GEOLOGY AND MINERAL RESOURCES OF THE FAR EAST

Edited by
Tsutomu OGURA

VOLUME THREE

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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.

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PREFACE TO VOLUME 3

The articles in Volume 3 deal with the same regions and nearly the same variety of fields in geology and mineral deposits as Volume 2. They are supposed to cover, in a general way, geologic features of cratons as well as an island arc in this part of the Far East.

Numbers of articles contained in each Volume which has been published are summarized as follows:

	Vol. 1 1967	Vol. 2 1969		Vol. 3 1971
Korea	6	9	Korea & Manchuria	12
Manchuria	7	6		
China	4	2	N. China,	4
			S. China &	1
			Taiwan	3
Total	17	17		20
Place names	1	1		1

We would like to thank Miss Reiko Fusejima who prepared the glossary and who edited the English text.

CONTENTS

KOREA AND MANCHURIA

The Manmo Group of the Mongolian Geosyncline in Manchuria and Adjacent Areas

Teiichi KOBAYASHI

I. Introductory Note

On the basis of the high altitude geotectonics of Asia it can be said that the Mongolian geosyncline belongs to the intracontinental megageosyncline between the Angara megakraton and the Koreo-Chinese heterogen and the Chichibu geosyncline belongs to the pericontinental megageosyncline between the Asiatic continent and the Pacific Ocean. Therefore, the Manmo group of the Mongolian geosyncline plays an important role in the geology of Asia. Because the group in Southeast Manchuria, the Touman area of Korea and southern Primoria, USSR is astonishingly allied to the contemporaneous formations of the Japanese islands, the conjunction between the two megageosynclines is extraordinarily interesting.

Little had been known of the geology of North and Central Manchuria before 1927 when AHNERT presented a paper on the geomorphology and geologic structure of North Manchuria and the USSR, Far East to the Third Pan-Pacific Science Congress, Tokyo. The paper included known facts on Palaeozoic and older rocks, but no Palaeozoic fossil from that part of Manchuria had been described before 1931 when I published a paper on some Upper Palaeozoic shells from the Great Khingan range. The distribution of the Palaeozoic Chilin and Touman formations was first shown in 1932 in coloured geological maps of Chilin (Kirin) and Touman-chiang sheets (scale: 1/400,000) by M. KAWADA and USHIMARU, respectively.

Significant advances in the geology of Central and North Manchuria were made from about 1940. Various Palaeozoic fossils were discovered successively at places as they were comprised already before 1946; marine faunas of four periods from Silurian to Permian in addition to Permian nonmarine shells and plants.

These Palaeozoic formations were combined into the proposed Manmo group in 1942, it being quite different from the South Manchurian stratigraphic sequence which consists of the Sinian-Chosen and Taitzuho groups intervened by a prolonged Middle Palaeozoic break. A comparative study of the Manchurian Manmo group with the related formations of the neighbouring areas has shown that it is the sediment of the Mongolian geosyncline which was deformed by the orogenies and consolidated by the batholitic granite invasion in the Permo-Triassic period. Therefore, I expressed this conclusion in my paper on "The Akiyoshi Orogenic Cycle in the Mongolian Geosyncline," in 1942.

Recently, considerable work has been carried out by Chinese geologists in Northeast China, yielding a wealth of valuable results among which is the discovery of Ordovician *Cardiograptus* on the Mongolian side of the Great Khingan range which is quite new to the Manchurian stratigraphy. Likewise, the find of the Cambrian archaeocyathid limestones in Transbaikalia, Northeast Mongolia and the Hanka Lake area are included in the considerable advancement made in the geology of the west, north and east sides of Manchuria made by Soviet and Mongolian geologists. I have tried, on one hand, to collect new data afforded by foreign scientists as much as possible. On the other hand, I referred to recent papers by YABE and IMAIZUMI (1946), KON'NO (1947, 1958), NODA (1951, 1956), HAMADA (1960, 1967, 1968) and KOBAYASHI (1947, 1948), as well as the geological maps of the Far East, 1956–60 (scale: 1/250,000).

Here the Manmo group is restricted to the formations of the Mongolian geosyncline from Middle Silurian to Middle Triassic, and the Infra-Manmo group is proposed for the formations from Sinian to Silurian which, though not well known, are the sediments in the progenitor of the Mongolian geosyncline probably not so far extended to the south.

The stratigraphy of the Manmo group and its faunas in Manchuria are described in detail in this paper and the groups in the neighbouring areas also elucidated for comparison. A discussion is given on the epirogenies of the Koreo-Chinese heterogen and the Silurian and Devonian marine ingressions on its east side. The concluding chapter discusses the history of the development of the Mongolian geosyncline by the Permo-Triassic orogenies on the basis of new data.

This paper is a synthetic study of the regional geology which I have studied for nearly 40 years with keen interest from the viewpoint of the tectonics of eastern Asia. My conclusion that the Manmo group of Manchuria and adjacent areas is the sediment of the Mongolian geosyncline which suffered strongly from the Permo-Triassic Akiyoshi orogenic cycle has been fairly well established by the facts gathered by many geologists and palaeontologists. Therefore, it is quite inadequate to refer the crustal deformation to the Hercynian cycle which was already declined in the type area of Europe before the rise of the Akiyoshi cycle.

A long bibliography has been added at the end of this synthesis to show the source of data.

II. The Manmo Group and its Substratum in Central and North Manchuria and Extreme Northeast Korea

Little was known of the pre-Mesozoic stratigraphy of Central and North Manchuria in 1927 when AHNERT summarized existing facts on the regional geology. In the same year ICHIMURA proposed the Hekijo group for a Palaeozoic formation in the northeastern part of Korea which I later called Touman area (1933). Its distribution in the area is shown in the General Geological Map of Chosen (Korea), 1927 (scale: 1/1,000,000) as the Heian system. No mention was made by KAWASAKI (1926) of the non-Heian speciality of the Touman area Palaeozoic formation in *The Geology and Mineral Resources of the Japanese Empire*, published in 1926.

Subsequently, TAN and WANG (1929) reported the Lower Sinian on the North Manchurian plateau; LICENT and TEILHARD DE CHARDIN (1930) reported some fossil localities in the Great Khingan range and proposed Linsi series for Upper Palaeozoic rocks in the southern part of the range; and KOBAYASHI (1931) described some Upper Palaeozoic molluscs from the central part of the range and named this fossiliferous formation the "Soron series."

