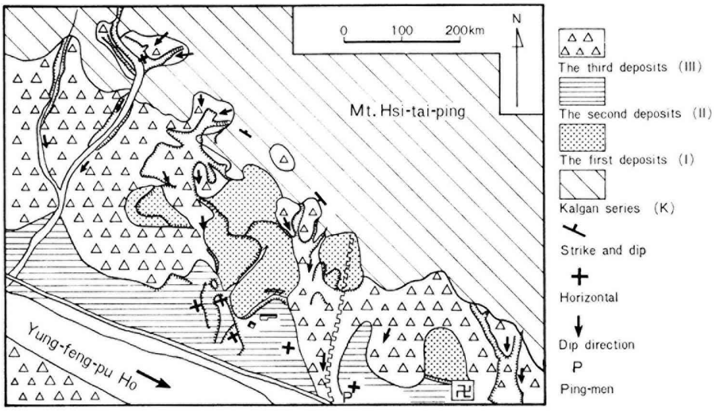


Fig. 1. Geological Map of the Ping-men District, Kalgan, South Cha-har.

The Cheng-ho village district

The valley-filling "Huangtu" formation occurs widely on both banks of the Ta-ho River, and two color bands are developed in the cliff outcrop 25 m above (I) southwest of Tung-pao-sha (Fig. 4). The lower bands (LB of Fig. 4) extend from the north outcrop (N) (Point "N" of Fig. 3) which is 7 m above the south outcrop (S) (Point "S" of Fig. 3) which is 13.5–14.5 m high. The upper band (UB of Fig. 4) bends upward to form a sudden arc at (N) which is about 8 m above (S) and dips southward. The lower part of LB is yellowish-brown or brown loam tinted with red, but in (S) the upper part is a light yellowish brown to yellowish-brown Huangtu. The color bands of the upper and lower parts are dark. Vertical platy joints are developed parallel to the vertical cliff outcrop in the loam at point S, while vertical columnar joints are noteworthy in the Huangtu. It is specially noteworthy that Huangtu spherulites are found not only in the loam and in the lower color band but also in the Huangtu. The second deposits form river terraces and cover (I) unconformably. The third deposit is a gravel bed and is not Huangtu.

The aeolian Huangtu formation (Ah) occurs only in ridges facing northwest (Table 13, No. 41224) or on slopes (Table 13, No. 41235), and its distribution is limited to a narrow area. At higher elevations the thickness and the breadth gradually decrease to the end of the aeolian formation.[8)]

[8)] The dip angle of the surface of Ah was 20 degrees at the northwestern ridge of Ta-tung-shan and at its northwestern foot. The angle which I measured was 12 degrees at Tai-ping-pu. I called this angle the critical angle of deposition of Ah.

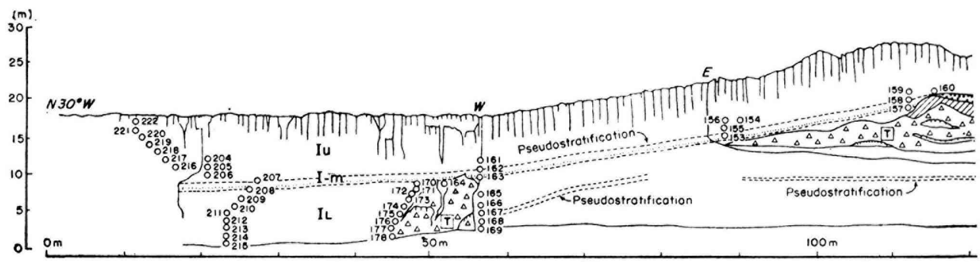
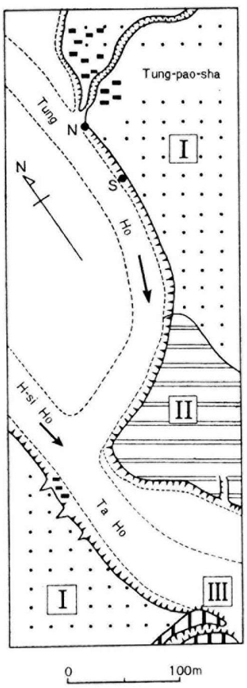


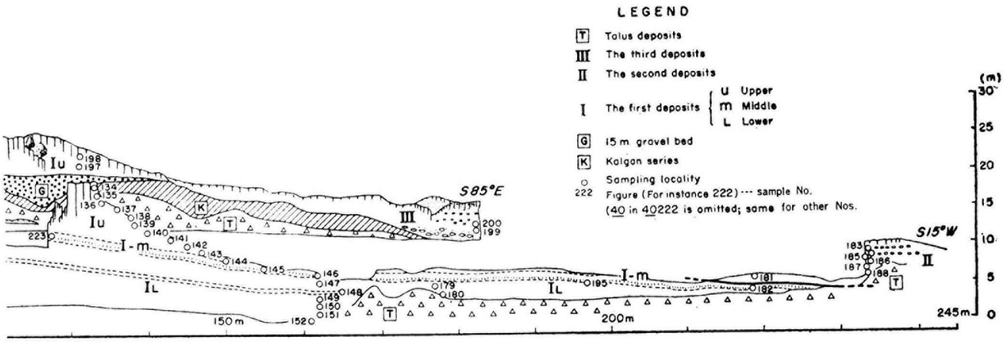
Fig. 2. Panoramic Diagram of the Outcrop of the Central Cliff, Northwest District of Ping-men Kalgan, South Cha-har.



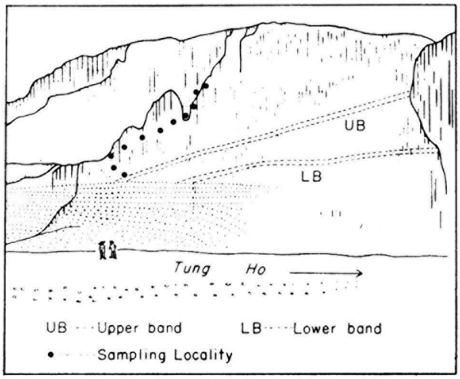
LEGEND

III The third deposits
II The second deposits
I The first deposits
N North outcrop
S Sorth outcrop

Fig. 3. Geological Sketch Map of the Southwest District of Tung-pao-sha, Cheng-ho Village, Hsuan-hua Prefecture, South Cha-Har.



Kalgan, South Cha-har



Southwest of Tung-pao-sha, Cheng-ho Village, Hsuan-hua Prefecture, South Cha-har.

Fig. 4. Upper and Lower Color Bands in the First Deposits.

The NW district of Hsi-men, Fan-shan-pu

Deposit (I) is well exposed in the cliff outcrops at points E and W (these two cliffs are 50–60 m apart) (Fig. 2). At E (17 m high, the portion lower than 5 m is not exposed), a sand bed (10–20 m thick, cross-bedded) is intercalated at a height of 6 m and an apparently homogeneous Huangtu occurs in the upper portion. At W (22 m high, the portion lower than 3 m is not exposed), loam (3 m thick, Huangtu spherulites included), Huangtu (3 m thick, vertical columnar joints developed), a gravel bed (less than 2 m thick, gravel is arranged imbricatedly), and Huangtu (11 m thick) occur in ascending order, above the elevation of 3 m. The author once thought a discontinuous plane of fineness of grain existed in that portion of the section 10–11 m high at point E.[9]

Deposit Ah of Tai-ping-pu (Nos. 4013 and 4014 in Table 13) south of Fan-shan-

[9] The screen used for mechanical analysis was defective at the time the author considered the existence of the discontinuous plane of fine grains. Therefore, the material was sorted again and the results of the first study were corrected as shown in Table 9. However, the height of the discontinuous plane is the same.

pu occurring in the western side of a saddle, is 15–16 m in maximum thickness which decreases gradually toward the ridge until the deposit disappears. The area of deposition is very small, like the Ah of the Cheng-ho village district.

The SSW district of Yung-ting-chiao

The lowest part of outcrop (I) faces south, is 15 m high, and is a gravel bed less than one m thick. Its upper portion is a light brownish-yellow sand bed and is apparently homogeneous. Vertical columnar joints in the upper part and vertical platy joints in the lower part are seen in this sand bed, but there are no joints in the middle part. Sieve analysis shows that the joints are developed in that portion of deposit (I) which has more than 5 per cent (by weight) of silt and clay particles (size less than 0.005 mm). Specimens from the sand bed effervesce when dilute hydrochloric acid is poured on them. The chemical study will be left for the future, but this is an important district for the study of the origin of joints.

Along the Shih-Tai Railway (between Shih-chia-chuang and Tai-yuan)

The columnar sections of deposit (I) are represented in Fig. 5; A for Chin-chuan, B for Chuang-tsun, C for Yang-chuan, D for Wei-shui, and E for Shang-an. As is shown, the Huangtu overlies a reddish clay, and there is neither unconformity nor disconformity between the two. The reddish clay gradually changes upward into a yellow clay, and there is no distinct border between the two (A, C, D, and E). The Huangtu concretion is remarkable in sections A and D, while Huangtu spherulites are found only in the reddish clay of sections A and C. Effervescence is conspicuous in the lower part of the Huangtu in sections A, B, and C. The effervescence in the upper part is remarkable in section C but not in A, and does not exist in D, E, and the lower part of A. Section B shows flat breccias arranged horizontally in the lower part of the Huangtu and contains round pebbles. The Huangtu of section E yields fossils of *Cathaica* sp.

The Chang-hsia and Chieh-shou district

The reddish loam (III-a) of the Chang-hsia district overlies (I) and (II) of the pre-Huangtu formation (loam) and the Man-tou shale. The relation between (III-a) and (III-b) is not that of an unconformity. Deposit (III-b) is a light yellowish-brown, intercalates horizontal and lenticular gravel beds, has vertical columnar joints, and shows the character of the Huangtu. Deposit (IV) covers (III-a) and (III-b), and (V) overlies (IV). Besides, (IV) and (V) are post-Huangtu formation and not Huangtu (a material term).

The hillside deposits (gentle slope) occur southwest of Hsia-lung-hua, unconformably overlie the Tai-shan metamorphic rocks and the Man-tou shale, and are composed of gravel bed, sand bed, and Huangtu (Table 8, No. 41237). These hillside deposits are clearly aqueous deposits. The Huangtu contains weathering products of bed rocks. The valley-filling deposits southeast of Tai-tien NNW of Chieh-shou are light greyish-brown to light reddish-brown, and effervescence is remarkable especially in No. 262; gravel beds are also found in the valley-filling deposits (Fig. 7). The gravel and sand are clearly aqueous deposits and are derived from gneisses and granites of higher elevations to the southeast.

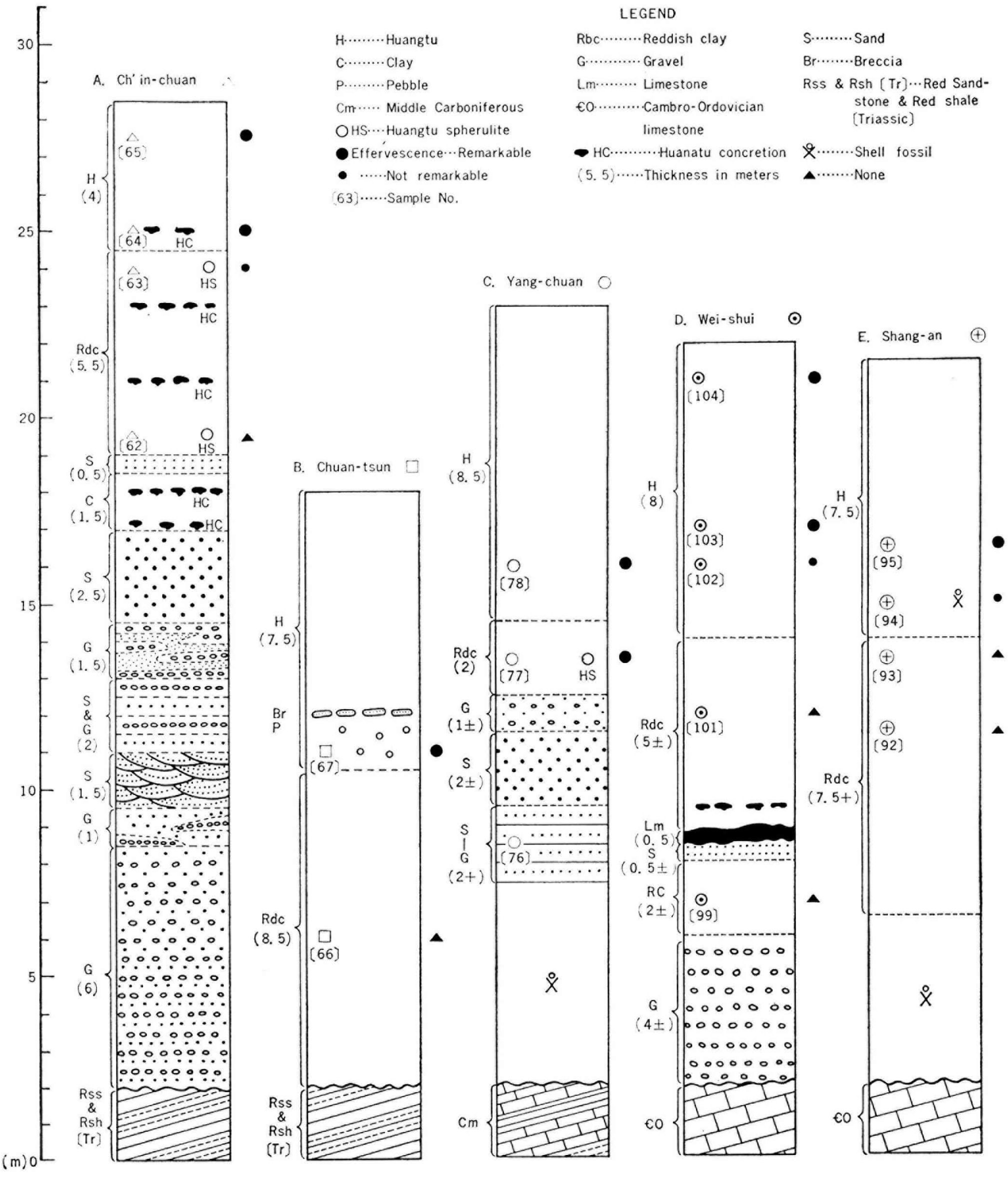
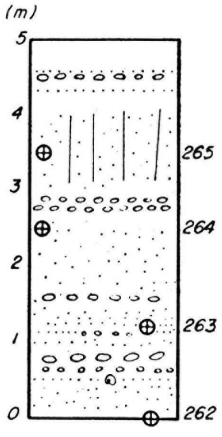


Fig. 5. Columnar Sketch of the "Huangtu Formation" (First Deposits) Along the Shih-tai Railway.



Road cut southeast of Tai-tien, 3 km NNW of Chieh-shou station, Chin-Pu Railway, Shan-tung (Sample Nos. 262-265)

Fig. 7. Gravel Beds in the Huangtu Formation.

General properties

Joints

Vertical columnar joints occur almost everywhere in the cliffs of the Huangtu. Examples: (I), (II) and (III) in the Ping-men district. Vertical platy joints parallel to the exposed plane of the cliff are seen in (I) loam in the Cheng-ho district, in (I) of the Yung-ting-chia sand within the author's surveyed area, and in (I-1) of the Ping-men district discovered by Tomita in 1941.

Fractures

Generally earthy, splendid conchoidal fractures over one m long in diameter are seen on the face of the platy joints of (I-1) at Ping-men. (Discovered by Tomita in 1941).

Brittleness

Breaks if crumpled between the thumb and forefinger. The Huangtu generally has this conspicuous characteristic. According to the findings of mechanical analysis, this characteristic is not conspicuous when the clay content is high.

Huangtu concretion

Called a loess child or loess doll in the past, it corresponds to the so-called Sha-chiang or Shih-chiang of North China. It is a concretion rich in calcium carbonate. It is found not only in the Huangtu but also in loam, reddish clay, and elsewhere and sometimes forms a bed. The size of the Huangtu concretions from (I-m) at Ping-men varies from one cm in diameter and 2 cm in height to 2 cm in diameter and 5 cm or so in height. Most of them are elongated vertically, and the lower end is pointed. Those collected from (I-m) in other places are generally 2–3 cm long in a horizontal direction, several mm thick, concave at the top, and pointed at the bottom. Globular ones and flat ones oriented vertically are rarely found. One of the Huangtu concretions collected from (I) north of Po-shan station, Shan-tung Province is approximately 10 cm in diameter, and the end of the projection which is elongated downward is hollow as in the lower end of a stalactite.