In the following year M. KAWADA proposed the designation "Chilin formation" for a Palaeozoic formation near Chilin in East Manchuria; USHIMARU named another formation in Chientao district, southeastern Manchuria the "Touman formation." Their distribution was shown in the geological maps of Chilin and Touman-chiang, and their sequences were described in the explanatory texts.

In 1934 RAUPACH compiled a summary of the geology of Central Mongolia, Manchuria and the Russian Far East. SAITO (1940) distinguished two types of Palaeozoic sequences, the North Manchurian type sequence which is quite different from the South Manchurian one in which the Sinian and Cambro-Ordovician formations are disconformably overlain by the Upper Palaeozoic from Moscovian to Upper Permian. The former is a sediment of the Mongolian geosyncline for which KOBAYASHI (1942) proposed, with NONAKA, the "Manmo group" as a collective term for a series of Palaeozoic rocks.

As described below, the stratigraphy of the group in Manchuria greatly improved in the years from 1940 to 1945, and as the result it was found that it comprised Middle Silurian, Coblenzian, Eifelian, Givetian, Visean, Moscovian, Sakmarian, Artinskian and later Permian faunas. In addition there are plant beds containing *Gigantopteris* flora and an Upper Permian naiad bed. There is pre-Eifelian clino-unconformity at the base of the Huolungmen formation and possibly a pre-Givetian one at the base of the Heitai formation. An early or middle Permian unconformity is found between the west Ujimuchin and Dabussumnor formations. In the Great Khingan range the nonmarine Hahai formation was deposited after the retreat of the Permian sea from Manchuria. A significant fanglomerate containing boulders of granite and gneiss is known to exist in the Chiente area.

The Silurian coralline limestone is contained in a volcanic breccia bed of Ertaokou. Tuffaceous rocks meet within the Devonian Huolungmen and Heitai formations. Pyroclastic rocks at the top of the Chilin formation are evidently post-Sakmarian. Together with tuff in the Soron series and the andesite flows in the Linsi series the pyroclastics must be products of Permian volcanic activity.

TANG and WANG (1929) suggested a Lower Sinian age for the quartzite south of Memachieh, along the Kanho on the North Manchurian plateau, but gave no evidence on this chronology. According to HARAGUCHI (1937), there is a Palaeozoic formation in Sanho, Barga, in Northwest Manchuria which consists of quartzite in the lower part, sandstone, shale and limestone in the middle part, and limestone in the upper part. The quartzite appears to be Sinian overlying ancient gneiss.

ASANO (1941) designated the metamorphic rocks near Titaoshan as the "Mashan series." From its lithology he correlated it with the pre-Cambrian Liaoho group in South Manchuria.

In the vicinities of Ch'eongchin (Seishin) and Yeonjin (Renshin) in northeastern Korea there are metamorphic rocks previously thought to be pre-Cambrian, but Mesozoic plants were discovered therein by SHIMAMURA (1933). A crystalline limestone mass south of Kungchuling was once referred to as Ordovician by HATA (1927), but this has not yet been proven by fossil evidence. Little is known of the metamorphic rocks of other places. In Central or North Manchuria no fossiliferous formation older than Silurian was known. The base of the Manmo group was unknown.

As shown in detail later, significant advancement has been made in the Palaeozoic stratigraphy of this part of Northeast China by Chinese geologists and palaeontologists in the past 25 years. Ordovician *Cardiograptus* was discovered recently in the Great Khingan range, although I have not yet seen a description and illustration. Additional contributions were made by YABE and IMAIZUMI (1946), KON'NO (1947, 1958), NODA (1951, 1956), HAMADA (1960, 1967, 1968) and others. In 1951 I contributed a paper entited "The Manmo Group in Central and North Manchuria and its Relation to the Geology of the adjoining Territories" to the Japanese Edition of *Geology and Mineral Resources of Eastern Asia,* Section on Manchuria.

A. ORDOVICIAN

In the Great Khingan range it was found that a thick formation, about 4,000 m in thickness, is overlain by the Devonian formation unconformably. Its upper division, or Suhuho formation, consists of slates in the upper part and sandstone and conglomerate in the lower part in which *Cardiograptus, Illaenus, Acrolichas, Strophomena* and *Rafinesquina* were found. The Haluhaho formation composed of

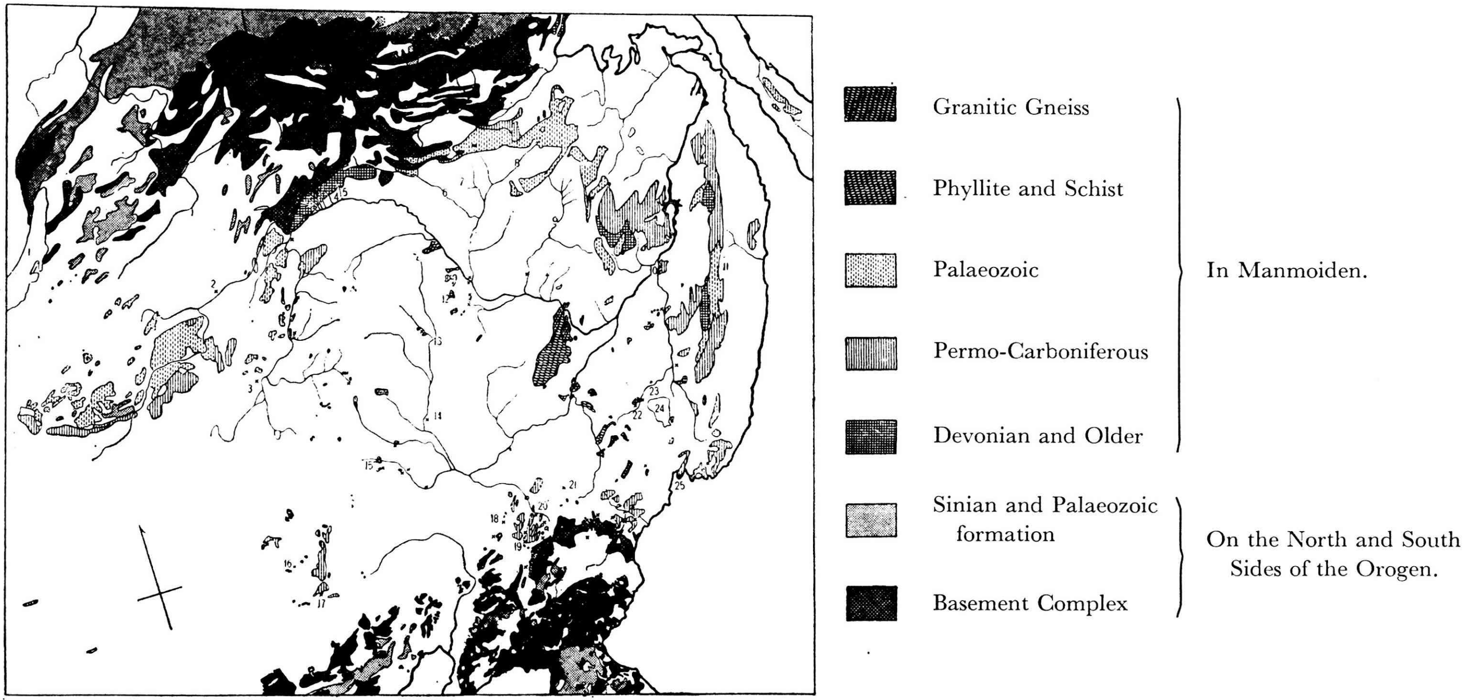

Fig. 1. Distribution of Older Rocks in Manchuria.

1. Baikal Lake
2. Nertschinsk
3. Manchouri
4. Urscha River
5. Oldoi River
6. Seja River
7. Dep River
8. Selimya River
9. Bureja River
10. Chabarowsk
11. Sikhota Alin Mountains
12. Houlungmen
13. Nengkiang
14. Tsitsihar
15. Soron
16. West Uji-muchin
17. Linsi
18. Hsinking
19. Panshih
20. Chilin
21. Yüchuan
22. Heitai
23. Mishan
24. Hanka Lake
25. Vladiostock

sandy shale and crystalline limestone in addition to porphyry and porphyrite is found in the lower division.

B. Silurian

Among the fossils distinguished in a limestone lens of a thick formation of breccia at Ertaokou, west of Chilin were *Pseudomphyma infundibula* Yabe and Eguchi, *Spongiophyllum sugiyamai* Yabe and Eguchi, *Favosites* sp. nov., *Striatopora* cf. *cristata* (Blumenbach), *Cladopora* (?) sp., *Aulopora* (?) sp. and *Pachypora* (?) sp. A vastly similar *S. sugiyamai* with *S. yoshii* Sugiyama from the Middle Silurian Kawauchi series in the Kitakami mountains, North Japan was also noted by Yabe and Eguchi (1943, 1944, 1945).

According to Hamada (1960), however, some of the fossils are allied to Devonian ones. Yu and Chang (1951) collected *Favosites* and *Disphyllum* and some other fossils in limestone in the middle part of a shale and limestone formation separated from the volcanic breccia and tuff by gneissose granite. *Disphyllum* is a Devonian coral known also in Korea and South China.

In the *Stratigraphic Tables of China* (1956) this formation is cited as the Ertaokou series of middle Silurian age overlying Pre-Sinian metamorphic formation which is composed of crystalline schists and granite gneiss. According to Yeh Chin-cheng and others the series is thicker than 900 m. They obtained *Coronocephalus rex* Grabau (?) in coralline limestone intercalated in the upper shale and sandstone formation of the series which is intruded by granite. This trilobite is a characteristic member of the middle Silurian fauna of South China.

In a report of the Chinese Stratigraphic Conference, Mu (1964) noted that the series reveals a cycle of sedimentation which is chiefly made up of limestone in the middle and clastic rocks in the lower and upper parts corresponding to the three series of the Silurian cycle in South China.

Kuo Hong-tsun (1962) described Silurian trilobites collected from massive coralline limestones in three horizons of the series at the Hsiaosuiho near Ertaokou and concluded that the age of the trilobites is late Wenlock or early Ludolow. They are

Calymene cf. *blumenbachi* Brongniart,
Otarion diffractum conveximarginatum Kuo,
Otarion sphaericum Kuo and
Encrinurus sinicus Kuo.

Tuff and acidic lava are contained here in the upper part of the series. Judging from these facts the Ertaokou series is Middle and Upper Silurian in age but its upper part probably extends up into the Devonian.

C. Devonian

In Manchuria Devonian fossils were first discovered at Mishan on the southeast foot of the Wantashan range, and then at Huolungmen and Nichuiho in North

Manchuria. Recently, a good display of the Devonian system has been found in the Great Khingan range.

Black shales which form the basement of the gold placer deposit at Nichuiho in the northern part of the North Manchurian plateau were considered to be Coblenzian by YABE and SUGIYAMA (1942), because it contained *Pleurodictyon nodai* YABE and SUGIYAMA, *Syringaxon* (?) sp., *Stropheodonta* cf. *sedgwicki* D'ARCHIAC et DE VERNEUIL and an indeterminable brachiopod.

In limestone at a point 41 km northeast of Huolungmen on the same plateau, R. KONDO found some fossils. Because his collection contained *Spirifer* of the *striatus* group, a strophomenid, *Hyolithes* and a phacopid, KOBAYASHI and NONAKA (1942) suggested Eifelian for this faunule. NONAKA (1944b) confirmed this chronology when he described *Stropheodonta* (*Leptostrophia*) n. sp., *Stropheodonta* n. sp., *Gypidula* cf. *mansuyi* GRABAU, *Camarotoechia* sp. indet., *Atrypa desquamata* SOWERBY and *Spirifer tonkinensis* MANSUY.

According to NONAKA, the succession of the Devonian formation near Chinshuei railway station on the plateau is in descending order as follows:

f. Green sandstone......more than 20 m thick

e. Conglomerate containing abundant and laterally thinning granite boulders......about 2 m thick

d. Green calcareous sandstone rich in brachiopods, pelecypods, gastropods, trilobites and other fossils......about 200 m thick

c. Dark green platy limestone......about 50 m thick

b. Trachytic tuff containing some fossils......about 10 m thick

a. Green massive calcareous sandstone......30 m thick

NONAKA (1944b) discriminated *Plectospirifer* cf. *grabaui* YABE and SUGIYAMA, *Hypthyrinda parallelepipeda* (BRONGN.) var., *Camarotoechia* sp. and *Schellwieniella* (?) sp. among the brachiopods. The formation, cut by numerous dykes, is steeply inclined to the NE with a strike N 60°W. It overlies reddish green or green siliceous slate clino-unconformably and is overlain by late Mesozoic (?) conglomerate.