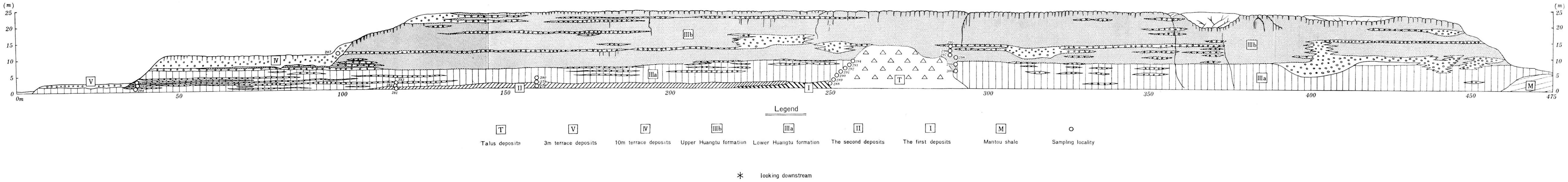
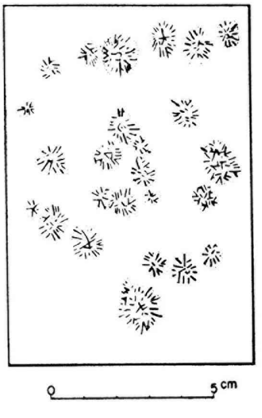


Fig. 6 Sketch of the "Huangtu Formation" the Cliff Along the Right Bank of the Sha Ho, 2.5 km. NNW of Chang-hsia Station, Chin-pu Railway, Shan-tung

Huangtu spherulite

These average one cm in diameter. The shapes are generally globular. Sometimes the center is hollow and rich in fissures which are nearly radial but not regular (Fig. 8). Concentric fissures are developed in the outermost margin. The soil which forms this globular body is a darker shade of brown than the other parts.



The first deposits (loam), SW of Tung-pao-sha, Cheng-ho village, Hsuan-hua Prefecture, South Cha-har.

Fig. 8. Sketch of the Huangtu Spherulite.

This distinction is difficult to make if the soil has been weathered. Vertical outcrops are commonly dotted with them, and they are sometimes connected vertically. They are sometimes gathered thickly in clusters. TOMITA and the author once reported that the Huangtu spherulites were found only in (I-1) at Ping-men in 1941, but the author confirmed their occurrence in the (I-m) deposit in September of that year. The author also confirmed that they are found not only in loam but also in the lower color band and in the Huangtu (I) of the Cheng-ho district. The location of Huangtu spherulites in North China is shown in Table 2. The Huangtu spherulite is the "loess spherulite," as named by TOMITA in 1941. P. TEILHARD DE CHARDIN and C. C. YOUNG (1933) called it a "hollow star."

It is geologically important that the hollow star is found in reddish and light-red loam, a typical "reddish loess" of the Chou-kou-tien geologic age. Twenty-five Huangtu spherulites (5–16 mm in diameter) were also found in a 8.8 sq. cm area within a vertical fissure face of (I) at point S at Cheng-ho village (Fig. 3). The area ratio is about 18 per cent (Fig. 8).

Adsorption

A fresh face of a small fragment adheres to the tip of the tongue. The mechanical analysis shows that this power of adsorption varies in direct proportion to the clay content.

Effervescence

If dilute hydrochloric acid is dropped on a specimen, effervescence occurs. The degree of effervescence depends on the calcium carbonate content.

Color

The Huangtu is light yellowish-brown to yellowish-brown but ranges sometimes from light greyish-brown to greyish-brown. The loam is light brown, greyish-brown, light reddish-brown, and sometimes yellowish-brown. The reddish clay varies from light red tinted with grey to dark reddish-brown.

Thickness

The thicknesses of the Huangtu loam and reddish clay are as shown in Table 1. The Huangtu of (I) in the Cheng-ho district is 16 m at point N, but 10 m at point S. Such difference in spite of continuous deposit is due to the color bands. It is of great interest that the color bands are related to the fineness of the grain.

Gravels

Spots of gravel from the bed rock and round fluvial pebbles from beds in the Huangtu formation were found. These are interesting for the study of the origin of the Huangtu of North China, which was regarded in the past as aeolian. The classification of the gravels and their distribution in North China are shown in Table 3.

Fossils

Non-marine shells found in the Huangtu formation are listed in Table 4.

Traces of plant roots

Deposits (I-l) and (I-u) of the Ping-men district contain many vertical traces of plant roots, but horizontal traces are rare.

Lateral holes (named by Tomita in 1941)

In a vertical outcrop lateral holes are nearly-elliptic or long-elliptic holes 1–3 cm in length horizontally along the long axis, one cm or so in width, and of unknown depth. They are conspicuous in acqueous deposits, but the origin is unknown. Examples: (II) and (III) at Ping-men.

Pseudostratification (named by Tomita in 1941)

This phenomenon is found in (I-l) and (I-m) of the cliff exposed in the center of the Ping-men district (Fig. 2). In (I-l), a light-grey band 30–40 cm in width extends continuously almost parallel to the present surface. Deposit (I-l) is less than one m thick; the lower part is rich in Huangtu concretion and the upper half contains a large amount of calcium carbonate and is greyish white. The light-grey band of (I-l) and (I-m) appears stratified if viewed from the south.

Color bands

As we have already stated, two color bands are seen in deposit (I) of Cheng-ho (Fig. 4). If we compare the lower color band at point S (Fig. 3) with the loam in the lower and upper parts of the Huangtu, the lower colored band is brittle and has a greater clay content (Table 8). The two color bands are noticeably darker in color than the other part and their north ends disappear diagonally into the horizontal sand bed (Fig. 4). Strictly speaking, the two color bands are not parallel to each other nor to the present surface. Comparing the grain size at points N and S, we see that the sand is richer at N and seems to be related to the development of the color bands (Table 8).

General properties to be considered will be confined within the above stated range.

Mechanical analysis

Tables 5–13 indicate the findings of the mechanical analysis of the Huangtu loam and reddish clay.

Characteristics of the particles

The crystal fragments of anorthoclase from (I-l) in the Ping-men district (3 mm; collected by TOMITA) are found only in the rhyolite and the trachyte of the Kalgan series of North China.

Mechanical analysis shows that the Huangtu at Chuang-tsun contains decomposed matter derived from the bed rock (red sandstone).

The particles greater than 1 mm in diameter found in the Huangtu formation southeast of Tai-tien are clearly all fragments of Tai-shan metamorphic rocks. The particles of less than 1 mm in diameter are microcline, plagioclase, muscovite, biotite, hornblende, epidote, tourmaline, zircon, and apatite. In addition hair-like rutile is sometimes found in the quartz. According to TOMITA, microcline is characteristic of the Tai-shan granite among the acidic plutonic rocks of the pre-Sinian period of North China. These minerals are all those composing the Tai-shan gneiss and the Tai-shan granite which are the bed rocks of this area.

The hillside deposits at Hsia-lung-hua contain many particles from the Tai-shan gneiss bed rock and Man-tou shale.

4. Summary

Vertical joints

The vertical joints are thought to have been formed by the cohesion of the deposit caused by a dry climate. Examples: (I) and (II) C4 in Ying-ting-chia district (Table 10).

Peculiarity of the locality

A considerable amount of weathering products from the bed rocks are found in the Huangtu formation at Ping-men, Chuang-tsun, Tai-tien, and Hsia-lung-hua. That of Tai-tien especially is an autochthonous deposit, which has not been transported from other places. Example: Meng-chiang region. The peculiarity of locality of the Huangtu deposit is thus clear.

Evidence of chemical and physical changes after deposition

The three pieces of evidence are: calcium carbonate is present; Huangtu concretion is formed; and color bands are developed.

The Huangtu spherulite

Huangtu concretions are found not only in the brown loam or the reddish clay of Chou-kou-tien age but also in the Huangtu of (I) in the Cheng-ho district. There is neither unconformity nor disconformity between the brown loam or reddish clay and the Huangtu.

Vertical distribution of fineness

There is a remarkable discontinuous plane formed by a vertical distribution of fine-grained particles in the Huangtu formation, which appears homogeneous in the outcrop (deposit I at Fan-shan-pu).

5. Conclusion

We have outlined the Huangtu formation. Considering the facts stated in this paper, the process of "huangtization", proposed by TOMITA, evidently took place in the districts stated above. Namely, the Huangtu of (I) and (III-b), mentioned earlier, seem to have been altered from A1 and A3 of the Chou-kou-tien bed of the lower Diluvium by "huangtization" (an unknown weathering process) *in situ*.

Table 1. Classification of the "Huangtu Formation".

Division \ District	South Cha-har				Ho-pei • Shanhsi (13)(15) (Along the Shih-tai Railway)	Shan-tung (28) (NNW of Chang-hsia station)
	NW of Ping-men, Kalgan (16)(27)	Cheng-ho village, Hsuan-hua Prefecture (14)	NW of Fan-shan-pu, Huai-lai Prefecture (17)	SSW of Yung-ting-chiao, Huai-lai Prefecture (13)(19)		
Aeolian "Huangtu" formation (Ah)	x	Ah (Huangtu) [2–6 m]	x	x	x	x
Valley-filling "Huangtu" formation (Vh)	III (Gravel, sand and Huangtu) Fan . . . [5–6 m], Talus . . . [10 m±]	III (Gravel) [3–4 m]	II (Gravel and sand) [3 m+]	II (Gravel and sand) [3 m +]	III (Gravel and sand) [2–3 m]	V (Gravel and sand) [1 m +]
	II (Huangtu, sand and gravel) [5–6 m]	II (Huangtu, sand and gravel) [10 m ±]	x	x	II (Huangtu, sand and gravel) [15–21 m]	IV (Gravel, sand and silt) [4 m±]
	Iu (Huangtu) [10 m] Im (Loam) [1 m ±] Il (Loam) [12 m ±]	I Upper (Huangtu) [10–16 m] Lower (Loam or sand and gravel) [14 m +]	I Upper (Huangtu) [16 m] Lower (loam, sand and gravel) [3 m +]	I Upper (Huangtu) [13 m] Lower (Loam, sand and gravel) [15 m]	I Upper (Huangtu) [7.5–8.5 m] Lower (Reddish or red clay) [2–8.5 m+]	IIIb (Huangtu and gravel) [17 m] IIIa (Huangtu-reddish loam) [8 m]
Pre-"Huangtu" formation	15 m gravel bed	x	x	x	Gravel and sand	II (Dark-brown soil) [2 m −] I (Dark-red-brown soil) [2 m +]

Figures in brackets show the thickness of the bed.
Numbers in parentheses refer to Bibliography.

Table 2. Localities of Huangtu Spherulite (Sakai, 1947).

South Cha-har	• NW of Ping-men, Kalgan • SW of Ping-men, Kalgan • NNW of Hsi-men, Fan-shan-pu, Huai-lai Prefecture °• SSW of Tung-pao-sha, Cheng-ho village, Hsuan-hua Prefecture	M R M VM
Shan-hsi	◎ About one km E of the northern end of Yang-chuan-ta-chiao ◎ Northern cliff of Chin-chuan station	R R
Shan-tung	• W of Ta-chien-kou, Li-cheng prefecture • Northern foot of Chin-lu-shan hill, Tao-ko village, Li-cheng Prefecture	R R

VM......Very much; M....Much; R....rare. ◎....Reddish clay;
• ....Yellow-brown loam, ○....Huangtu.

Table 3. Arrangement of Pebbles in the "Huangtu Formation", Their Distribution According to the Enclosing Beds (SAKAI, 1950).

District \ Arrangement	Horizontal	Imbricate
Ping-men	II	II, III
Cheng-ho village	II	II, III
Fan-shan-p'u	–	I, II
Yung-ting-chiao	–	I
Chuang-tsun	I	–
Yang-chuan	–	II
Chang-hsia	IIIa, IIIb	IIIa, IIIb, IV, V
Tai-tien	(Lower)	(Lower and Upper)
Pi-chia-tien	(B)	(C)

Table 4. Non-Marine Shells from the Huangtu Formation (SAKAI, 1943).

Genus and Species	Site (1)*	(2)	(3)*	(4)*	(5)*	(6)	(7)*
1. *Anisus* (*Gyraulus*) sp.	−	−	−	−	−	+	−
2. *Bradybaena* (*Manchurohelix* TAKAI) *lavrushini* (COCKERELL)	−	+	−	−	−	−	−
3. *Bulimus striatulus* BENSON	−	−	−	−	−	−	+
4. *Cathaica fasciola* (DRAPAUNAUD) SUZUKI	−	+	−	−	−	−	−
5. *Cathaica pulveratrix* (VON MARTENS) SUZUKI	−	+	−	−	−	−	−
6. *Cathaica* sp.	−	−	+	+	−	−	−
7. *Gyraulus* sp.	+	−	−	−	+	−	−
8. *Hyppeutis schmackeri* (CROSSE)	+	−	−	−	−	−	−
9. *Lymnaea auricularia* LINNE var.	−	−	−	−	+	−	−
10. *Lymnaea* (*Galba*) *pervia* VON MARTENS	−	−	−	−	−	+	−
11. *Lymnaea* (*Radix*) *plicatula* BENSON SUZUKI	−	−	−	−	−	+	−
12. *Lymnaea* sp.	+	−	−	−	−	−	−
13. *Metodontia houaiensis* ? (CROSSE) [weathered]	+	−	−	−	+	−	−
14. *Metodontia yantaiensis* (CROSSE and DEBEAUX) SUZUKI	−	−	−	−	−	+	−
15. *Opeas pyrgula* SCHMACKER & BOETTGER	+	−	−	−	−	−	−
16. *Unio douglasiae* GRIFFITH et PEDGION	−	−	−	−	−	−	+
17. *Viviparus chinensis* REEVE	−	−	−	−	−	−	+
18. *Viviparus heudei* REEVE	−	−	−	−	−	−	+

(1) Between Huang-tu-chia-chen and Ta-meng-chen, NNE of Tai-yuan, Shan-hsi Province. (I) (SAKAI, No. 4055)
(2) Huangtu formation, west of Ching-hsing station, Ho-pei Province. (SUZUKI, 1939)
(3) About 200 m east of Shang-an station, Ho-pei Province. (I) (SAKAI, No. 4094)
(4) Tung-tu-men, SW of Huai-lu station, Ho-pei Province. (II?) (SAKAI, No. 40106)
(5) NE of Shih-men station, Ho-pei Province. (III) (SAKAI, No. 4091)
(6) East of Shih-men station, Ho-pei Province. (III) (SUZUKI, 1939)
(7) Hsi-ta-yuan, about 500 m north of Pao-ting station, Ho-pei Province. (II or III) (SAKAI, No. 40112)

*Specimens from (1), (3), (4), (5) and (7) were collected by the writer and identified by Y. OTUKA.

Table 5. Granularity of the Huangtu, Area Northwest of Ping-men, Kalgan, Southern Cha-har (Upper Part of the First Deposits) (SAKAI, 1950).

No.	Sample No.	(m)* Height	Diameter (mm)							Sum
			<4	4–2	2–1	1–0.5	0.5–0.05	0.05–0.01	<0.01	
1	40222	17	–	–	0.02	0.01	58.89	22.54	18.54	100.00
2	40221	16	–	–	–	0.02	56.46	24.48	19.04	100.00
3	40220	15	–	–	–	0.02	46.62	29.10	24.26	100.00
4	40219	14	–	–	0.02	0.08	40.02	33.12	27.76	100.00
5	40218	13	–	–	–	0.02	55.30	23.70	20.98	100.00
6	40217	12	–	–	–	–	59.08	21.84	19.08	100.00
7	40216	11	–	0.32	0.08	0.12	41.16	31.66	26.66	100.00
8	40204	12	–	–	0.02	0.08	32.20	44.66	23.04	100.00
9	40205	11	–	0.01	0.01	0.02	45.30	30.50	24.16	100.00
10	40206	10	–	0.02	0.02	0.28	42.98	34.00	22.70	100.00
11	40161	11.5	–	–	0.22	0.32	41.64	41.16	16.66	100.00
12	40156	16.5	–	–	–	0.01	61.01	23.80	15.18	100.00
13	40154	16.5	–	–	0.02	0.17	57.50	20.47	21.84	100.00
14	40155	15.5	–	–	0.01	0.07	59.72	21.96	18.24	100.00
15	40134	18	–	–	0.03	0.18	47.34	31.58	20.86	100.00
16	40135	17	–	–	–	0.08	40.86	34.22	24.84	100.00
17	40136	16	–	–	0.02	0.04	29.60	43.36	26.98	100.00
18	40137	15	–	–	–	0.12	36.80	39.16	23.92	100.00
19	40138	14	–	–	0.02	0 .08	29.58	·37.84	32.48	100.00
20	40139	13	–	–	–	0.02	40.06	36.57	23.35	100.00
21	40140	12	–	–	–	0.07	51.74	29.66	18.53	100.00
22	40141	11	–	–	–	0.05	47.92	31.47	20.56	100.00
23	40142	10	–	–	–	0.18	39.80	37.03	23.00	100.00
24	40143	9	–	0.07	0.16	0.24	40.62	36.10	22.82	100.00
25	41159	20.5	–	–	0.26	0.20	52.75	23.90	22.89	100.00
26	40198	22	–	0.32	0.44	0.72	25.46	37.76	35.30	100.00
27	40197	21	0.15	1.22	0.79	1.12	36.39	30.89	29.44	100.00

* The height of the site where the sample was collected. (The vertical distance from the base of the outcrop exposure up to the spot where the sample was collected.)

Table 6. Granularity of the Loam, Area Northwest of Ping-men, Kalgan, Southern Cha-har (Middle Part of the First Deposits) (SAKAI, 1950).

No.	Sample No.	(m)* Height	Diameter (mm)							Sum
			>4	4–2	2–1	1–0.5	0.5–0.05	0.05–0.01	<0.01	
28	40207	9	3.34	3.84	4.34	4.74	28.74	29.66	25.34	100.00
29	40208	8	1.32	1.16	3.06	3.10	36.28	25.92	29.16	100.00
30	40162	10.5	–	0.12	0.54	1.24	39.90	29.24	28.96	100.00
31	40163	9.5	0.34	–	0.04	0.18	32.32	38.34	28.78	100.00
32	40153	14.5	–	0.39	1.98	1.92	26.92	32.67	36.12	100.00
33	40144	8	–	–	0.60	1.34	28.49	31.45	38.12	100.00
34	40145	7	–	0.16	0.04	0.06	38.83	24.25	36.67	100.00
35	40146	6	2.47	0.32	0.07	0.05	38.87	30.29	27.93	100.00
36	40160	20.5	1.03	5.18	6.09	7.02	51.94	20.58	8.16	100.00
37	40158	19	–	0.51	1.08	1.53	33.36	30.90	32.62	100.00
38	40157	18	0.95	1.47	1.92	3.23	31.66	30.68	30.10	100.00
39	40182	4	–	–	0.02	0.19	37.75	36.85	25.19	100.00

* The height of the site where the sample was collected.

Table 7. Granularity of the Loam, Area Northwest of Ping-men, Kalgan, Southern Cha-har (Lower Part of the First Deposits) (SAKAI, 1950).

No.	Sample No.	(m)* Height	Diameter (mm)							Sum
			>4	4–2	2–1	1–0.5	0.5–0.05	0.05–0.01	<0.01	
40	40209	7	1.74	2.48	3.02	3.22	39.44	22.94	27.16	100.00
41	40210	6	–	0.12	0.14	0.44	53.12	25.42	20.76	100.00
42	40211	5	–	0.38	0.56	0.50	38.02	34.08	26.46	100.00
43	40212	4	4.22	3.98	4.10	3.48	30.42	26.62	27.18	100.00
44	41213	3	–	1.37	6.40	7.96	35.77	28.58	19.92	100.00
45	40214	2	8.70	0.78	0.60	0.90	24.06	25.84	39.12	100.00
46	40215	1	0.25	1.02	0.80	1.24	46.05	24.10	26.54	100.00
47	40170	9	0.22	0.50	0.20	0.33	33.07	39.54	26.14	100.00
48	40171	8	0.98	0.30	0.70	1.14	31.86	38.18	26.84	100.00
49	40172	7.5	–	0.10	0.16	0.26	31.68	40.16	27.64	100.00
50	40173	6.5	0.16	0.44	1.70	1.96	35.46	35.58	24.70	100.00
51	40174	5.5	0.18	1.90	2.32	2.86	39.66	32.90	20.18	100.00
52	40175	4.5	0.86	0.36	0.28	0.42	37.52	34.78	25.78	100.00
53	40176	3.5	–	–	0.01	0.04	36.09	33.82	30.04	100.00
54	40177	2.5	–	0.18	0.28	0.32	30.40	38.46	30.36	100.00
55	40178	1.5	–	0.02	–	0.01	43.59	31.28	25.10	100.00
56	40164	8.5	8.58	0.26	0.12	0.16	35.62	29.60	25.66	100.00
57	40165	7.0	–	–	0.02	0.16	39.52	30.68	29.62	100.00
58	40166	5.5	–	0.08	0.01	0.20	33.99	34.38	31.34	100.00
59	40167	4.5	–	–	0.02	0.10	30.66	34.80	34.42	100.00
60	40168	3.5	–	–	0.04	0.34	38.36	32.40	28.86	100.00
61	40169	2.5	–	–	0.06	0.20	37.24	38.70	33.80	100.00
62	40147	5	2.73	0.05	0.01	0.09	37.18	34.00	25.94	100.00
63	40148	4	–	0.02	0.02	0.11	33.52	33.93	32.41	100.00
64	40149	3	–	–	0.01	0.33	39.30	31.89	28.46	100.00
65	40150	2	–	–	0.04	0.40	54.19	21.11	24.26	100.00
66	40151	1	–	–	0.05	0.13	45.17	30.78	23.33	100.00
67	40152	0	–	–	0.02	0.17	34.37	42.14	23.30	100.00
68	40180	3.5	0.99	0.49	0.75	0.95	371.7	32.35	27.30	100.00

* The height of the site where the sample was collected.

Table 8. Granularity of the Valley-Filling Huangtu Formation, the Area of Cheng-ho-ts'un, Hsuan-hua-hsien, Southern Cha-har (First Deposits) (SAKAI, 1950).

No.	Sample No.	(m)* Height	Diameter (mm)					Sum	Remarks
			2–1	1–0.5	0.5–0.05	0.05–0.005	<0.005		
69	41255	18	–	0.01	54.35	28.02	17.62	100.00	Huangtu
70	41256	17	–	0.02	48.12	22.38	19.48	100.00	”
71	41257	16	–	0.02	35.04	38.26	26.68	100.00	”
72	41262	15	0.01	0.01	37.76	38.66	23.56	100.00	”
73	41263	14	0.06	0.18	33.22	38.68	27.86	100.00	”
74	41264	13	0.24	0.20	39.18	32.78	27.60	100.00	”
75	41265	12	–	0.12	64.58	13.30	22.00	100.00	”
76	41266	11	0.02	0.04	46.00	26.58	27.36	100.00	”
77	41267	10	0.02	1.08	53.70	21.22	23.90	100.00	”
78	41268	9	0.04	0.22	54.86	20.60	24.28	100.00	”
79	41269	8	0.02	0.94	64.12	17.84	17.08	100.00	”
80	41236	15	–	0.02	37.20	33.58	29.20	100.00	” HS
81	41237	14.5	0.01	0.03	25.44	41.28	33.24	100.00	Loam HS
82	41238	13.3	–	0.01	49.35	24.84	25.80	100.00	” HS
83	41239	12.3		42		29	29	100	” HS
84	41240	11		35		38	27	100	” HS
85	41241	10		28		40	32	100	” HS
86	41242	9		31		38	31	100	” HS very rich
87	41243	8		32		41	27	100	” HS
88	41244	7		27		39	34	100	”
89	41245	6		29		42	29	100	”
90	41246	5		28		44	28	100	”
91	41247	4		28		43	29	100	”
92	41248	3		40		34	26	100	”
93	41249	2		51		31	18	100	” HS
94	41250	1		32		35	33	100	”
95	51251	0		39		27	34	100	” HS

* The height of the site where the sample was collected.

Note: nos. 69–79: north outcrop; nos. 80–95: south outcrop; HS Huangtu spherulite.

Table 9. Granularity of the Valley-Filling Huangtu Formation, Northwestern Area of Fan-shan-pu, Huai-lai-hsien, Southern Cha-har (Eastern Outcrops, First Deposits) (SAKAI, 1950).

No.	Sample No.	(m)* Height	Diameter (mm)						Sum	Remarks
			4–2	2–1	1–0.5	0.5–0.05	0.05–0.01	<0.01		
96	4036	22	–	0.02	0.13	40.96	34.02	24.87	100.00	Light-yellow-brown
97	4035	21	–	0.21	0.51	37.30	37.67	24.31	100.00	”
98	4034	20	–	0.03	0.19	59.30	24.18	16.30	100.00	”
99	4033	19	–	–	0.22	57.65	26.12	16.01	100.00	”
100	4032	18	–	0.03	0.16	41.24	36.91	21.66	100.00	”
101	4031	17	–	–	0.20	40.22	37.54	22.04	100.00	”
102	4030	16	–	0.01	0.12	44.50	35.53	19.84	100.00	”
103	4029	15	–	0.30	1.61	40.88	35.07	22.14	100.00	”
104	4028	14	–	0.01	0.07	53.81	26.24	19.87	100.00	”
105	4027	13	–	0.01	0.49	51.11	29.88	18.51	100.00	”
106	4026	12	–	0.02	0.16	44.14	36.85	18.83	100.00	”
107	4025	11	–	0.17	1.42	61.38	24.00	13.03	100.00	”
108	4024	10	0.17	0.40	1.48	48.60	26.81	22.54	100.00	Light-brown
109	4023	9	–	–	0.04	49.93	28.36	21.67	100.00	”
110	4022	8	–	0.17	0.75	64.41	16.12	18.55	100.00	”
111	4021	7	0.14	0.43	1.35	68.09	15.05	14.94	100.00	”
112	4020	6	0.38	3.37	2.10	62.32	23.94	7.89	100.00	”
113	4019	5	–	0.35	1.44	70.52	25.19	2.50	100.00	Light-yellow-brown

Table 10. Granularity of the Huangtu in the Terrace Deposit, Area of Yung-ting-chiao, Hu-lai-hsien, Southern Cha-har (First Deposits) (SAKAI, 1950).

No.	Sample No.	(m)* Height	Diameter (mm)				Sum	Remarks
			4–2	2–0.05	0.05–0.005	<0.005		
114	4120	15	(0.13)	82.60	10.97	6.43	100.00	Vertical columnar joint
115	4121	14	–	96.83	1.77	1.40	100.00	”
116	4122	13	(0.33)	86.90	8.44	4.66	100.00	”
117	4123	12	–	94.59	3.91	1.50	100.00	”
118	4124	11	–	93.57	4.51	1.92	100.00	”
119	4125	10	–	98.55	0.85	0.60	100.00	”
120	4126	9	–	93.70	4.23	2.07	100.00	”
121	4127	8	–	98.49	0.64	0.87	100.00	
122	4128	7	–	97.80	1.33	0.87	100.00	
123	4129	6	–	97.32	1.16	1.52	100.00	
124	4130	5	(0.01)	97.47	1.67	0.86	100.00	
125	4131	4	–	96.79	2.24	0.97	100.00	
126	4132	3	–	94.90	3.65	1.45	100.00	Vertical platy joint
127	4133	2	(0.56)	91.86	4.64	3.50	100.00	”

* The height of the site where the sample was collected.

Table 11. Granularity of the Huangtu Formation, along the Shih-Tai Railway (First Deposit) (SAKAI, 1950).

No.	Sample No.	(m)* Height	Diameter (mm)								Sum	Locality
			>4	4–2	2–1	1–0.5	0.5–0.05	0.05–0.01	0.01–0.005	<0.005		
128	4065	25.5	–	0.06	0.02	0.40	31.80	45.82	21.90		100.00	
129	4064	23	–	–	0.05	0.54	31.73	40.60	27.08		100.00	North of Chin-chuan station, Shanshi.
130	4063	22	–	–	0.34	0.90	20.54	42.08	36.16		100.00	
131	4067	9	–	–	–	0.02	41.18	31.62	12.38	14.30	100.00	Chuang-tsun, near Tse-shih station,
132	4066	4	–	0.96	3.08	8.24	46.74	13.07	8.98	18.93	100.00	Shan-hsi.
133	4078	8.5	–	–	0.02	0.04	23.14	49.86	3.48	23.46	100.00	About 1 km E of P.C.I.W., Yang-
134	4077	6	0.14	0.38	1.66	3.56	30.36	32.94	4.62	26.34	100.00	chuan, Shan-hsi.
135	40104	19	–	0.11	0.11	0.14	18.52	44.60	7.68	28.84	100.00	
136	40103	15	0.76	–	0.08	0.18	16.76	47.82	7.92	26.48	100.00	About 500 m SW of
137	40102	14	0.60	0.24	0.19	0.36	34.20	40.90	4.56	18.95	100.00	Wei-shui station,
138	40101	10	–	0.05	0.14	0.44	22.59	37.77	0,81	38.20	100.00	Ho-pei.
139	4099	5	–	–	0.24	2.11	26.95	27.14	43.56		100.00	
140	4095	10	–	–	0.28	1.84	19.53	49.90	28.45		100.00	
141	4094	8.5	–	–	0.04	0.43	20.23	55.02	24.28		100.00	About 200 m E of Shan-an station,
142	4093	7	–	0.02	0.14	0.13	29.85	45.58	24.28		100.00	Ho-pei.
143	4092	5	–	–	0.14	0.19	36.41	31.63	31.63		100.00	

* The height of the site where the sample was collected.

Table 12. Granularity of the Valley-Filling Huangtu Formation and the Hillside Huangtu Formation, Chang-hsia and Chieh-shou Areas Along the Chin-Pu Railway (Tomita and Sakai, 1942).

No.	Sample No.	Height (m)*	Diameter (mm) >4	4–2	2–1	1–0.5	0.5–0.05	0.05–0.005	<0.005	Sum	Remarks
144	40288	1	–	–	0.08	0.10	32.14	50.40	17.28	100.00	I
145	40278	1	–	–	0.02	0.08	11.82	43.88	44.20	100.00	II
146	40281	0.5	–	–	0.02	0.08	15.72	46.40	37.78	100.00	”
147	40294	8.5	–	–	0.22	0.26	32.48	43.54	23.50	100.00	IIIa
148	40293	7.5	–	0.38	0.68	1.28	34.96	41.68	21.02	100.00	”
149	40292	6.5	–	0.26	0.28	0.78	27.46	45.78	25.44	100.00	”
150	40291	5	–	–	0.01	0.07	20.98	51.24	27.70	100.00	”
151	40290	4	–	–	0.06	0.10	22.54	51.20	26.10	100.00	”
152	40289	2.5	–	–	0.06	0.12	24.48	50.36	24.98	100.00	”
153	40279	2	–	–	0.04	0.06	24.18	50.58	25.14	100.00	”
154	40282	1	–	–	0.10	0.14	24.50	54.02	21.24	100.00	”
155	40284	1	–	–	0.12	0.26	26.38	45.62	27.62	100.00	”
156	40299	7.5	–	–	0.09	0.19	24.56	50.04	25.12	100.00	”
157	40300	5.5	–	0.06	0.22	0.28	28.32	44.80	26.32	100.00	”
158	40295	12.5	–	0.08	0.50	1.32	45.48	41.18	11.44	100.00	”IIIb
159	40296	11.5	0.10	0.38	1.40	4.40	43.64	39.58	10.79	100.00	”
160	40297	10	–	–	0.10	0.20	37.34	49.00	13.36	100.00	”
161	40298	9	–	0.10	0.10	0.18	35.64	48.96	15.02	100.00	”
162	40287	12	2.72	1.08	1.30	1.22	30.06	45.92	17.70	100.00	IV
163	40237	2.5	0.18	0.56	2.48	7.44	44.34	36.68	8.32	100.00	Hillside deposit
164	40265	3.5	0.78	2.16	3.40	2.28	25.02	49.38	16.98	100.00	Valley-filling deposit
165	40264	2.5	2.46	4.40	5.46	6.02	32.40	37.04	12.22	100.00	”
166	40263	1	4.38	7.98	8.80	14.10	54.36	7.34	3.04	100.00	”
167	40262	0	–	1.32	3.62	3.68	35.16	38.64	17.58	100.00	”

* The height of the site where the sample was collected.

Note: Nos. 144–162 (Valley-filling deposit): Chang-hsia; No. 163: Hsia-lung-hua, 2.5 km N 70[W of Chang-hsia station; Nos. 164–167: Tai-tien, 3 km NNW of Chieh-shou station.

Table 13. Granularity of the Aeolian Huangtu Formation, Tai-ping-pu and Ch'eng-ho-tsun, Southern Cha-har (SAKAI, 1950).