HOU Hung-fei (1959) distinguished Coblenzian and Givetian species among the brachiopods from the Huolungmen and Chinshuei areas. Recently, HAMADA (1968, 1971) identified 30 species in 29 genera of brachiopods in NONAKA's collection from Huolungmen and Chinshuei and determined their age to be Siegenian to Emsian, possibly early Emsian, by the presence of *Proschizophoria, Chonostrophia, Aesopomum, Leptostrophia*, etc. This fauna shows close similarity to the contemporaneous faunas of Kazakhstan and the Altai, but includes also typical genera of Rheinish-Bohemian, Appalachian, Cordilleran and Australasian regions.

WAN and YU (1964) classified the Devonian strata in the Lesser Khingan range as follows:

5. Tungkulan group, about 3,000 m thick, consisting chiefly of liparite and tuff in the upper part and sandstone in the lower part.

4. Kenlyho formation, about 1,400 m thick, Givetian; mainly bedded limestone and sandstone, but porphyrite also included.
3. Upper Huolungmen formation, thickness unknown, Eifelian, composed of sandstone, limestone and slate with intercalation of acidic lava.
2. Lower Huolungmen formation, 800~900 m thick, Coblenzian; variegate sandstone, sericite schist, tuffaceous sandstone, siliceous limestone and shale.
1. Nichuiho formation, 1,500 m thick, Gedinnian, Silurian; variegate sandstone, sandy shale, diabase, diabase-porphyrite and tuff.

The slightly metamorphosed Silurio-Ordovician group lies below the above-mentioned sequence and the Lower Permian above it, both unconformably.

The *Clymenia* limestone is absent in the above sequence, but is found in the northern part of the Great Khingan range. As the result of geological surveys by WAN Ying and NING Chi-sheng (1957) and NING and TANG Ke-tung (1959), and palaeontological studies by CHANG An-chi (1958–60) and HOU Hung-fei, the Devonian system, particularly its middle and upper parts, was well clarified in this district. Its sequence is summarized by WAN and YU (1954) as follows:

Famennian Upper Taminshan formation, about 1,600 m thick, chiefly built up of acidic volcanic rocks and their tuffs with intercalation of andesitic porphyrite; *Clymenia* limestone in the basal part.

Frasnian Lower Taminshan formation, about 1,000 m thick; tuff, sandstone and conglomerate in addition to *Alvelolites* limestone.

Givetian Kentuho formation, about 300~800 m thick, chiefly composed of porphyrite, shale and sandstone; *Mucrospirifer* and other brachiopods abundant in siliceous limestone and graywacke in the lower part.

Eifelian Wunuerh formation, about 5,000 m thick, coralline limestone and conglomerate, beside shale and porphyrite.

Silurian-Devonian Lukuo group built up with phyllitic shale, black slate and sandstone in the upper and coralline limestone in the lower part.

List 1. The Clymenienkalk Fauna of Haishen near Taminshan (A. C. CHANG, 1958)

Cheiloceras subpartitum MÜNSTER
Cheiloceras globosum MÜNSTER
Sporadoceras pompeckji WEDEKIND
Sporadoceras biferum PHIL.
Sporadoceras subbilobatum MÜNSTER
Sporadoceras latilobatum CORRENS
Sporadoceras spp. nov.
Pseudoclymenia weissi WEDEKIND
Pseudoclymenia spp. nov.
Postprobolites frechi WEDEKIND
Postprobolites spp. nov.
Platyclymenia annulata MÜNSTER

The last group overlies the Ordovician unconformably and the first is overlain by the Tournaisian Hungshueichuan formation probably with conformity.

CHANG (1958) is of opinion that the above Clymenienkalk contains a unique fauna in China which is intimately related to the early and middle Famennian *Sporadoceras-Prolobites* fauna of the Rheinland. YAO Shu-chih (1959) disagreed with CHANG in correlating it with the *Yunnanella* fauna in South China.

In East Manchuria HATORI discovered a fossiliferous limestone at Mishan on the south side of the Wantashan range. Its stratigraphic succession is as follows:

d. Dark blue tuff containing dark gray quartzite about 10 m thick...... 70m thick

c. Sandstone with dark gray quartzite intercalations......30 m thick

b. Fossiliferous limestone......50 m thick

a. Quartzite......5 m thick

The last appears to be underlain by metamorphic rocks. Devonian age was suggested by KOBAYASHI (1941) for the fossils collected from the limestone at Shinano village, Mishan-hsien.

In NAGAO and MORITA's collection from the same limestone at a point about 8 km northeast of Heitai station, YABE (1940) identified *Spirifer* (*Adolfa*) sp. aff. *S. lorigea, Atrypa aspera* (SCHLOTHEIM), *Leptaena rhomboidalis* (WILCKENS), *Favosites* sp. and *Lioclema* (*Lioclemella*?) sp. Subsequently, YABE and SUGIYAMA (1942) described two new species, *Plectospirifer grabaui* and *Favosites multispinulosus*, and reported their age to be not older than Givetian. There the Devonian formation which underlies the Jurassic coal-bearing formation of Mishan, is composed of green tuff, alternation of black and fine sandstone, coarse sandstone, conglomeratic arkose sandstone and calcareous sandstone, the last of which transmits into limestones at various places. The formation strikes ESE, dipping about 40° to the southwest.

On the basis of YÜ and CHANG's observation, it is cited in the *Stratigraphic Tables of China* (1956) that the sequence of the Heitai formation, about 200 m thick, is, though discontinuous, pebbly arkose and tuffaceous sandstone beds, black silicified shale, alternation of sandstone and shale, sandstone beds, impure crystalline limestone intercalating shale and sandstone, shale beds with sandstone intercalation, fossiliferous crystalline limestone and a 23 m thick sandstone bed which overlies gneiss.

MU (1955) described *Devonoblastus heitaiensis* (nov.), YANG (1956, 1958) described 28 species in 20 genera of Bryozoa and TANG Chan-chiu (1966) described 10 species in 6 genera of corals, while HOU (1959) criticised YABE and SUGIYAMA's identification of brachiopods. YANG considered bryozoans collected from 4 horizons to be distinct from early Devonian ones and to be Givetian or Frasnian in age. Likewise HOU considered the brachiopods from Peichenchutaishan, Heitaichen to be of Givetian age. This conclusion was supported by HAMADA. On the contrary, TENG believed the Heitai tabulate corals to be Eifelian. YANG and TENG agreed that the Heitai fauna was distinct from South Chinese faunas, but similar to those of Central Asia and North America.