<table>
<tr><th rowspan="2">No.</th><th rowspan="2">Sample No.</th><th rowspan="2">(m)* Height</th><th colspan="6">Diameter (mm)</th><th rowspan="2">Sum</th><th rowspan="2">Locality</th></tr>
<tr><th>4–2</th><th>2–1</th><th>1–0.5</th><th>0.5–0.05</th><th>0.05–0.005</th><th><0.005</th></tr>
<tr><td>168</td><td>41244</td><td>1</td><td>0.23</td><td>0.18</td><td colspan="2">17.99</td><td>59.02</td><td>22.58</td><td>100.00</td><td>NW ridge of Mt. Ta-tung-shan, Cheng-ho village, South Cha-har.</td></tr>
<tr><td>169</td><td>41235</td><td>1</td><td>1.32</td><td>2.96</td><td>4.70</td><td>37.90</td><td>33.94</td><td>19.18</td><td>100.00</td><td>NW foot of Mt. Ta-tung-shan, Cheng-ho village, South Cha-har.</td></tr>
<tr><td>170</td><td>4014</td><td>10</td><td>–</td><td>–</td><td>–</td><td>32.06</td><td>56.55</td><td>11.39</td><td>100.00</td><td rowspan="2">Coal field, SSW of Tai-ping-pu, Huai-lai Prefecture, South Cha-har.</td></tr>
<tr><td>171</td><td>4013</td><td>3</td><td>0.26</td><td>0.18</td><td colspan="2">22.22</td><td>58.84</td><td>18.50</td><td>100.00</td></tr>
</table>

* The height of the site where the sample was collected.

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General Review of the Coal Fields in Central and South China

Misaburo SHIMAKURA

Preface

Central and South China include the environs and southern districts of the Yang-tze-chiang (Yangtze River), six prefectures of Central China, three prefectures of South China, and four prefectures of West China. Most of the coal fields in the northern part of Chiang-su Province and An-hui Province, as well as those in the western provinces, are excluded from this paper because they are geologically considered to belong to the coal fields of North China. Most of the four prefectures in West China are not dealt with either, as they are outside the designated survey area.

Coal resources in Central and South China are extremely inferior to those in Manchuria and in North China. Only a few coal fields in the northern part of An-hui Province and in some parts of Chiang-hsi Province and Hu-nan Province are worth discussing, as our survey during 1938–1945 was limited to checking the previous investigations in known coal fields. The results of the survey were not clarified by the discovery of new coal fields, and very little new information on stratigraphy was gathered, as it had already been well studied. The mining companies which had prospected and developed the coal fields are as follows:

The Central China Mining Company carried out a precise survey of the coal fields, as well as of other mineral resources, in the Yang-tze-chiang area.

The Huai-nan Coal Mining Company carried out precise geological surveys and the seismic prospecting of the Huai-nan coal field and vicinity.

The Oriental Colonization Company conducted prospecting by boring in the Hsi-shan-tao coal field.

The newly discovered coal field in the northwestern extension of the Huai-nan coal field, which was reported by C. Y. HSIEH,[1] was not included in our area of survey because of wartime conditions.

The present report only outlines my investigation, because most of the survey and research data were lost in the surveyed area in 1945, and neither the report nor

[1] HSIEH, C. Y., 1949. Pai-kung-shan coal field—A new discovery in the Huai-nan Basin, North An-hui, Central China. *Econ. Geol.*, v. 44, no. 2, pp. 128–142.

a copy of it had been sent to Japan. Therefore, I have been obliged to complete this paper from memory.

1. Geographical Distribution of the Coal Fields

Many small coal fields are distributed in Central and South China, but there are only a few important ones. Throughout all the provinces the coal fields are arranged in several zones of an almost E-W trend.

The largest coal field in Central China—the Huai-nan coal field—is located in the drainage area of the Huai-ho River, the north-central region of An-hui Province. Many small coal mines are distributed in the Nan-ching mountainland (Ning-chen mountain range) in Chiang-nan,[2] and in the western region is the Han-chao coal field, An-hui Province. Along the coast of the Yang-tze-chiang from An-ching to Nan-kou there are several small coal fields: Tao-chung, Su-sung, Tai-hu, Su-chun, Yang-hsin, Ta-yeh, Hsieng-ning, Pu-chi, Chia-yu, and Pao-nan. One of these, the Ta-yeh coal field at Shih-hui-yao, is relatively large. In Chiang-su Province there are coal localities at Hsi-shan-tao on Lake Tai-hu, at Hu-chou on its southern shore, and at I-hsing on the west; of these, the Chang-hsing coal field in the northern region of Che-chiang Province is most famous. In the region between Chang-hua and Chi-chi there are some localities of characteristic calcareous anthracite and in its western region—the southwestern region of An-hui Province—there is the relatively wide I-ching coal field.

In the east corner of Chiang-hsi Province, there are some small coal fields in the districts of Yu-shan and Kuang-feng, and along the Hsiu-shui River; the coal fields of Chin-hsien, Lin-chuan, Yu-yu, Le-ping, Feng-cheng, etc are distributed in the area southeast of Nan-chang. The An-yuan and the Ping-hsiang coal fields in the western region of the province are as famous as the Ta-yeh iron mine for production of caking coal. The zone of this coal field reaches the coal fields of Li-ling and Shi-men-kou in Hu-nan Province.

In Hu-nan Province there are many small coal fields: Shih-men-kou, Lai-ho, Chi-chang, Hsia-liu-chung, Hsiang-tan in the vicinity of the Hsiang-shui River, and Tzu-men-chiao, Hung-shan-tien, Hu-ping, Feng-kuan-shan, and Ching-chi-chung in the district of Hsiang-ning. There are also some coal localities in the districts of Hsin-hua, An-hua, and Shao-yang along the drainage area of the Tzu-chi-ang River. In the southern part of the province lie the coal fields of Yang-mei-shan and Kou-ya-tung in the Wan-yang-shan range, which grade into the Ju-yuan coal field in Kuang-tung Province.

In Fu-chien Province, there are only a few small coal fields—some anthracite localities near Lung-yen. In Kuang-tung Province are the Ju-yuan coal field mentioned above and some coal fields in the east and west. In Kuang-hsi Province there are some small coal fields in the districts of Chuan-hsien in the north and Kuei-

[2] The term Yang-tze-chiang, or "Chang Chiang," refers to the course of the Yangtze-River below Chen-kiang (Chen-chiang), and the term Chiang-nan denotes the southern coastal region.

hsien in the south, as well as along the course of the Liu-chiang River. Some areas of lignite are found in the districts of Ho-hsien in the east and Nan-ning and Ping-ma in the southwest. In Kuei-chou Province there are several coal fields in the districts of Kuei-yang and Ta-ting; in Ssu-chuan Province some thin coal beds are distributed throughout the Pa-shu basin, and some of them along the course of such rivers as Yang-tze-chiang, Chi-chiang, and Wu-chiang have been worked on a small scale.

2. Geological Distribution of the Coal Beds

The stratigraphically oldest coal in Central and South China is the so-called "stony coal" in the graptolite-bearing Ordovician shale in the northwestern part of Che-chiang Province. It is used as fuel by the inhabitants and contains 70–80 per cent ash. Microscopic examination shows that fine-grained carbonaceous material is finely dispersed in the inorganic material; it can be said to belong to the *brand schiefer*, but, as the carbonaceous matter probably originated from algae by a huminous phenomenon, it is considered sapropelic coal.

Proper coal is found in the Carboniferous systems. Lower Carboniferous coal measures are found in the Tseshui system in central Hu-nan Province, in the Chin-hsien system in Fu-chien Province to the southwestern part of Chiang-hsi Province, in the Linwu system in the eastern region of Kuang-tung Province, in the Ssumen system in the western part of Kuang-hsi Province, in the Hsiwan system in the district of Ho-hsien, and in the Eulkai system in central-eastern Yun-nan Province. It is not clear whether there are any coal measures in the middle Carboniferous system in Yun-nan Province.

The most important coal measures in Central and South China are found in the Permian system: the Middle and Upper Permian Huai-nan coal measure and the Lung-tan coal measure of the Nan-ching mountainland and of the border regions of Chiang-su Province and An-hui Province, the Li-hsien coal measure in the northwestern part of Che-chiang Province, the I-ching coal measure in the southern part of An-hui Province, the Chin-hsien coal measure in the central part of Chiang-hsi Province, the Feng-tien coal measure in the western part of the same province, the Lao-hu-shan coal measure and the Wangchiopo system in the northwestern part of Chiang-hsi Province and in the western part of An-hui Province, the Tou-ling coal measure in the central part of Hu-nan Province, the Tan-shan-wan coal measure and the Chushan system in Hu-pei Province, the Huang-kang-ling coal measure in the northern part of the Deoling system in the eastern part of Nan-ling, Kuang-tung Province, the I-chia-ping coal measure in the southern part of Kuei-chou Province, etc. Most of them are characterized by the presence of *Gigantopteris nicotianaefolia—Leptodus* flora and belong to the Upper Permian.

The above-mentioned coal measures in the central regions of Central China are often grouped under the name of the Le-ping system. The Yuan-chia-chung coal measure in Hu-nan Province has been assigned to Middle Permian, but this has not yet been checked by the author.

The Hsiang-chi coal measure, distributed widely in the Pa-tung region of Hu-pei Province and in the Pa-shu basin of Ssu-chuan Province, has been identified as Triassic (Rhaeto-Liassic), but the other Mesozoic coal measures, relatively widely distributed, belong to the Jurassic system. One of these, the Hsiang-shan formation in the Nan-ching mountainland, is intercalated with some nonworkable coal beds. On the other hand, the Shih-men-kou system (Ping-hsiang coal measure) in the western part of Chiang-hsi Province and in the eastern part of Hu-nan Province is intercalated with rich coal beds. In addition, the Tsungjen system is distributed in the southeastern part of Chiang-hsi Province and in the northern part of Fu-chien Province, the Chin-chu-wo coal measure in Kuang-tung Province, the Kenkou system in the eastern part of Nan-ling, the Yang-mei-shan coal measure from the southern part of Hu-nan Province to the northern part of Kuang-tung Province, and some Jurassic coal measures in the course of the Han-shui River in Hu-pei Province.

The Paishan system in the southern part of Fu-chien Province is intercalated with some thin coal beds and may be cited as an example of Cretaceous coal measures; the others are not yet clear.

In the provinces of Kuang-tung and Kuang-hsi, there are some Tertiary lignite-bearing formations called the Yung-ning system, which contains fresh-water shells and plants and has been identified as Pliocene. Almost the same formations are reported to be distributed in Ning-erh and other places in Yun-nan Province.

Near Hai-cheng, Fu-chien Province, there are some peat areas, and the peat is considered Quaternary. Some layers of peat have formed on the bottom of Lake Hsi-hu near the city of Hang-chou, Che-chiang Province. They are only a few centimeters thick and are of no economic value, but are interesting in regard to the genesis of peat.[3)]

3. Coal Measures

In another paper, "The Paleozoic Era in Central and South China," the author discusses the stratigraphic succession and the correlation of the coal measures. Here, the author will briefly describe the characteristics of the coal measures. The Paleozoic coal measures are generally thin and composed of sandstone, shale, sandy shale, calcareous material, and occasionally black or bituminous limestone. The lower and upper formations consist of thick limestone. This may indicate that the coal measures were paralic sediments in the coastal region during the repeated transgressions and regressions, but sometimes some marine coal measures are found

[3)] SHIMAKURA, M. and KASUYA, T. (1943). The sediments on the bottom of Lake Hsi-hu near Hang-chou. *Science* (Kagaku), v. 13, no. 5, pp. 168–169 (J).

intercalated with limestone. For example, the Lung-tan coal measure[4] exists between the Chi-hsia and the Ching-lung limestone and is generally 30–50 m thick and occasionally 100 m thick where workable coal seams are contained. The Tan-shan-wan coal measure is between the Yang-hsin and the Ta-yeh limestone and is about 80 m thick. The Tse-shui coal measure lies between the Shih-teng-tzu and the Tzu-men-chiao limestone and is 30–100 m thick.

The Lower Mesozoic coal measures lie on thick Triassic basement rocks and are of various thicknesses; the Hsiang-chi coal measure is 450 m, the Ifeng coal measure 300 m, and the Tsungjen coal measure 1,000 m thick. These facts may indicate that Central and South China have been land since the Rhaetic stage and that the coal measures were formed in the lake basins under remarkable orogenic movements (the Yen-shan orogenic movement).

Judging from their topographic characteristics, the fossils contained, and the existence of oogonium of *Chara*, geologists consider the Tertiary coal measures small-scale limnic sediments.

4. Types of Coal Fields

The Paleozoic coal fields in China are generally classified into the Central and South China type and the North China type. The latter has many thick coal seams which often form large coal fields and which are intercalated with aluminous shale, while the former has thinner and fewer coal seams and the mode of occurrence of the cyclothem is different. The coal fields of the Central and South China type are widely distributed along the course and the more southern regions of the Yangtze River. The coal fields in the central and northern parts of An-hui Province, for example the Huai-nan coal field, are extensive and have relatively thick coal beds and more aluminous shale, which is characteristic of the coal fields of the North China type.

There is a stratigraphic difference between the coal measures of these two types. The Lower Carboniferous coal measure, for example the Tse-shui coal measure in Central and South China, is not found in North China, and the Lower to Middle Permian coal measures, such as the Po-shan—Tsu-chuan series and Tai-yuan—Shan-hsi series in North China, are very small or completely absent in Central and South China. The main coal measures in Central and South China are characterized by the Upper Permian flora, *Gigantopteris nicotianaefolia—Leptodus*, but in the Huai-nan coal field this flora is confined to the uppermost coal measure, whereas in the lower coal measure an older flora, *Caulopteris—Callipteridium*, is found.

The same relation is observed in the Liu-chuan coal field in the northern part of Chiang-su Province and in the Chung-hsing coal field in the southern part of Shan-tung Province. The well-developed coal measures of the Po-shan and the Tai-yuan series in the regions north of the Huang-ho River thin out toward Central China,

[4] The Ku-feng formation, 20 m thick, is included.

and the upper coal measures in the Shih-ho-tzu series are worth working.[5] The Huai-nan and Liu-chuan type of coal fields, therefore, is considered a transitional type between the North China type and the Central and South China type.

Among the Mesozoic coal fields, the Hsiang-chi coal measure can be tentatively correlated with the Men-tou-kou coal measure as well as with the coal measure in the Ta-tung series of North China, but this is not a positive correlation because of lack of satisfactory data. The other coal measures, the Hsiang-shan system, the Shih-men-kou system, the Yang-mei-shan system, etc., cannot be correlated with the Mesozoic coal measures of North China and Manchuria at present because of the lack of data.

5. Coal Beds and Coal Quality

Although the coal beds are generally thin and few in number, except in the region of Huai-nan, they often expand and these expanded parts are workable.

There are three or four coal seams in the Tse-shui coal measure and they are 0.3–1.4 m, rarely 3 m, thick. There are from one to seven coal beds in the Lung-tan coal measure which are generally 0.2–one m thick, rarely 2–3 m in the expanded parts. In the Huai-nan coal field there are more than twenty coal seams, of which fourteen or fifteen are workable; the largest seam is about 8 m thick. In the Ping-hsiang coal field there are five or six coal seams and the largest seam is about 2 m thick.

Most coal fields underwent such remarkable orogenic movement after they were deposited that the strata dip steeply, and are sometimes perpendicular or recumbent. They are also cut by several faults. The coal of Central and South China, except that in the Huai-nan and Ping-hsiang coal fields, is generally rich in ash and sulphur and powders easily. Only the shallow parts of the smaller coal fields are worked by native methods and the coal produced is of low quality, containing much weathered coal and soil. The anthracite produced in the districts along the Yangtze River is brittle and full of ash, but that near Lung-yen, Fu-chien Province, and near Kuei-yang, Kuei-chou Province, is of good quality.

Permian and Jurassic coal is generally high-grade bituminous coal or semi-bituminous coal, and sometimes low-grade bituminous coal. The coal of the Ping-hsiang and the Huai-nan coal fields is of the best quality: ash, 15–20 per cent; volatile matter, 30–40 per cent; fixed carbon, 50–60 per cent; calorific value, 6,000–7,000 cal.; and generally non-caking. No strongly caking coal, such as that of the Kai-luan and the Chung-hsing coal fields of North China, has been found.