List 2. The Devonian Heitai Fauna, East Manchuria (Yabe, 1940, Yabe and Sugiyama, 1942, Mu, 1955, Yang, 1956, Wang, 1956, Hou, 1959, Hamada, 1960, Deng, 1966)

Favosites multispinulosus Yabe and Sugiyama	
Thamnopora cf. *pulchra* (Tchernyshev)	1
Thamnopora mishanensis Deng	2
Thamnopora mishanensis capistriata Deng	1
Thamnopora yangi Deng	2
Pachypora wangi Deng	1
Pachypora wangi thamnoporpides Deng	2
Striatopora linneata Billings	1
Cladopora cf. *cylindrocellularis* Dubatolou	2
Coenites khinganensis radiatus Deng	2
Syringocystis tabulata Deng	1
Fistulipora frondosa Yang	1
Fistulipora cf. *irregularis* Yang	2
Fistulipora mishanensis Yang	1,2
Fistulipora yui Yang	1
Fistulipora tatouhuensis Yang	2
Fistulipora leei Yang	1
Fistulipora changi Yang	2
Dybowkiella wangi Yang	2,3
Lioclema heitaiensis Yang	1
Lioclema tungi Yang	1
Lioclema jeni Yang	1,2
Lioclema irregulara Yang	1
Lioclema minor Yang	2
Lioclema sp.	4
Batostomella lineaxis Yang	1
Fenestella mishanensis Yang	2
Fenestella tatouhuensis Yang	1
Unitrypa acaulis Hall	1
Unitrypa sp.	1,4
Hemitrypa devonica heitaiensis Yang	2
Hemitrypa megafeestrula Yang	2
Hemitrypa sp.	3
Semicoscinium thyene sinensis Yang	2
Semicoscinium cf. *striatum* Nekhoroshev	1,2
Semicoscinium megafenestrula Yang	2
Semicoscinium delicatum Krasnopayaga	4
Semicoscinium kirinensis Yang	4
Semicoscinium sp.	4
Polypora lineata Yang	2
Orthopora sinensis Yang	1
Atrypa aspera (Schlotheim)	
Atrypa aspera kwangsiensis Grabau	
Lepataena rhomboidalis (Wilckens)	
Acrospirifer ? grabaui (Yabe and Sugiyama)	
Leptostrophia heitaiensis (Wang)	
Leptostrophia cf. *heitaiensis* (Wang)	

Stringocephalus sp.
Spirifer spp.
Devonoblastus heitaiensis Mu
Proetus-like trilobite

1, 2, 3, 4 indicate the lowest, second, third and fourth horizon of the Heitai formation in Chinchuhoushan, 9 km north of Heitai station.

D. Carboniferous

The principal part of the Chilin formation in the mountainous land of East Manchuria is known now to be Carboniferous in age. According to M. Kawada (1932), the formation in the Chilin sheet map area is 3,000 m to 4,000 m thick. It consists chiefly of hornfels, breccia containing acidic volcanic blocks and limestone. In the lower and middle parts limestones are generally found as small lenses, but thick limestone beds, over 500 m thick, are in the upper part. Ozaki (1941) found Moscovian fusulinids in limestones at Yentungshan, 90 km south of Changchun and at Ertaohotzu, Pingchi-hsien, while Yoshimura discovered *Syringopora* and other Dinantian fossils in the vicinity of Panshih (Kobayashi, 1941).

Okada (1940) surveyed the Chilin formation near Mincheng and found the following succession:

Upper	f. Pyroclastic rocks e. Black slate
Middle	d. Limestone, 2,000 m thick, containing crinoids and corals. c. Clayslate mainly, but some limestone, sandstone and hornfels are added.
Lower	b. Limestone, 500 m thick, crinoid and coral bearing. a. Shale with thin beds of limestone, clayslate and hornfels.

Okada noted that it would be better not to include the pyroclastic rocks on the top with the Chilin formation. In my opinion, the post-Sakmarian pyroclastic rocks at the top of the Chilin formation may be correlated to the Lower or Middle Permian tuffaceous facies in the Ussuri-Suifung region mentioned later.

According to Saito's preliminary determination, Okada's collection from the division west of Taoshan contained *Dibunophyllum* cf. *platiforme, Plicatifera* aff. *chaoi, P.* aff. *trenulata, Cribrogerina* sp., *Spirifer* sp., *Fenestella* sp., *Productus* aff. *giganteus* and *Orthothetes* aff. *crenistriata. Orthothetes* aff. *ruber* was contained in clayslate of the same division 500 m north of this locality. Crinoids, corals and productids were collected in the passage beds between the a and b divisions at a locality 500 m west of Luchuantzu. Pectinids and plant fossils were found in clayslate of the c division 1 km west of Laotaokou and other places.

Toriyama and Minato (1942, 1943 and 1950) distinguished the following fossil zones in the limestone between Luchuantzu and Tungluchuantzu:

f. *Pseudoschwagerina* zone......Sakmarian

e. *Londsaleia floriformis floriformis* zone with *Siphonodendron asiatica* var. *minor* MINATO

d. *Auloclisia* zone with *Caninia, Clisaxophyllum* and *Thysanophyllum*

c. *Siphonodendron* zone with *S. asiatica minor*

b. *Gigantella latissima* zone with *Gigantella manchuriensis* MINATO, *Siphonodendron asiatica minor* and *Millerella* sp.

a. *Dibunophyllum* zone with *Clisaxophyllum, Palaeosmilia* (?), *Carcinophyllum* and *Dibunophyllum*

MINATO is of opinion that zones a to e belong to Dinantian and most probably to Visean or Chesterian in North America. YABE and MINATO (1944) added *Aulina manchuriensis*, nov. from Taoshan to this fauna. No Uralian fossil has been uncovered from the Chilin formation.

YU and CHANG classified the Lower Carboniferous near Mincheng into the lower alternation of limestone and sandstone, middle dark gray limestone and upper light gray limestone and collected *Caninia* in the lower alternating beds suggesting the Tournaisian age.

YEH Chihcheng and others divided the Permo-Carboniferous formations of this district into the Upper Permian(?) Tanshan formation, Lower Permian Shuoshan formation and three Carboniferous groups as follows:

3. Upper Carboniferous Panshih group

   Upper part, about 500 m thick; shale, sandstone and thin beds of limestone containing *Schwagerina* and *Pseudoschwagerina*.

   Middle part, about 570 m thick; *Triticites* limestone.

   Lower part, about 940 m thick; black hornstone, shale, limestone and basal sandstone.