Liptobiolith, the so-called lopinite, which contains a large amount of tar and is favorable for dry distillation, is found near Le-ping, Chiang-hsi Province. Near the boundary of Chiang-hsi and Che-chiang Provinces, there is a small amount of limy coal of small economic value; nearly all the inorganic matter of this coal is lime

[5] Onuki, Y. (1951). Upper Paleozoic formations of coal fields in North China. *Geology and Mineral Resources of the Far East*, v. 1.

and powders easily, or is scoriaceous and foams in a dilute acidic solution. The limestone of Hsi-shan-tao, Chiang-su Province is intercalated with some coal seams 10–20 cm thick, which microscopically show a fibrous texture and carbonaceous matter mixed with limestone distinctly showing the algal origin.

The lignite in the provinces of Kuang-hsi and Yun-nan is yellowish-brown or brown and earthy, resembling the *Braunkohle* of Germany. Also, some blackish-brown woody coal, similar to the Japanese coaly lignite, has been found.

6. Reserves

The author's revised calculation of reserves cannot be cited here because all the data and survey results were lost during the war. According to one published report,[6] the reserves in Central and South China are as follows:

Province	Reserves (unit, million tons)
Chiang-su	217
Che-chiang	100
An-hui	360
Chiang-hsi	992
Hu-pei	440
Hu-nan	1,764
Ssu-chuan	9,784
Kuei-chou	1,549
Fu-chien	396
Kuang-tung	421
Kuang-hsi	300
Yun-nan	1,627

[6] Hou, T. F., 1935. *General Statement on Mining Industries of China*, 5th ed. Peking, China (C).

Fluorite Deposits in the Vicinity of Hsiang-Shan Che-Kiang Province

Zennojō IGARASHI

1. Wu-shih-shan Fluorite Deposit

Locality and transportation

Wu-shih-shan is a mountain in Hsiang-shan Prefecture, which is in the eastern part of Che-kiang Province. Wu-shih-shan is about 1,500 m south of Mao-yang, about 9 km SSW of the capital of the prefecture. The fluorite deposit is found on the northern slope of Wu-shih-shan. Mao-yang is almost at the center of the Hsiang-shan Peninsula, about 5 km west of the coast of the East China Sea and about 4 km east of Tai-tou, the landing place in Tai-tou Bay. Because Tai-tou Bay is shallow, direct shipping is impossible. The ore is loaded on 70-ton barges at Tai-tou and shipped to Shih-pu[1] at the southern edge of the Hsiang-shan Peninsula, a distance of 27 km, where 3,000 ton freighters put in (Fig. 1).

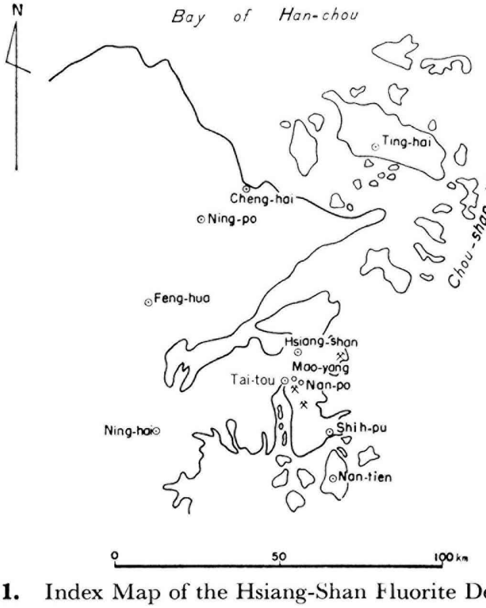

Fig. 1. Index Map of the Hsiang-Shan Fluorite Deposits.

Editor's Note: This area lies between 29[–30] N Lat., and 121[–122] E Long. Place names were not checked against usage recommended by U.S. Board on Geographic names.

[1] Shih-pu is a small port about 350 km south of Shanghai.

History

In 1931, the fluorite deposit was worked by the Kitada Co., a Japanese company, and about 150 tons of ore were shipped to Shanghai. However, because of its low quality, operations were ceased in 1932 after a five-month period. In its place the higher quality I-wu fluorite were worked. In June 1934 the operations were resumed and about 250 tons of ore were transported to Shanghai before the mining was again abandoned because of financial losses. In 1936, transportation from I-wu became almost impossible because of a long drought and the fluorite stock became low in Shanghai. As a result, working of the Wu-shih-shan deposit was resumed. About 100 tons a month from October 1936 to March 1937, and 300 tons a month for June and July 1937, were transported to Shanghai. However, because the sino-Japanese War spread to Shanghai the work was discontinued again. The total yield up to that time was 2,350 tons. Immediately after the Japanese army occupied the Hsiang-shan Peninsula in June, 1941, the Central China Mining Co. was ordered to begin operations, and in December of the same year about 2,500 tons of ore were shipped to Kawasaki, Japan. In 1942–1943, the ore was transported regularly every month by up to three ships, but transportation difficulties arose in 1944, and the ore was stockpiled at the mine, at Tai-tou, and at Shih-pu port. At the end of World War II, the stockpile and equipment were left behind and nothing is known of what became of them.

Topography and geology

Wu-shih-shan is a steep (20–30° slope) mountain of mature stage, rising to about

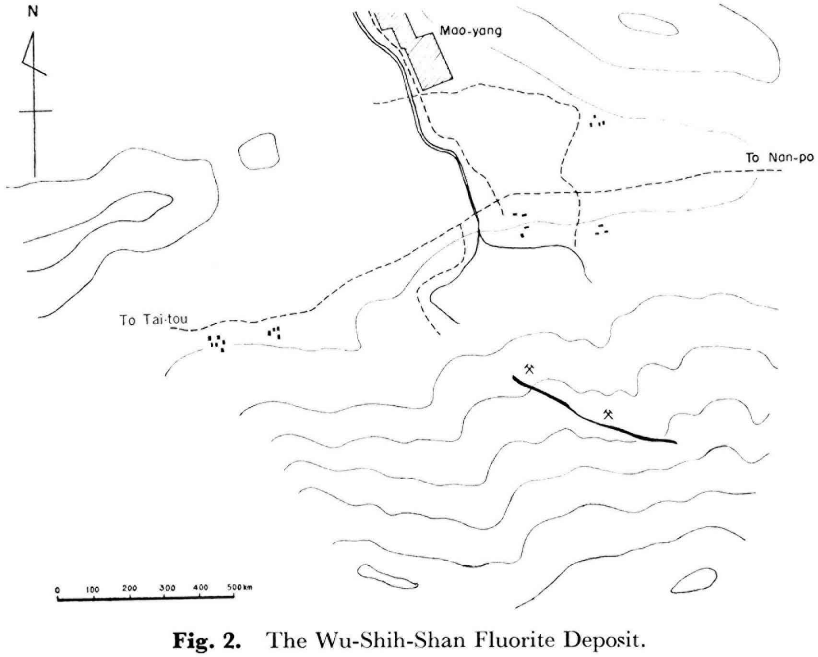

Fig. 2. The Wu-Shih-Shan Fluorite Deposit.

600 m above sea level and trending east-west. The ore-bearing vein is on the northern slope and crops out at a height of 80–180 m above the plain.

Wu-shih-shan and vicinity are composed of tuff intercalated by some rhyolite. The rhyolite is considered to be an effusive rock of Cretaceous age.

Ore deposits

The fluorite-bearing veins are fissure-filling, contain gangue of the country rock, and are cut by quartz veins. The vein strikes N 50° W to E-W, but generally N 70–80° S, towards the ridge. The length of the vein is estimated to be about 2,500 m, but the part worth working is in the middle and about 540 m long. There are also some thin parts which branch into east and west veins. The east vein is longer and narrower, higher in quality but smaller in reserves than the west vein. Both veins are described in the following table:

	West Vein	East Vein
Length	150 m	200 m
Width	1–12 m	0.5–6 m
Quality	Brittle and soft, contains clayey gangue of the country rock. CaF_2 60–70%	Compact and hard, of good quality. CaF_2 80–85%

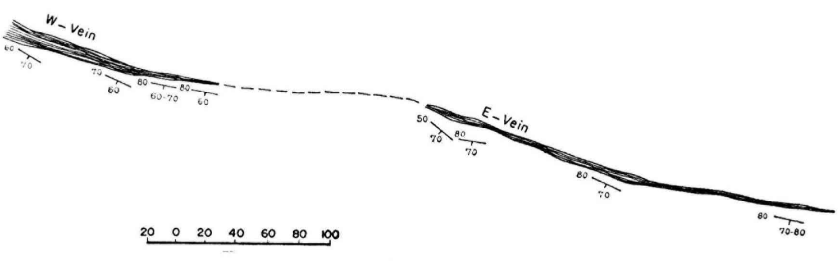

Fig. 3. The Wu-Shih-Shan Fluorite Deposit.

Ore reserves

When the Central China Mining Co. was operating, the calculated ore reserves were 172,400 tons, as shown in the following table. About 150,000 tons of the ore were transported by the end of World War II. At that time, the remaining reserves, estimated at 20,000 tons as proven and 100,000 tons as possible amounts may have existed.

Mining

Because the east and west veins differ, the same method of mining could not be

Ore Reserves			Calculation: Length × Depth × Width × Sp. Gr.
Proven reserves	Reserves	253,750 t	West vein 150 × 50 × 6.5 × 3.0 = 146,250 t East vein 200 × 50 × 3.25 × 3.0 = 107,500 t
	Extractable	215,500 t	Extraction ratio, 85%
	Sortable	172,400 t	Efficiency of hand-sorting, 80%
Possible reserves		100,000 t	

used for both. In general, the shrinkage method was used in the east vein, but in places narrower than 1.5 m the ascending step method was used. At first, horizontal plugging was adopted for the west vein, but because of the low quality of the plugging mud and sand and insufficient support, the Mitchel method, square-set stopping methods were adopted. Supports were not easily attainable. The five or six rock drills were worked by a 100 HP air-compressor and two or three were worked by a 50 HP compressor. Some hand work was adopted.

Crude ore was carried from the west and east veins to the sorting plants at the foot of the mountain and separated into lump ore of high grade, common grade, powdered ore, and waste. The rope pulley system and railway were operated between the mine and the sorting plants. The same railway and sorting plant were not used for the east and west veins; the transportation systems varied according to the particular area, as follows:

Mao-yang to Tai-tou: in 1941 and the first half of 1942 ore was transported by ox-cart, in the latter half of 1942 by ox-drawn railway and from 1943 to 1945 by gasoline-driven locomotives.

Tai-tou to Shih-pu port: two 70-ton barges were used.

Shipping from Shih-pu port: the ore was loaded from the barges to freighters two or three times a month. In the port, the rise and fall of the tide was considerable and ocean steamers could not easily be brought alongside the piers.

Estimate of future possibilities

As mentioned, the extractable amount of fixed ore reserves by hand-sorting was calculated to be about 170,000 tons; about 150,000 tons of sorted ore were shipped up to the end of the war, and the remaining reserves are considered to have been only 20,000 tons. It may be expected that some ore exists in the extreme and deeper parts of the worked veins (east and west) but the deposit is apparently considered to have been in a waning stage. As mentioned, the stocks at the mine, Tai-tou and Shih-pu amounted to 50,000 tons and were ready for shipment.

Table 1. Mine Equipment.

1. Diesel generator	150 KVA	1
2. Air Compressor	100 HP	1
,, ,,	50 HP	1
3. Rock drills	15 (7 operated daily)	
4. Workshop equipment	lathe	1
,, ,,	drilling machine	1
5. Hand-sorting plant	2	2
6. Rope pulley system and railway	180 & 240 m	

Table 2. Transportation Equipment.

Mao-yang to Tai-tou	about 4 km of railway 2 gasoline-driven locomotives
Tai-tou Port	2 piers
Shih-pu Port	2 floating piers 10 barges 3 tugboats

Table 3. Personnel (Approximate number).

	Staff	Laborers
1941	30	300
1942	50	600
1943	60	700
1944	60	700
1945	55	500

Table 4. Yield; the Total of All the Grades and the Average Quality.

1941	5,200 tons	CaF_2	85%
1942	40,000 ,,	,,	88%
1943	56,000 ,,	,,	88%
1944	40,000 ,,	,,	87%
1945	10,000 ,,	,,	85%
Total	151,200 tons		

2. Po-hou-shan Fluorite Deposit

Locality and transportation

The deposit is directly southwest of Nan-pu or 3.5 km from Mao-yang and is on the eastern slope of Mt. Po-hou-shan, which is in the southern Tung-chi-ling mountain range. Between this deposit and the Wu-shih-shan deposit is a ridge of the Tung-chi-ling mountain range. The deposit is surrounded on three sides by mountains and transportation is possible only on the side facing Tung-chi-pu, a port on Tai-tou Bay south of Tai-tou. Tung-chi-pu is about 10 km SW from the mine and transportation is inconvenient.

History

The deposit was worked in 1936–1937; work was said to have been done by a foreign miner about 20 years earlier.

Geology and ore deposit

The deposit is small. The vicinity of the ore deposit is composed of rhyolite that

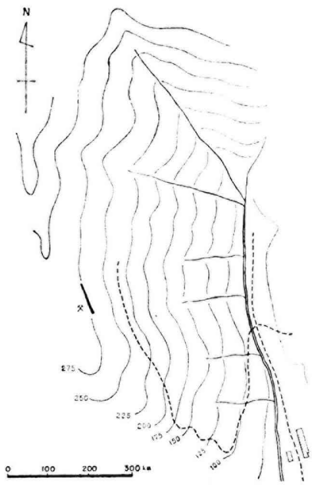

Fig. 4. The Po-Hou-Shan Fluorite Deposit.

is cut by fissure-filling ore veins. The main vein is a vertical one about 100 m long with varying width. There are some lenticular ore bodies. One lenticular ore body is 3–5 m long and locally 2.6 m thick. The average thickness is only 0.6 m. The main vein trends N 20° W but a small branch 5–50 cm thick trends N 60° W, dipping 70° N.

Ore reserves

The ore in the main vein above the level of the valley and the reserve in the deposit below the level may be 9,000 tons. The calculation is:

Length (m)		Depth (m)		Average thickness (m)		Sp. gr.
100	×	50	×	0.60	×	3.0=9,000 (t)

Economic value

Because of the smallness of the deposit and inconvenience of transportation, the deposit was considered to have little economic value unless the market were to improve suddenly. Below the level of the valley, considerable drainage work seemed to be necessary.

3. Fluorite deposit in the eastern coastal region, Hsiang-shan Peninsula

Locality

Several veins are found traversing a promontory (60 m above sea level and 100 m wide across the middle part) which projects eastward from the coast southeast of the town of Hsiang-shan. The veins generally crop out on the southern cliff and a few on the face of the northern cliff.

Geology and ore deposits

The promontory is composed of rhyolite and is cut by fissure-filling ore veins, which, in the southern part of the promontory, were found to be more than 20 cm wide. They trend N 20° W and dip 70–80° S. In the northern part of the promontory were found one or two veins. The cliff rises directly from the sea and storm waves made the survey difficult.

Economic value

As the ore reserves are small, the deposits were considered to be nearly valueless unless the market price was high.