2. Middle Carboniferous Mincheng group

   Upper part, 800～900 m thick; black hornstone, shale, sandstone, limestone; corals and brachiopods.

   Lower part, 500～600 m thick; limestone containing *Profusulinella, Choristites* and *Chaetetes*; basal conglomeratic sandstone, 8 m thick.

1. Lower Carboniferous Luchuan formation, 1,000 m thick; variegate shale, sandstone, thin limestone beds; Visean corals and brachiopods.

The so-called Yüchuan group in the Ashiho tributaries southeast of Harbin has slate, limestone and sandstone in the lower part which are altered into marmor and graywacke by contact effect of granite and porphyry intrusion. *Zaphrentis, Productus* and other Lower Carboniferous fossils are contained in this part.

Visean brachiopods are reported to occur in tuffaceous slate beds near Tungkulan, Aihung-hsien, Lesser Khingan range.

The Hungshueichuan formation on the right bank of the Argun river begins with thin basal conglomerate overlying metamorphosed Older Palaeozoic formation. It is composed of sandstone, siliceous limestone and shale in alternation and yields Tournaisian fossils; it is 700 to 1,150 m thick.

The Meningkuho formation, 700 to 1,000 m thick, in the Hailar and the

Halaha river districts consists chiefly of andesitic tuff which is, however, associated with limestone, sandstone and porphyry. Corals and brachiopods therein are close to those of Transbaikalia and Central Siberia.

E. PERMIAN

This system is widely distributed in Manchuria from the Great Khingan range to East Manchuria. In the southern part of the range there is an Upper Palaeozoic formation for which LICENT and TEILHARD DE CHARDIN (1930) proposed a name "Linsi series." It is mainly composed of green slate and conglomerate but is also intercalated with thin beds of limestone containing Permian fossils.

On the southwestern hill of West Ujimuchin several brachiopods were found by UEDA in a limestone formation. Preliminary determination indicated that they were *Productus* sp., *Spirifer moosakhailensis, S.* cf. *cristata* var. *octaplicata, Martinia* sp. and *Camarophoria* cf. *purdoni.* Between West Ujimuchin and East Hochit as well as between West Ujimuchin and Dabussumnor, the West Ujimuchin formation is overlain unconformably by the Dabussumnor formation.

A part of UEDA's collection from the West Ujimuchin formation was studied by NONAKA (1944a). In describing *Productus (Marginifera) gobiensis* CHAO, *Spiriferina multiplicata* SOWERBY and *Spiriferella* cf. *saranae* VERNEUIL mut. *lita* EHRENBERG, he noted that the age of the faunule was younger than Uralian as the first species occurs in the Jisu Honguer formation.

According to OKADA, Permian rocks in the north of Dabussumnor are different on the two sides of a meridional fault zone. On the east side graywacke and clayslate are predominant and some conglomerate; limestone and arkose are also added. On the west side conglomerate is well developed beside clayslate and graywacke and among them limestone, andesite and agglomerate are intercalated.

NODA confirmed that the faunas contained in the formations on the two sides were intimately related to that of Jisu Honguer.

LICENT and TEILHARD DE CHARDIN (1930) found crinoidal limestone at Kharto, west of Erekto on the railway line between Tsitsihar and Mandsduri (or Manchouli). According to USHIMARU and others (1932), Upper Palaeozoic graywacke, quartzite and limestone are found near Djalaitewanfu and *Palaeofusulina*, brachiopods and pelecypods are found in a limestone at Wannuobo.

At Shihlaiyao located about 10 km northeast of Djalaitewanfu on the Chuoerho tributary, a branch of the Nengkiang, K. KAWADA (1953) collected the following fossils:

Schwagerina pusila (SCHELLWIEN)
Ozawainella angulata (COLANI)
Codonofusiella cf. *paradoxina* DUNBAR and SKINNER
Cribrogenerina permica LANGE
Waagenophyllum sp.

In addition to them, some bryozoans and calcareous algae were also found. FUJIMOTO who examined these fossils suggested Middle or Lower Permian for the

Shihlaiyao limestone. This locality is located 50 km to the northeast of Soron.

At Soron 200 km WNW of Taonan HATCHO collected the following fossils from a tuffaceous sandy shale bed:

Aviculopecten khinganensis KOBAYASHI
Aviculopecten (*Deltopecten*) sp.
Crenipecten soronensis KOBAYASHI
Pleurotomaria yabeshigerui KOBAYASHI

According to S. YABE (1959) the Soron (Solun) formation consists of siliceous slate, schalstein, sandstone, quartzite and graywacke, locally accompanied by such metamorphics as schists, hornfels, spotted shales and crystalline limestones and widely covered by various Mesozoic volcanic rocks. According to K. KAWADA this fossil bed lies above the Shihlaiyao limestone. Therefore the age of the Soron faunule may be Middle or Upper Permian.

CHANG Li-Sho (1941) discovered naiads in dark yellow or gray clayslate and yellow sandstone exposed along the Hahai River adjacent to the north of Soron. KOBAYASHI and HISAKOSHI (1942) described the following species:

Carbonicola(?) *khinganensis* KOBAYASHI and HISAKOSHI
Carbonicola(?) *soronensis* KOBAYASHI and HISAKOSHI
Palaeomutela choi KOBAYASHI and HISAKOSHI
Palaeomutela hahaiensis KOBAYASHI and HISAKOSHI
Palaeomutela subrectangularis KOBAYASHI and HISAKOSHI
Palaeonodonta cf. *longissima* (NETSCHAJEW)

Because the last species was reported from the Kolchugino series in the Kuznetsk basin, West Siberia, the Hahai nonmarine shells are most probably late Permian in age.

In East Manchuria AHNERT found Palaeozoic sandstone, clayslate and limestone exposed as patches in the vicinities of Erhtsengtientzu, i.e., Yüchuan, southeast of Harbin and they were first thought Devonian (GRABAU, 1923–24). FREDERIKS identified the following species in AHNERT's collection and suggested Middle Permian for this fauna.

Polypora sykesi WAAGEN
Productus cf. *boliviensis* D'ORBIGNY
Productus weyprechi TOUL.
Productus mammatiformis FREDRIKS
Productus aculeatus MART.
Productus waagenia ROTHOPLETZ
Productus purdoni DAV.
Paramarginifera peregrina FREDERIKS
Spirifer striatus mut. *neostriatus* FREDERIKS
Spiriferella rajoh SALTER
Spiriferella lytha FREDERIKS
Spiriferella cf. *vercherei* WAAGEN
Bellerophon sp.

Aviculopecten cf. *subclathratus* KAYS.

Recently NODA described *Neospirifer moosakhailensis* (DAVIDSON), *Waagenoconcha* cf. *purdoni* (DAVIDSON), *Linoproductus cora* (D'ORBIGNY) and *Pseudomonotis* (*Aviculomonotis*) *kazanensis* (DE VERNEUIL) from a greenish gray sandstone interbedded with shales at Hsiehshao 8 km south of Yüchuan Station. According to him this faunule, early Permian in age, is intimately reluated to the Jisu Honguer fauna in Mongolia.

In the northern part of the Wanta-shan range, East Manchuria there is a Palaeozoic formation composed mainly of chert and clayslate beside some thin beds of limestone and sandstone. It is found between Hsiaochiaochi and Tungchen. According to K. KAWADA, two formations can be distinguished there. One called Toumuho is chiefly composed of quartzite, but is also intercalated with thin beds of sandstone, radiolarian chert and significant conglomerate. This may represent the extension of the Radiolaria-bearing siliceous slate formation of Chabarowsk mentioned later. The other is KAWADA's Kungszu formation which consists of sandstone containing plant remains, shale and conglomerate. The conglomerate containing red chert and quartzite, as in this formation, is also found in the Touman formation. It is probable that the two formations are separated by some kind of discordance.

The Permian formation on the two sides of the middle and lower Touman River is called Hekijo or Pyeoksoeg on the Korean side and Touman or Tumen on the Manchurian side. USHIMARU (1932) adopted HARIO's Touman (1923) for a Palaeozoic formation, about 800 m thick, in the Chientao district in the southeastern part of Manchuria. It is chiefly composed of conglomerate, sandstone, clayslate, hornfels, chlorite schist and limestone. NISHIDA (1940) states that the upper part of the Touman formation near Lungching is more than 500 m thick and consists mainly of sandstone, shale and limestone. ASANO (1939) reported the occurrence of *Spiriferina*, *Productus*, *Fenestella*, *Chonetes*, *Marginifera*, *Retzia*, (*Hustidia*) and *Camarophoria* in the clayslate and hornfels of the Touman formation at Tsaihsioutung and South Kaishantun.

Later, MINATO (1943) found *Polypora manchoukuoensis* MINATO, *Waagenophyllum indicum* (WAAGEN and WENTZEL), *Linoproductus lineatus* (WAAGEN), *Echinochonus* sp. and *Spiriferina* cf. *nasuta* WAAGEN at Kaishantun and correlated the fossil bed with the Middle *Productus* limestone in the Salt range and the *Yabeina* limestone of the Kitakami mountains in Japan.

NODA (1956) divided the formation into three parts as follows:

3. Upper division, more than 1,000 m thick, composed of gray clayslate, black phyllitic clayslate, conglomerate, sandstone and mica schists; dark greenish conglomerate 50 m thick at the base.
2. Middle division, about 600 m thick, built up with black and red clayslate, siliceous clayslate, conglomerate, and sandstone in which red clayslate and conglomerate are developed in the upper part.
1. Lower division, more than 1,000 m thick, consists of black clayslate,

shale, sandstone and hornfels in addition to two fusulinid limestones in two horizons.

He is of opinion that the Touman fossils which he obtained from different horizons are, as a whole, contemporaneous with the Kuma fauna of Kyushu; West Japan both characterized by *Lepidolina* and late Upper Permian in age.

List 3. Kaishantun Fauna (After NODA, 1956)

	Lower Division	Upper Division
Endothyra sp.	×	
Textularia sp.	×	
Tetrataxis subsphericus NODA	×	
Tetrataxisis sp.	×	
Lunucammina (?) *conica* LANGE	×	
Pachyphloia pediculus LANGE	×	
Pachyphloia tomanensis NODA	×	
Langena permica LANGE	×	
Geinitzina ovata LANGE	×	
Ozawainella sp.	×	
Schwagerina sp.	×	
Parafusulina imlayi DUNBAR	×	
Parafusulina cf. *constricta* CHEN	×	
Parafusulina spp.	×	
Misellina spp.	×	
Neoschwagerina (?) sp.	×	
Yabeina cf. *shiraiwnesis* OZAWA	×	
Yabeina sp.	×	
Lepidolina sp.	×	
Wentzelella timorica (GERTH)	×	
Waagenophyllum (?) sp.	×	
Fenestella sp.		×
Polypora (?) sp.		×
Chonetes sp.		×
Spirifer cf. *moosakhailensis* DAVIDSON		×
Spiriferella sp.		×
Spiriferina (*Tylotoma*) *cristata* SCHLOTH.		×
Pseudomonotis (*Aviculomonotis*) *kazanensis* (VERN.)		×
Crinoid gen. et sp. indet.	×	×
Mizzia velebitana SCHUBERT	×	

KON'NO (1947, 1968) classified the Touman formation near Kaishantun and Shan-Tsaihsiutung into 5 members in descending order as follows:

(5) Deep greenish phyllite with conglomerate including fanglomerate which contains boulders of granitic and gneissose rocks.

(4) Black sapropelic slate, more than 400 m thick, presumably of inland sea origin.

(3) Kaishantun plant beds, 170 m thick, composed of conglomerate, conglomeratic sandstone and varicolored shales.

(2) Conglomerate, 130 m thick, partly intraformational conglomerate.
(1) Red and gray phyllites.

Marine shells are contained in members 1 and 3, and the plant beds are considered possibly as an intercalated wedge or synchronous with but heteropic from member 3. On the contrary, IMAIZUMI (1946) noted that the plant-bearing conglomerate overlies marine sediments with unconformity of great importance.