PLACE NAMES

KOREA

A

Amnok-kang 鴨緑江
Ampen (Anbyŏn) 安辺
An'ak 安岳
Anbyŏn (Ampen) 安辺
Andong 安東
Andugal 安図割
Anju 安州
Ap-san 鴨山

B

Bansong 盤松
Bantatsuzan (Mandal-san) 晩達山
Bonkokuri (P'omgong-ni) 凡谷里
Bukkokuji (Pulguk-sa, Pulgoksa) 仏国寺

C

Chaedŏk 載徳
Chaedŏk-san 在徳山
Chajungmul-li 左中文里
Chak-pong (K'ach'i-bong) 鵲峯
Chamiweon 紫味院
Changbaeng-myŏn 長白面
Changdŏk 長徳
Ch'angdo-myŏn 昌道面
Changgi (Chōki) 長鬐
Changgun-bong 将軍峰
Ch'ang-ni 倉里
Changp'ung-ni (Chōhōri) 長豊里
Changseong-ni 長省里
Ch'angsŏng-gun 昌城郡
Chang'yŏn-gun 長淵郡
Chang'yŏn-ho 長淵湖
Chasŏ-myŏn 自西面
Chasŏng 慈城
Chaun 資雲
Chech'eon 堤川
Cheju-do 済州島
Cheolla-namdo 全羅南道
Cheongan-sa 淨菴寺
Ch'eongch'eon-gang 清川江
Cheongni 鼎里
Cheongseon 旌善
Ch'eongsan 青山
Ch'eongyang 青陽
Cheonju 全州
Chesŏk-san 帝釈山
Chikch'ong-gok 直川谷
Chikhyŏn (Chokken) 直峴
Chiktang 稷洞
Chikunsan 織雲山
Ch'ilbo-san (Shichihōzan) 七宝山
Chimabawi-san (Sangam-san) 裳岩山
Chin'an 鎮安
Chinju 晋州
Ch'o-bong 草峰
Chodong-ni 鳥洞里
Chōhōri (Changp'ung-ni) 長豊里
Chōki (Changgi) 長鬐
Chokken (Chikhyŏn) 直峴
Chŏlla-do 全羅道
Ch'ŏlwŏn 鉄原
Chomok-san 槽木山
Ch'o-ni 初里
Ch'ŏndŏng-ni 泉徳里
Choneogam-bong 朝緑巌峰
Chong-bong 宗峰
Chonggwan-myŏn 鐘関面
Chŏngju 定州
Chŏn'gok 全谷
Chŏngong-ni 全谷里
Chŏngp'yŏng-gun 定平郡
Chongsŏng-gun 鐘城郡
Ch'ŏn-ji 天池
Ch'ŏnsŏng-ni 天聖里
Ch'op'yŏng 草坪
Ch'osan (Sozan) 楚山

Chōsen (Chosŏn)	朝鮮
Chosŏn (Chōsen)	朝鮮
Chu-bong	周峰
Chugam	竹岩
Ch'uga-ryŏng	楸哥岺
Chukryeon	竹簾
Ch'unch'eon	春川
Chungbang	中坊
Chung-bong (Sil-bong)	甑峯
Chungbongsan	中峰山
Ch'ungch'eong-bukto	忠清北道
Ch'ungch'eong-namdo	忠清南道
Ch'ungch'ŏng-do	忠清道
Chunghwa-gun	中和郡
Ch'ungju	忠州
Chung-myŏn	中面

D

Daebo	大宝
Daedong, Taedong (Daidō)	大同
Daegi	大基
Daidō (Taedong, Daedong)	大同
Dongjeom	銅店

E

Ennichi (Yŏnil, Yeonil)	延日

G

Gobangsan (Kopangsan)	高坊山

H

Hadong-myeon	下東面
Haeal-li	海安里
Haeju	海州
Haengnam	杏南
Haengyŏng (Kōei)	行營
Hago-myŏn	下古面
Halla-san	漢拏山
Hambaek-san	咸白山
Hamgyŏng-do	咸鏡道
Hamhŭng (Kankō)	咸興
Hamjin	咸鎮
Hanae-ni	下乃里
Handal-ch'ŏn	寒達川
Han-gang	漢江
Hansan	韓山
Hapsu	合水
Haŭng-pong	下鷹峯
Heian (P'yŏng'an) system	平安
Hoemun-dong	会文洞
Hoeryŏng	会寧
Hoeryŏng-gun	会寧郡
Hoeryŏng-ŭp	会寧邑
Holgol	笏洞
Hongjeom, Hongjŏm (Kōten)	紅店
Hongjŏm, Hongjeom (Kōten)	紅店
Hōzan (Pongsan)	鳳山
Huch'ang	厚昌
Hŭksŏk	黒石
Hwajeol-chi	花折峙
Hwang-bong	黄峯
Hwanghae-do	黄海道
Hwangji-ri	黄池里
Hwangju-gun	黄州郡
Hwan-san	丸山
Hwasun	和順
Hyonam	硯岩

I

Ich'ŏn	伊川
Imjin-gang	臨津江
Immyŏng-dong	臨溟洞

J

Jangsan	壯山
Jeongseon	旌善
Jidō (Sa-dong)	寺洞
Joseon (Korea)	朝鮮
Jōsuiyō (Sangsuyang)	上水陽

K

K'ach'i-bong (Chak-pong)	鵲峯
Kaema (Gaima)	蓋馬
Kaesim-dong	開心洞
Kaesŏng-bu	開城府
Kaesŏng-gun	開城郡
Kal-san (Kŏm-san)	剣山
Kamp'o	甘浦
Kanggye	江界
Kangnung	江陵
Kangsŏ-gun	江西郡
Kangweondo, Kangwŏn-do	江原道

Kangwŏn-do, Kangweondo 江原道
Kankō (Hamhŭng) 咸興
Kariwang-san 加里旺山
Keirin (Kyerim) 鶏林
Keonch'on-ni 乾川里
Keongseong (Seoul) 京城
Kilchu 吉州
Kilchu-up 吉州邑
Kobang-san (Kōbōsan) 高坊山
Kobangsan (Gobangsan) 高坊山
Kōbōsan (Kobang-san) 高坊山
Koch'am-dong 古站洞
Kodong-myŏn 古東面
Kōei (Haengyŏng) 行營
Kogi 高基
Koguryŏ (Kōkuri) 高句麗
Koho (Kopo) 古堡
Koksan-gun 谷山郡
Kokueo (Kokulian) granite 高句麗花崗岩
Kōkuri (Koguryŏ) 高句麗
Kom-san 熊山
Kŏm-san (Kal-san) 劍山
Kongju 公州
Kongsuweon 公須員
Kopo (Koho) 古堡
Korea (Joseon) 朝鮮
Kōten (Hongjeom, Hongjŏm) 紅店
Kot'o-ri 古土里
Kowŏn-gun 高原郡
Kucha-myŏn 旧左面
Kuhyŏn (Kuken) 駒峴
Kŭiu-san 祈雨山
Kuken (Kuhyŏn) 駒峴
Kuk-tong 極洞
Kuam 亀岩
Kumch'eon 金川
Kŭmch'eon-ni 黔川里
Kŭmch'ŏn-gun 金川郡
Kŭmgang-san 金剛山
Kŭmhwa 金化
Kŭmnyŏng 金寧
Kŭm-p'o 金浦
Kŭm-san 錦山
Kunsan 群山
Kurae-ni 九來里
Kurang-ni 九郎里
Kuryongp'o 九龍浦
Kuryongso 九龍沼
Kusan (Kyŭzan) 九山
Kusŏktŏk 九石徳
Kwandu-bong 冠頭峰
Kwangji-bong 筐芝峯
Kwanmo-bong 冠帽峯
Kwangsŏkch'on 広石村
Kyeho-dong 桂湖洞
Kyejŏng 鶏井
Kyesan-mal 鶏山村
Kyeomi-p'o, Kyŏmip'o 兼二浦
Kyeonggi-do 京畿道
Kyeong-ji 慶州
Kyeongseong, Kyŏngsŏng 京城
Kyerim (Keirin) 鶏林
Kyeomi-p'o, Kyŏmip'o 兼二浦
Kyeonggi-do, Kyŏnggi-do 京畿道
Kyeongsang-do, Kyŏngsang-do 慶尚道
Kyeongseong, Kyŏngsŏng 京城
Kyūzan (Kusan) 九山
Kyulam-ni 橘岩里

M

Maan-san 馬鞍山
Mach'a-ri 磨磋里
Mach'eollyeong, Mach'ŏl-lyŏng (Maten-rei) 摩天岺
Mach'ŏl-lyŏng, Mach'eollyeong (Maten-rei) 摩天岺
Mach'ŏnmol 摩天隅
Madae-san 馬岱山
Maegong-ni 梅谷里
Maggol (Makkol) 莫洞
Magyo-ri 馬橋里
Majŏl-li 麻田里
Majon-ch'i 麻田峙
Makkol (Maggol) 莫洞
Mandal-san (Bantatsuzan) 晩達山
Manho-dong 万古洞
Manji-dong 満地洞
Masŏng 麻城
Matenrei (Mach'eollyeong, Mach'ŏl-lyŏng) 摩天岺

Moha-ri	茅下里
Mokchin-dong	木津洞
Mudong-ni	舞童地
Mudu-bong	無頭峯
Muhak-san	舞鶴山
Mungog	文谷
Mun'gyeong	聞慶
Munsan	汶山
Munŭng-ni	武陵里
Musan	茂山
Myeongch'eon, Myŏngch'ŏn	明川
Myeon-san	綿山
Myobong	猫峰
Myŏngch'ŏn, Myeongch'eon	明川

N

Naesan-dong	内山洞
Nangnang	楽浪
Naktong (Rakutō)	洛東
Naktong-gang	洛東江
Namae-ni	南崖里
Namdae-ch'ŏn	南大川
Namjeong-ni	南庭里
Namjŏng-ni	楠亭里
Nam-myŏn	南面
Namp'o	藍浦
Namsŏl-lyŏng	南雪岺
Namyang-dong	南陽洞
Nan-bong	卵峯
Nokcheon-ni	碌田里
Nogam	緑岩
Nŭng-dong	陵洞

O

Odae-ch'eon	五台川
Ŏil-li	魚日里
Okcheon, Okch'ŏn (Yokusen)	沃川
Okch'eon-gun, Okch'ŏn-gun	沃川郡
Okch'ŏn, Okcheon (Yokusen)	沃川
Oktong	玉洞
Olchong-ni	乭足里
Ŏnjin-san	彦真山
Op'yeong	於呼
Ŏrang-ch'ŏn	漁郎川
Osip-ch'eon	五十川

P

Paegam	白岩
Paekhwa-san	白華山
Paeksa-bong	白沙峰
Paektu-san	白頭山
Paekpyeong-san	白屏山
Paek'un-san	白雲山
Paengnoktam	白鹿潭
Paengnyong-do	白翎島
Pangsŏng-ni	芳城里
Pansong	盤松
P'arŭl-myŏn	八乙面
Pibong-san	飛鳳山
Pogwang-ni	宝光里
P'ohang	浦項
P'omgong-ni (Bonkokuri)	凡谷里
Pongdugon-ni	鳳頭崑里
Pongsan (Hōzan)	鳳山
Poksin-san	福辰山
Puhyang	富郷
Pukp'ot'ae-san	北胞胎山
Puksil-li	北寶里
Puktuil-myŏn	北斗日面
Pulgoksa, Pulguksa (Bukkokuji)	仏国寺
Pulguk-sa, Pulgoksa (Bukkokuji)	仏国寺
Pung-myŏn	北面
P'ungsan-gun	豊山郡
Pusan	釜山
P'yeongan, P'yŏngan (Heian)	平安
P'yeongbuk	平北
P'yeongan-bukto	平安北道
P'yeongch'ang	平昌
P'yŏngan-do	平安道
P'yeongan-namdo	平安南道
P'yeongnam	平南
P'yeongweon	平原
P'yeongyang	平壌
Pyŏksŏng-myŏn	碧城面
Pyŏlto-bong	別刀峯
P'yŏngan, P'yeongan (Heian)	平安
P'yŏnggang	平康
P'yŏngnyuk-tong	坪六洞
Pyŏngsiam	兵使岩

R

Rakutō (Naktong) 洛東
Rensen (Yŏnch'ŏn, Yeonch'eon) 連川
Ritsura (Yulla) 栗羅
Ryūdō (Yong-dong) 龍洞
Ryūyō-ri (Yongyang-ni) 龍陽里

S

Saam 寺岩
Sadangmol (Shidōgū) 祠堂隅
Sa-dong, Sadong, Satong (Jidō) 寺洞
Saengyang-ni 生陽里
Sakchu-gun 朔州郡
Sambang-san 三方山
Sambōsan (Sanbang-san) 山房山
Samch'eok, Samch'ŏk 三陟
Samch'ŏk, Samch'eok 三陟
Sam-do 森島
Samgot 三串
Samp'o-bong 三浦峰
Samsu-gun 三水郡
Sanbang-san (Sambōsan) 山房山
Sangam-san (Chimabawi-san) 裳岩山
Sangdong-myeon 上東面
Sangga-myŏn 上加面
Sanggo-myŏn 上古面
Sangnong-ni 上農里
Sangsambong 上三峯
Sangsuyang (Jōsuiyō) 上水陽
Sangweon, Sangwŏn (Shōgen) 祥原
Sangwŏn, Sangweon (Shōgen) 祥原
Sansŏng-san 山城山
Sap'o 泗浦
Sariwŏn 砂里院
Satong (Sadong) 寺洞
Seikiho (Sŏgwi-p'o, Soengwip'o) 西帰浦
Seikoshin (Sŏhojin) 西湖津
Seison, Sesong 細松
Seongwip'o, Sŏgwi-p'o (Seikiho) 西帰浦
Seoul (Keongseong) 京城
Shidōgū (Sadangmol) 祠堂隅
Shichihōzan (Ch'lbosan) 七宝山
Shinkō (Sinhŭng) 新興
Shiragi (Silla) 新羅
Shōgen (Sangwŏn, Sangweon) 祥原
Shōrin (Songnim, Songim) 松林
Sibyŏn 市辺
Sil-bong (Chung-bong) 甑峯
Silla (Shiragi) 新羅
Sinbokchiang 新福場
Sindongch'on 新洞村
Sin'gok 辰谷
Singye 新溪
Sinhŭng (Shinkō) 新興
Sinp'o-dong 深浦洞
Sobaek-san 小白山
Sŏdal-lyŏng 西達岺
Sŏgwi-p'o, Seongwip'o (Seikiho) 西帰浦
Sŏhojin (Seikoshin) 西湖津
Sŏkp'o-ch'i 石浦峙
Sŏkp'o-dong 石圃洞
Sŏktal-li 石達里
Sŏ-myŏn 西面
Songbong 松峰
Sŏngch'ŏn-gun 成川郡
Songim, Songnim (Shōrin) 松林
Sŏngin-bong 聖人峯
Sŏngmak-tong 石幕洞
Songnim, Songim (Shōrin) 松林
Sozan (Ch'osan) 楚山
Suan 遂安
Suha-myŏn 水下面
Sukch'ŏn 肅川
Sunch'ŏn 順川

T

Taebaeg-san, Taebaek-san, Taepaiksan 大白山
Taebaek-san, Taebag-san, Taepaiksan 大白山
Taebo (Taihō) 大宝
Taedong, Daedong (Daidō) 大同
Taedong-gang 大同江
Taegi 大基
Taegu 大邱
Taeha-dong 台霞洞
T'aejawŏn (Taishiin) 太子院

Taejong-bong	大正峯
Taejŏng-myŏn	大静面
Taepaiksan, Taebaeg-san, Taebaek-san	大白山
Taeyŏnji-bong	大臙脂峯
Taihō (Taebo)	大宝
Taishiin (T'aejawŏn)	太子院
Talmun	闥門
Tanch'eon, Tanch'ŏn	端川
Tanch'ŏn-gun, Tanch'eon-gun	端川郡
Tan'yang	丹陽
Teokch'eon	徳川
Teokyu-san	徳祐山
To-dong	道洞
Tokp'o-ni	徳浦里
Tomap'yeong	道馬坪
Tomkol, Tomudong	斗務洞
Tomudong, Tomkol	斗務洞
Tondo-ak	敦道岳
T'ongch'eon, Tongch'ŏn	通川
Tongch'ŏn, T'ongch'eon	通川
T'ongjin	通津
Tonggwan-dong, Tonggwanjin	潼関鎮
Tonggwanjin, Tonggwan-dong	潼関鎮
Tonghwalli	東活里
Tongho-dong	東湖洞
Tongjeom-ni	銅店里
Torak-san	道楽山
Tōryūsan (Turyu-san)	頭流山
T'osan	兎山
Tot'am-ni	都呑里
Tsuibon, Tuwibong	斗囲峰
Tuman-gang	豆満江
Tumu-dong	斗務洞
Tŭngnyong-gul	蝀龍窟
Tunjeon	屯田
Turyu-san (Tōryūsan)	頭流山
Tuwibong, Tsuibon	斗囲峰

U

U-gang	禹江
Uiimgil	義林吉
Ŭiju-gun	義州郡
Uiseong	義城
Ulchin	蔚珍
Ullŭng-do	鬱陵島
Ulsan	蔚山
U-myŏn	右面
Undusŏng	雲頭城
Ŭngbong-san	鷹峯山
Ŭngdŏk	鷹徳
Ungp'yŏng-myŏn	雄坪面
Unhakch'am	雲鶴站
Unhŭng-myŏn	雲興面

W

Wagok	瓦谷
Want'aek-san	完沢山
Weonju	原州
Weonsan, Wŏnsan	元山
Winam-dong	渭南洞
Wŏnsan, Weonsan	元山
Wŏnsŏk-tong	元石洞

Y

Yangdŏk (Yōtoku)	陽徳
Yanghap	両合
Yech'eong-gang	礼清江
Yeoju	驪州
Yeonch'eon, Yŏnch'ŏn (Rensen)	漣川
Yeongch'un	永春
Yeongdong	永同
Yeonghae	寧海
Yeongheung	永興
Yeongju	栄州
Yeongnam	嶺南
Yeongyang	英陽
Yeonil, Yŏnil (Ennichi)	延日
Yeongweol	寧越
Yŏch'ŏk	余尺
Yokusen (Okch'ŏn, Okcheon)	沃川
Yŏnch'ŏn, Yeonch'eon (Rensen)	連川
Yŏndae-bong	烟台峯
Yŏngbyŏn-gun	寧辺郡
Yongch'ol-li	龍川里
Yongch'ŏn-gun	龍川郡
Yongdam	龍潭

Yong-dong (Ryūdō)	竜洞	Yōtoku (Yangdŏk)	陽徳
Yongil-man	迎日湾	Yulla (Ritsura)	栗羅
Yongsan-myŏn	龍山面	Yul-li	栗里
Yongtong	嶺東	Yukpaek-san	六百山
Yongyang-ni (Ryūyō-ri)	龍陽里	Yūsen (Yusŏn)	遊仙
Yŏnil, Yeonil (Ennichi)	延日	Yusŏn (Yūsen)	遊仙

MANCHURIA and CHINA

(* Japanese name)

A

A-shi-ho	阿什河
A-tang	亜当
Ai-gun (Ai-hun)	愛琿
Ai-hun(Ai-gun)	愛琿
Ai-kou-tsun	艾口村
Amur River (Hei-lung Chiang)	黒龍江
An-ching	安慶
An-hua	安華
An-hui (An-hwei) Province	安徽省
An-hwei (An-hui) Province	安徽省
An-shan	鞍山
An-tu	安圖
An-tung	安東
An-yang-hsien	安陽県
An-yuan	安源

C

Cha-ha-erh (Chahar)	察哈爾
Cha-lai-no-erh	札賚諾爾
Chahar (Cha-ha-erh)	察哈爾
Chai-chia-wo-peng	翟家窩棚
Chan-ho	占河
Chang-chia-kou (Kalgan)	張家口
Chang-chia-kou	張家溝
Chang-chia-pu	張家堡
Chang-chiang (Chang Chiang)	長江
Chang-chiu	章邱
Chang-chun	長春
Chang-hsia	張夏
Chang-hsing	長興
Chang-hua	昌化
Chang-kang-shan	長崗山
Chang-pai Hsien	長白県
Chang-pai-shan (Chang-pai Shan)	長白山
Chang-shan-yu	長山峪
Chang-tien	張店
Chang-tu	昌図
Chang-yu	胆楡
Chao-mi-tien	炒米店
Chao-tsuo (Chiao-tso)	焦作
Chao-yang	朝陽
Chao-yang-kou	朝陽溝
Che-chiang (Che-kiang) Province	浙江省
Che-kiang (Che-chiang) Province	浙江省
Chen-chia-pu	沈家堡
Chen-chiang (Chen-kiang)	鎮江
Chen-kiang (Chen-chiang)	鎮江
Chen-tung	鎮東
Cheng-chia-tun	鄭家屯
Cheng-ho	政和
Cheng-te	承徳
Chi-chang	祁常
Chi-chi	績溪
Chi-chi-ha-erh (Tsitsihar)	斉々哈爾
Chi-chiang (Chi Chiang)	綦江
Chi-hsia	棲霞
Chi-hsing County	七星郡
Chi-hsing-shan	七星山
Chi-hsing Volcano	七星火山
Chi-lin (Kirin, Ki-rin) Province	吉林省
Chi-shan	稷山
Chi-tao-kou	七道溝
Chi-tung	冀東
Chia-mu-ssu (Kiamusze)	佳木斯
Chia-pi-kou	夾皮溝
Chia-yu	嘉魚
Chiang-hsi (Kiang-si) Province	江西省
Chiang-su (Kiang-su) Province	江蘇省
Chiao-ho	蛟河
Chiao-tou	橋頭
Chiao-tso (Chao-tsuo)	焦作
Chiao-tzu-shan	轎子山

Chieh-shou 界首
Chien-cheng 建昌
Chien-kuo-chi 前郭旗
Chien-ping (Kien-ping) 建平
Chien-shan 千山
Chien-shan-tzu 尖山子
Chien-tao Province 間島省
Chih-feng 赤峰
Chih-Po-Chang (Tze-Po-Chang) 淄博章
Chin (Tsin) Plateau 沁高原
Chin-chou 金州
Chin-chou 錦州
Chin-chu-wo 筋竹窩
Chin-chuan 芹泉
Chin-hsi (Chin-si) 錦西
Chin-ling (Tsin-ling) (Mts.) 秦岺(山脉)
Chin-ling 金陵
Chin-nan (Tsin-nan) 晋南
Chin-pei (Tsin-pei) 晋北
Chin-peng-hsien 経棚県
Chin-Pu Railway 津浦線
Chin-hsien 進賢
Chin-si (Chin-hsi) 錦西
Chin-shan-ssu 金山寺
Ching-chi-chung 清溪冲
Ching-hsing 井陘
Ching-lung 青龍
Ching-shan-chuan 青山泉
Ching-shui 清水
Ching-yuan 靖遠
Ching-yuan-hsien 清原県
Chiu-chin-chung 九鐔冲
Chiu-fo-tang 九仏堂
Chiu-fu 曲阜
Chou-kou-tien 周口店
Chou-shan Islands 舟山群島
Chu-lien 竹簾
Chu-pao-shan 聚宝山
Chu-tang 竹塘
Chu-tun 朱屯
Chuan-hsien 全県
Chuan-shan 船山
Chuan-tou 泉頭
Chuang-ho (Chuang Ho) 莊河
Chuang-tsun 莊村
Chung-hsing 中興
Chung-wu-shan 中巫山

D

Dairen (Ta-lien) 大連

E

E-mao-kou 鵞毛口
E-mei-shan 蛾眉山
Erh-ko-shan 二克山
Erh-tseng-tien-tzu 二層甸子

F

Fa-pieh-la-ho (Fupielahe) 法別拉河
Fan-chih 繁峙
Fan-chuang 范莊
Fan-hê system 汎河系
Fan-shan-pu 礬山堡
Fang-chung 方冲
Fang Shan 方山
Fang-shan 房山
Fang-tzu 坊子
Fen-ho 汾河
Feng-cheng 豊城
Feng-huang-shan 鳳凰山
Feng-kuan-shan 鳳冠山
Feng-man 豊満
Feng-shan 鳳山
Feng-shui 豊水
Feng-tien (Mukden) 奉天
Feng-tien Province 奉天省
Feng-tien 楓田
Fu-chia-tan 富家灘
Fu-chien (Fu-kien) Province 福建省
Fu-chin 富錦
Fu-chou 復州
Fu-hsin 阜新
Fu-kien (Fu-chien) Province 福建省
Fu-la-erh-chi (Fularki) 富拉爾吉
Fu-lung-chuan 伏龍泉
Fu-lung-shan 富隆山
Fu-niu (Mts.) 伏牛 (山脉)
Fupielahe (Fa-pieh-la-ho) 法別拉河
Fu-shun 撫順
Fu-yu 扶余

Fu-yuan 撫遠
Fularki (Fu-la-erh-chi) 富拉爾吉

G

Greenstone series 緑岩統

H

Ha-erh-pin (Harbin) 哈爾賓
Ha-ma-tang 哈嗎塘
Hai-cheng 海城
Hai-la-erh (Hailar) 海拉爾
Hai-lun 海倫
Hailar (Hai-la-erh) 海拉爾
Hai-nan 海南
Han-chao 含巣
Han-kou 漢口
Han-po-ling 寒坡岺
Han-shui 漢水
Hang-chou 杭州
Hao-kang (Tsuruoka) 鶴岡
Hao-li-kang 鶴立崗
Harbin (Ha-erh-pin) 哈爾賓
Hei-ho 黒河
Hei-ho Province 黒河省
Hei-Liao divide 黒遼分水岺
Hei-lung-chiang (Hei-lung Chiang) (Amur River) 黒龍江
Hei-lung-chiang Province 黒龍江省
Hei-shan 黒山
Hei-tai 黒台
Hêng-shan 桓山
Ho-chia-kou 何家溝
Ho-chou 和州
Ho-hsien 賀県
Ho-nan Province 河南省
Ho-pei Province 河北省
Ho-shang-chuang-tzu 和尚莊子
Ho-shang-tun 和尚屯
Hou-ho 厚和
Hou-to-lo 後妥羅
Hsi-an 西安
Hsi-an-shan 西鞍山
Hsi-chiao-te-pu Shan 西焦得布山
Hsi-chih-chieh 汐止街
Hsi-ching-peng 西経棚
Hsi-ha-la-pa Shan 西哈拉巴山
Hsi-heng-tao Shan 西恒道山
Hsi-ho 細河
Hsi-hsia-hsien 棲霞県
Hsi-hu 西湖
Hsi-lo-chen 西洛鎮
Hsi-men 西門
Hsi-po 西坡
Hsi-shan (Si-shan) 西山
Hsi-shan-tao 西山島
Hsi-ta-yuan 西大園
Hsi-wan 西湾
Hsi-ying-pan 西営盤
Hsi-yuan-pao-shan 西元宝山
Hsia-hei-yu-kou 下黒魚溝
Hsia-hsi-tai 下戯台
Hsia-liu-chung 霞流中
Hsia-lung-hua 下龍化
Hsian-kang-chen 軒崗鎮
Hsiang-chi 香溪
Hsiang-lu-shan 香炉山
Hsiang-ning 湘寧
Hsiang-shan 象山
Hsiang-shui 湘水
Hsiang-tan 湘潭
Hsiao-hsing-an-ling 小興安岺
Hsiao-ko Shan 小克山
Hsiao-ku-lun 小庫倫
Hsiao-li-kou 小李溝
Hsiao-ling-ho 小凌河
Hsiao-ling-tzu 小岺子
Hsiao-pei-kou 小北溝
Hsiao-ping-tao-hui 小平島會
Hsiao-sheng-shui-ssu 小聖水寺
Hsiao-shih 小市
Hsiao-tu-ko-erh-tsai Shan 小吐各爾祭山
Hsiao-weng-chuan 小甕圏
Hsien-shui-ting-tzu 城水頂子
Hsieng-ning 咸寧
Hsin-ching 新京
Hsin-chu Province 新竹州
Hsin-hua 新化
Hsin-kuan-mien-shan 新関門山
Hsin-min-tun 新民屯
Hsin-tai 新泰
Hsing-an Province 興安省

Hsing-an-hsi	興安西
Hsing-an-ling (Khingan range)	興安岺
Hsing-cheng	興城
Hsing-lung	興隆
Hsing-lung-hsien	興隆県
Hsing-tai	刑台
Hsiu-shui	修水
Hsu-chia-chuang	徐家荘
Hsu-chia-tun	許家屯
Hsuan-chia-ping	宣家坪
Hsuan-ching	宣涇
Hsuan-hua-hsien	宣化県
Hu-chia-pu-tzu	胡家堡子
Hu-chou	湖州
Hu-kou	湖口
Hu-lu-lung-wan	葫芦龍湾
Hu-nan Province	湖南省
Hu-pei Province	湖北省
Hu-ping	湖坪
Hu-to	滹沱
Hu-yu-erh-ho (Wu-yu-erh-ho)	呼裕爾河
Hua-shan (Kabayama)	樺山
Hua-tien	樺甸
Hua-tung-kou	華銅溝
Huai-ho (Huai Ho)	淮河
Huai-jen	懐仁
Huai-jou	懐柔
Huai-lai-hsien	懐来県
Huai-lu	獲鹿
Huai-nan (Hwai-nan)	淮南
Huai-yang (Hwai-yang)	淮陽
Huang-chi	黄旗
Huang-hai	黄海
Huang Ho (Hwang Ho) (Yellow River)	黄河
Huang-kang-ling	黄崗岺
Huang-lung	黄龍
Huang-ni-kang-hsi	黄泥崗西
Huang-tu-chia-chen	黄土家鎮
Hui-nan	輝南
Hui-shih-tun	灰石屯
Hun-chun	琿春
Hun-ho	渾河
Hun-yuan	渾源
Hung-la	紅砬
Hung-lo-hsien	虹螺峴
Hung-miao-ling	紅庙岺
Hung-shan	洪山
Hung-shan-tien	洪山殿
Hung-shih-la-tzu	紅石磊子
Hung-tsu Lake	洪沢湖
Hung-yao	紅窰
Huo-lien-chai	火連寨
Huo-shao Shan	火焼山
Huo-shih-ling	火石岺
Hwai-nan (Huai-nan)	淮南
Hwai-yang (Huai-yang)	淮陽
Hwang Ho (Huang Ho) (Yellow River)	黄河

I

I-chia-ping	宜家坪
I-ching	宜涇
I-chou	沂州
I-hsien	沂県
I-hsien	嶧県
I-hsing	宜興
I-lan	依蘭
I-tan-shan	一担山
I-tung	伊通
I-tung-ho	伊通河
I-wu	義烏
*Iyasaka village	弥栄村

J

Je-ho (Jehol)	熱河
Jehol (Je-ho)	熱河
Ju-yuan	乳源

K

*Kabayama (Hua-shan)	樺山
Kai-lan	開滦
Kai-ping	開平
Kai-ping	蓋平
Kai-tung	開通
Kai-yuan	開原
Kai-yuan	開源
Kalgan (Chang-chia-kou)	張家口
Kan-an	乾安

Kan-ching-tzu 甘井子
Kan-chu-erh-miao (Kanchur) 甘珠爾庙
Kanchur (Kan-chu-erh-miao) 甘珠爾庙
Kan-ho 甘河
Kang-chieh-kang 康詰坑
Kang-ta-jen-tun 康大人屯
Kao-yu Lake 高郵湖
Khanka Lake 興凱湖
Khingan range (Hsing-an-ling) 興安岺
Kiamusze (Chia-mu-ssu) 佳木斯
Kiang-si (Chiang-hsi) Province 江西省
Kiang-su (Chiang-su) Province 江蘇省
Kien-ping (Chien-ping) 建平
Ki-rin (Chi-lin) Province 吉林省
Ko-erh-fen-ho 科爾芬河
Ko-shan 克山
Ko-tung Hsien 克東県
Kou-chuan 口泉
Kou-chuan-kou 口泉溝
Kou-ya-tung 狗牙洞
Ku-feng 孤峯
Ku-hsiang-tun 顧郷屯
Ku-pei-kou 古北口
Ku-shan 崮山
Ku-yeh 古冶
Kuan-cheng 寛城
Kuan-chuang 官荘
Kuan-men-shan 関門山
Kuan-tso Ling 官挫岺
Kuan-tung Province 関東省
Kuang-feng 広豊
Kuang-hsi (Kwang-si) Province 広西省
Kuang-i 光義
Kuang-ning-ssu 広寧寺
Kuang-tung Province 広東省
Kuei-chou (Kwei-chou) Province 貴州省
Kuei-hsien 貴県
Kuei-yang 貴陽
Kun-lun 崑崙
Kun-ming 昆明
Kung 鞏
Kung-chang-ling 弓張岺
Kung-chu-ling 公主岺
Kuo-chia-tun 郭家屯
Kuo-ti Shan 鍋底山
Kwang-si (Kuang-hsi) Province 広西省
Kwang-tung (Kuang-tung) Province 広東省
Kwei-chou (Kuei-chou) Province 貴州省

L

La-lin-ho 拉林河
La-tzu-shan 磊子山
Lai-ho 来河
Lai-pa-kou 耒壩口
Lai-wu 萊蕪
Lan-chou (Lan-chow) 蘭州
Lan-chow (Lan-chou) 蘭州
Lao-chang-kuang-sui-ling 老張広歳岺
Lao-chin-chang 老金廠
Lao-ha 老哈
Lao-ha-ho 老哈山
Lao-hei-shan 老黒山
Lao-hu-shan 老虎山
Lao-niu-kou 老牛溝
Lao-tou-kou 老頭溝
Le-ping (Lo-ping) 楽平
Lei-chou Peninsula 雷州半島
Li-chia-ling 李家岺
Li-hsien 礼賢
Li-ling 醴陵
Li-shan-hsien 立山綫
Li-shu-kou 梨樹溝
Li-shu-shan 梨樹山
Liao-ho 遼河
Liao-hsi 遼西
Liao-ning 遼寧
Liao-tung 遼東
Liao-tung Bay 遼東湾
Liao-yang 遼陽
Lien-shan-kuan 連山関
Lin-cheng 臨城

Lin-chuan	臨川
Lin-fen	臨汾
Lin-hsi	林西
Lin-hsi-hsien	林西県
Lin-hsien	臨県
Lin-kou	林口
Lin-tung	林東
Lin-tzu-tou	林子頭
Ling-ho	凌河
Ling-shui-ho	凌水河
Ling-yuan	凌源
Liu-chiang	柳江
Liu-chuan	柳泉
Liu-ho	柳河
Liu-ho-kou	六河溝
Liu-mao	柳毛
Liu-tang	柳塘
Lo-chia-tun	楽家屯
Lo-ja-ping	羅惹坪
Lo-ping (Le-ping)	楽平
Lo-tzu-kou	羅子溝
Lu-an	潞安
Lu-ku	鹿窮
Lu-nan	路南
Lu-shih	盧氏
Lu-shun (Port Arthur)	旅順
Luan-ping	滦平
Lung-an	龍安
Lung-chen	龍鎮
Lung-chiang Province	龍江省
Lung-ching	龍井
Lung-ching-chieh	龍井街
Lung-hua	隆化
Lung-kang Mountains	龍崗山脉
Lung-men	龍門
Lung-men Shan	龍門山
Lung-tan	龍潭
Lung-wan	龍湾
Lung-wang-tang	龍王塘
Lung-yen	龍巖

M

Ma-chia-kou	馬家溝
Ma-ho-ssu	馬和寺
Ma-lan	馬蘭
Ma-lu-kou	馬鹿溝
Ma-wu-tu	馬武督
Man-chou-li	満洲里
Man-kou	満溝
Man-tou shale	饅頭頁岩
Mao-chuang	毛荘
Mao-kou	茅口
Mao-yang	毛洋
Men-tou-kou	門頭溝
Meng-chiang	蒙江
Meng-chiang	蒙疆
Mergen (Mo-erh-ken)	墨爾根
Mi-shan	密山
Miao-erh-kou	庙児溝
Miao-tao	庙島
Ming-cheng	明城
*Misaki stage	三崎階
*Miyanohara group	宮之原層群
Mo-erh-ken (Mergen)	墨爾根
Mo-la-pu Shan	莫拉布山
Mu-lin	穆林
Mu-ling	穆稜
Mu-ling-ho	穆稜河
Mu-tan-chiang	牡丹江
Mu-tan-chiang Province	牡丹江省
Mukden (Feng-tien)	奉天

N

Na-lo-mu-tu	奈勒穆図
Na-mu-erh-ho	納謨爾河
Nan-chang	南昌
Nan-ching (Nanking)	南京
Nanking (Nan-ching)	南京
Nan-ling	南岺
Nan-ning	南寧
Nan-pei-ho	南北河
Nan-piao	南票
Nan-pu	南堡
Nan-ting	南定
Nao-po Shan	閙宝山
Nen-chiang	嫩江
Ni-chiu-ho	泥鰍河
Ni-ho-wan	泥河湾
Ning-chen	寧鎮
Ning-erh	寧洱
Ning-ku-ta	寧古塔
Ning-nien	寧年

Ning-wu 寧武
Niu-hsin-shan 牛心山
Niu-hsin-tai 牛心台
Niu-la-cheng-tzu 牛拉城子
No-erh Railway 諾爾鉄道
No-ho 訥河
No-min-ho 諾敏河
Nü-chen system 女真系
Nu Shan 女山

P

Pa-shu 巴蜀
Pa-tao-chiang 八道江
Pa-tao-hao 八道濠
Pa-tung 巴東
Pa-wang-chao 覇王朝
Pai-cheng-tzu 白城子
Pai-chia-pu-tzu 白家堡子
Pai-chuan 拝泉
Pai-shan 白山
Pai-tou-shan 白頭山
Pan-chiao 板橋
Pan-kou 畔溝
Pan-shih 磐石
Pan-tao-ling 磐道岺
Pang-fu 蚌埠
Pao-an 保安
Pao-li-chen 宝力鎮
Pao-te 保徳
Pao-ting 保定
Pao-tou 包頭
Pei-an 北安
Pei-ching (Peking) 北京
Pei-Hei Line 北黒線
Pei-ko-la-chiu Shan 北格拉球山
Pei-piao 北票
Pei-tai 北台
Peking (Pei-ching) 北京
Pen-chi (Pen-hsi) 本渓
Pen-chi-hu (Pen-hsi-hu) 本渓湖
Pen-hsi (Pen-chi) 本渓
Pen-hsi-hu (Pen-chi-hu) 本渓湖
Peng-cheng-chen 彰城鎮
Peng-hu Tao 澎湖島
Pi-chia Shan 筆架山
Pi-tzu-wo 皮子窩
Pi-tzu-wo 貔子窩
Pien-chiang-shan 辺墻山
Pin-chiang (Pin-kiang) Province 浜江省
Pin-kiang (Pin-chiang) Province 浜江省
Pin-Pei Line 浜北線
Ping-an 平安
Ping-chuan 平泉
Ping-hsiang 萍郷
Ping-hsin 憑心
Ping-ma 平馬
Ping-men 平門
Ping-ting 平定
Pting-ing-shan 平頂山
Ping-yang 平陽
Ping-yang-chen 平陽鎮
Po Hai 渤海
Po-hou-shan 破後山
Po-li 勃利
Po-li Shan 玻璃山
Po-po-tu Shan 餑々吐山
Po-shan 博山
Port Arthur (Lu-shun) 旅順
Pu-chi 蒲圻
Pu-lan-tien 普蘭店
Pu-te 堡徳

R

*Roppyakuzan 六百山

S

Sa-ha-ling (Mts.) 薩哈岺 (山脉)
Sa-ho-chiao 撒河橋
Sa-la-chi (Sa-la-tsi) 薩拉斎
Sa-la-tsi (Sa-la-chi) 薩拉斎
Sai-chia 彩家
Sai-ma-chi 賽馬集
San-cha-tzu 三岔子
San-chia-tzu 三家子
San-chiang Province 三江省
San-chien Ho 桑乾河
San-ho 三河
San-hsing 三姓
San-ko-shu 三棵樹
San-leng-shan 三稜山

San-men	三門
San-tao	三道
San-tao-kou	三道溝
Sang-kan gneiss	桑乾片麻岩
Sha-ho	沙河
Shan-chiang-an (Shan-kiang-an)	山江安
Shan-hai-kuan	山海関
Shan-hsi (Shan-si) Province	山西省
Shan-kiang-an (Shan-chiang-an)	山江安
Shan-si (Shan-hsi) Province	山西省
Shan-sung-kang	杉松崗
Shan-tung Province	山東省
Shan-wang	山旺
Shang-an	上安
Shang-hai (Shanghai)	上海
Shang-i-hsiang	尚義郷
Shang-yao	上窰
Shanghai (Shang-hai)	上海
Shao-yang	邵陽
Shen-hou	神后
Shen-pei basin	陝北盆地
Shen-yang	瀋陽
Shi-erh-tao-kou	十二道溝
Shih-chia-chuang	石家荘
Shih-chiao	石橋
Shih-chien-feng	石千峰
Shih-ho-tzu	石盒子
Shih-hui-yao	石灰窰
Shih-kai-tzu	石拐子
Shih-lung	石龍
Shih-men-chai (Shih-men-tsai)	石門寨
Shih-men-kou	石門口
Shih-men-tsai (Shih-men-chai)	石門寨
Shih-pu	石浦
Shih-Tai Railway	石太鉄路
Shih-tang	石塘
Shih-teng-tzu	石燈子
Shih-ting-chuang	石碇庄
Shih-tou-fang-tzu	石頭房子
Shih-tou shan	石頭山
*Shokozan	勝光山
Shou-yang	寿陽
Shu-lan	舒蘭
Shuan-ma-chun	栓馬椿
Shuang-chuan	双泉
Shuang-ling-tzu	双岺子
Shuang-miao-tzu	双庙子
Shuang-yang-tung Ho	双陽洞河
Shui-feng	水豊
Si-shan (Hsi-shan)	西山
Sinian system	震旦系
Ssu-chuan (Sze-chwan) Province	四川省
Ssu-mi-kou	蘇密溝
Ssu-ping	四平
Ssu-ping-chieh	四平街
Ssu-tung	寺洞
Ssu-yen	四眼
Su-chun	蘇春
Su-sung	宿松
Sui-chung	綏中
Sui-fen	綏芬
Sung-chia-wan	孫家湾
Sui-hua	綏化
Sung-hua-chiang (Sungari)	松花江
Sung-shu-chen	松樹鎮
Sung-shu-tai	松樹台
Sungari (Sung-hua-chiang)	松花江
Sze-chwan (Ssu-chuan) Province	四川省

T

Ta-chin-niu	大金牛
Ta-ching	大青
Ta-ching-shan (Ta-tsing-shan)	大青山
Ta-chu-chuan	大猪圏
Ta-feng-kou	大風口
Ta-hei-shan	大黒山
Ta-ho	大河
Ta-ho-shang-shan	大和尚山
Ta-hsing-an-ling	大興安岺
Ta-huang-kou	大荒溝
Ta-i shan	大椅山
Ta-ku-shan	大孤山
Ta-ku-tung	大古洞
Ta-la-tzu	大拉子
Ta-lai	大賚

Ta-li-po	達里泊
Ta-li-tzu	大栗子
Ta-liang-shang	大良上
Ta-liao-ho	大遼河
Ta-lien (Dairen)	大連
Ta-lien Bay	大連湾
Ta-ling-ho	大凌河
Ta-lung-wan	大龍湾
Ta-ma-lu-kou	大馬鹿溝
Ta-meng-chen	大孟鎮
Ta-nan-kou	大南溝
Ta-pan-shang	大板上
Ta-ping-chen	大平鎮
Ta-sha-ho	大沙河
Ta-she	大社
Ta-shih-chiao	大石橋
Ta-ting	大定
Ta-tsing-shan (Ta-ching-shan)	大青山
Ta-tu-ko-erh-tsai Shan	大吐各爾祭山
Ta-tun	大屯
Ta-tung	大同
Ta-tung Prefecture	大同県
Ta-tung-shan	大東山
Ta-wai-tzu-shan	大歪子山
Ta-wang-miao	大王庙
Ta-wen-kou	大汶口
Ta-yang-ho	大洋口
Ta-yeh	大冶
Tai-an	泰安
Tai-an Hsien	泰安県
Tai-hang mountain range	太行山脉
Tai-hu	太湖
Tai-lai	泰来
Tai-pei Province	台北州
Tai-ping-fang	太平房
Tai-ping-pu	太平堡
Tai-shan	台山
Tai-shan	泰山
Tai-tien	台店
Tai-tou	台頭
Tai-tzu	太子
Tai-tzu-ho	太子河
Tai-yuan	太原
Tai-yuan	太源
Tan-shan-wan	炭山湾
Tang-hsien	唐県
Tang-shih	当十
Tang-kang-tzu	湯崗子
Tang-shan	唐山
Tao-chung	桃沖
Tao-ke	桃科
Tao-lai-chao	陶頼招
Tao-nan	洮南
Te-tu Prefecture	徳都県
Ti-tan-shan	地蛋山
Tiao-yu-tai	釣魚台
Tieh-chang	鉄廠
Tieh-ling	鉄岺
Tieh-shih-shan	鉄石山
Tien-chin (Tien-tsin)	天津
Tien-shih-fu	田師付
Tien-shih-fu-kou	田師付溝
Tien-tsin (Tien-chin)	天津
Ting-chia-shan	丁家山
Tou-ling	斗岺
Tou-man-chiang (Tu-men-chiang)	豆満江
Tou-tao-cha	頭道岔
*Toyama stage	外山階
Tsai-chia (Sai-chia)	彩家
Tsai-chia-fen	蔡家攻
Tsao-ho-kou	草河口
Tsao-shih-erh	草市児
Tsao-tzu-shan	棗茨山
Tse-chou	澤州
Tse-shui	測水
Tsin (Chin) plateau	沁高原
Tsin-ling (Chin-ling) (Mts.)	秦岺 (山脉)
Tsin-nan (Chin-nan)	晋南
Tsin-pei (Chin-pei)	晋北
Tsitsihar (Chi-chi-ha-erh)	斉々哈爾
Tsu-erh-shan	茨児山
*Tsuruoka (Hao-kang)	鶴岡
Tu-men-chiang (Tou-man-chiang)	豆満江
Tu-men-tzu	土門子
Tu-shan-tzu	土山子
Tui-mien-shan	対面山
Tung-an	東安
Tung-an-shan	東鞍山

Tung-chao-te-pu Shan	東焦得布山
Tung-chi-ling	東渓岺
Tung-chi-pu	東渓埠
Tung-ching Bay	東京湾
Tung-ching-cheng (Tung-king-cheng)	東京城
Tung-ha-la-pa Shan	東哈拉巴山
Tung-hai	東海
Tung-hua	通化
Tung-king-cheng (Tung-ching-cheng)	東京城
Tung-ning	東寗
Tung-pao-sha	東泡沙
Tung-shan	東山
Tung-shan-chin-chang	東山金廠
Tung to-yao-tzu	東駝腰子
Tung-tu-men	東土門
Tung-wu	東呉
Tung-yang-kang	東陽港
Tung-yuan-pao-shan	東元宝山
Tze-chuan (Tzu-chuan)	淄川
Tze-hsien (Tzu-hsien)	磁県
Tze-Po-Chang (Chih-Po-Chang)	淄博章
Tzu-chiang	資江
Tzu-chin shan	紫金山
Tzu-chuan (Tze-chuan)	淄川
Tzu-hsien(Tze-hsien)	磁県
Tzu-men-chiao	梓門橋

U

U-yun-ho-erh	烏雲呼爾
Ussuri River (Wu-su-li-chiang)	烏蘇里江

W

Wa-fang-tien	瓦房店
Wa-fang-tzu	瓦房子
Wa-pen-yao	瓦盆窰
Wa-pen-yao-chuan (Wa-pen-yao-ho)	瓦盆窰川 (河)
Wa-pen-yao-ho (Wa-pen-yao-chuan)	瓦盆窰河 (川)
Wai-tou-shan	歪頭山
Wan-kou	湾溝
Wan-pao-shan	萬宝山
Wan-shan	萬山
Wan-ta(Mts.)	完達 (山脉)
Wan-tse-shan	完沢山
Wan-wan Series	湾々統
Wan-yang-shan	萬洋山
Wan-chia-pu-tzu	王家堡子
Wang-ping	王平
Wang-ping-hsien	王平県
Wang-ping-kou	王平口
Wei-chang Hsien	圍場県
Wei-chou Tao	潿州島
Wei-hsien	濰県
Wei-ning	威寧
Wei-sha-ho	葦沙河
Wei-shan	尾山
Wei-shui	微水
Wei-yang (Huai-yang)	准陽
Wen-chuan-ho	温泉河
Wen-shan County	文山郡
Wo-hu shan	臥虎山
Wo-ken-ho	倭肯河
Wu-an	武安
Wu-chiang	烏江
Wu-hu-tsui	五湖嘴
Wu-lung	五龍
Wu-shih-shan	五獅山
Wu-pu	呉堡
Wu-su-li-chiang (Ussuri River)	烏蘇里江
Wu-ta-lien-chih	五大連地
Wu-tai	五台
Wu-tai-shan	五台山
Wu-tan-cheng	烏丹城
Wu-tao-cha	五道岔
Wu-tao-chiang	五道江
Wu-tao-ling	五道岺
Wu-ting	五頂
Wu-tung	烏桐
Wu-yu-erh-ho (Hu-yu-erh-ho)	呼裕爾河
Wu-yun	烏雲
Wünhordongui	烏雲和爾冬吉

Y

Ya-lu River	鴨緑江
Ya-tsu-chuan	鴨子圏

Yang-chuan	陽泉
Yang-erh-shan	楊耳山
Yang-hsin	陽新
Yang-mei-shan	楊梅山
Yang-shu-kou	楊樹溝
Yang-tze-chiang (Yang-tzu Chiang) (Yengtze River)	楊子江
Yangtze River (Yang-tze-chiang)	楊子江
Yang-tzu (Yang-tze) Chiang	楊子江
Yao-chuan Shan	薬泉山
Yellow River (Huang-ho) (Hwang-ho)	黄河
Yen-chi	延吉
Yen-chien-shan	眼前山
Yen-chou	燕州
Yen-shan	燕山
Yen-tai	煙台
Yen-wa-shan	硯瓦山
Yin-shan (Mts.)	陰山 (山脉)
Ying-cheng-tzu	営城子
Ying-e-men	英額門
Ying-kou	営口
Ying-tao-yuan	桜桃園
Yu-ho	峪河
Yu-hsi-kou	于西溝
Yu-hsien	禹県
Yu-shan	玉山
Yu-she	楡社
Yu-yu	余于
Yuan-chia-chung	袁家冲
Yuan-chiu	恒曲
Yueh-men-kou	月門溝
Yun-nan Province	雲南省
Yung-ning	邕寧
Yung-ning	永寧
Yung-ting	永定
Yung-ting-chiao	永定橋