List 4. Early Upper Permian Kaishantun Flora (KON'NO, 1968)
Lobatannularia heianensis (KODAIRA)
Paracalamites manchuriensis KON'NO
Sphenophyllum koboense KOBATAKE
Sphenophyllum trapaefolium STOCKM. et MATH. subsp. *minor* KON'NO
Sphenophyllum cf. *speciosum* KAWASAKI subsp. *minor* KON'NO
Alethopteris cf. *kaipingiana* STOCKM. et MATH.
Sphenopteris (*Asterotheca*) *Hallei* KAWASAKI
Sphenopteris (*Discopteris*) *Renieri* STOCKMANS et MATHIEU
Jidopteris satohokotoi KON'NO
Pecopteris arcuata HALLE
Ptychocarpus (*Pecopteris*) *arcuatus* STOCKM. et MATH.
Pecopteris kaishanensis KON'NO
Pecopteris (*Ptychocarpus*) *subcontigua* KON'NO
Pecopteris Yabei KAWASAKI
Neuropteridium kaishanense KON'NO
Neuropteridium kaishanense KON'NO (fertile)
Neuropteridium (?) sp.
Gigantopteris nicotianaefolia SCHENK
Protoblechnum Imaizumii KON'NO
Taeniopteris crassicaulis JONGMANS and GOTHAN
Aphlebia sp. HALLE, 1927
Nilssonia laciniata KON'NO
Cordaites Schenkii HALLE
Rhipidopsis baieroides KAWASAKI and KON'NO
Rhipidopsis Imaizumi KON'NO
Rhipidopsis cf. *palmata* ZALESSKY
Psygmophyllum cf. *flabellatum* (LINDLEY et HUTTON)

KON'NO distinguished 27 species in 19 genera in the Kaishantun flora which consists of 5 species of Sphenophyta, 13 of Filicophyta and Pteridospermatophyta, one of Cycadophyta, one of Cordaitophyta and 4 of Gingkophyta. He concluded that the flora "shows the typical assemblage of the flora of the Upper Shihhotse Series of North China, viz. *Gigantopteris nicotianaefolia–Lobatannularia heianensis* Assemblage, representing rather its earlier half" and that its age "should be Early Kazanian." YABE (1946) noted that the inclusion of *Brongniartites* sp. in the flora shows its connection with the Kuznetsk flora, but the species was later identified by KON'NO with *Protoblechnum Imaizumii* KON'NO. The Kaishantun flora, according to KON'NO, "differs essentially in its composition from any flora in the southern Primoriye of either the early or the later epoch of the Permian Period."

Concerning the Hekijo formation, TORIYAMA (1942) considered the *Pseudodoliolina-Parafusulina* limestone at Kokeouweon, North Hamyeongto to be Middle-Upper Permian. Black sandstone in the upper part of the formation and underlying limestone at Sangsanbong on the Korean side of the Touman river yield *Mizzia velobitana* SCHUBERT, *Pachypholia ovata* LANGE, *P. pedicurus* LANGE, *Parafusulina imlayi* DUNBAR, *P. subextensa* CHEN, *P. lungtanensis* CHEN, *P.* cf. *constricta* CHEN, "*Doliolina*" sp., *Neoschwagerina* cf. *margaritae* DEPRAT, *Yabeina hayasakai* OZAWA, *Y. shiraiwensis* OZAWA, *Sumatrina gemmellaroi* SILVERSTI, *Wentzelella timorica* (GERTH), *Fenestella* sp., *Chonetes chonetoides* (CHAO), and *Spirifer* cf. *mooskahailensis* DAVIDSON, *Spiriferella persaranae* GRABAU, *Spiriferina* (*Tylotoma*) cf. *cristata* SCHLOTHEIM (*Stratigraphic Tables of China*, 1956).

In the Touman area in Korea the formation consists of mica schist, sericite-chlorite schist and tourmarine-sericite schist beside limestone lenses in the lower part, green rocks, schalstein, tuff breccia and tuffite in the middle and clayslate and sandstone in alternation with intercalation of limestone lenses in the upper part. The tuffite and limestone lenses in the middle part yield *Productus* (*Linoproductus*) *ussuricus* FRED., *Lyttonia richthofeni* KAYSER, *Spiriferina*, *Pseudomonotis* and *Pseudodoliolina*. The upper part contains plants, foraminifers, corals, brachiopods, bryozoans, etc., among which *Yabeina*, *Sumatrina*, *Neoschwagerina*, *Mizzia*, *Paracalamites tenuicostatus* RAD., *Tersiella suchanica* RAD., *Pecopteris maritima* ZAL. are typical members. The fossils from the middle and upper parts are late Permian in age. The lower part contains only obscure corals and its age is indeterminable (KIM, 1967).

Recently, *Comia yinchunensis* HUANG, *Pecopteris anthriscifolia* (GEOPP.) ZAL., *Callipteris* ex gr. *Zeilleri* ZAL., *Rhipidopsis* sp., *Taeniopteris* sp., *Noeggerathiopsis* sp., etc. were collected in the Upper Permian Hungshan formation at Ichun and Shenshu on the Manchurian side of the Upper Amur valley (HUANG Peng-hung, 1966). Furthermore, it is noted by LEE Hsinghsueh (1964) that *Noeggeratiopsis* sp. is found at places in the Great Khingan range and that the Kuznetsk flora is widely distributed in Central and North Manchuria to the north of the line through Szupingchieh and Yenchi.

F. PALAEOZOIC HISTORY

The Palaeozoic formations in Central and North Manchuria can be classified into the Manmo and the Infra-Manmo groups, the latter of which consists of the Older Palaeozoic and late Proterozoic formations. More precisely, it includes the Silur-Ordovician in the Great Khingan range, the Cambrian(?) and Sinian (?) formations in the Great and Lesser Khingan ranges. The existing knowledge is still meager, but they are probably overlain by the Silur-Devonian unconformably.

The oldest fauna of the Manmo group is represented by the Silurian fossils in the Ertaokou series ranging from Middle Silurian to Devonian. The Chilin formation s.l. had primarily included various Palaeozoic formations in East

Table 1. Correlation of the Manmo Group in Central and North Manchuria and Northeast Korea.

Age		Great Khingan Range: South-West	Great Khingan Range: North, Central	Lesser Khingan	East Manchuria	Touman Area (NE Korea)
Permian	Upper	Dabussumnor	Hahai Soron	Hungshan		Touman: Upper Kaishantun
	Lower	Dabussumnor W. Ujimchin	Shihlaiyao		Yüchuan	Touman: Lower
Carbon.	Upper Middle		Upper Carbon.		Chilin s. s.: Panshih Mincheng	
	Lower		Meningkuho Hungshueiehuan		Chilin s. s.: Luchuan	
Devonian	Upper		Taminshan	Tungkulan	Heitai	
	Middle		Kentuho Wunuerh	Kenlyho Huolungmen		
	Lower		Lukuo	Nichuiho	Ertaokou	
Silurian						
Ordovician			Suhuho			
Cambrian			Haluhaho			

Manchuria from which, however, the Ertaokou, Heitai and Yüchuan formations (s. str.) were later eliminated. The Chilin formation thus restricted is mainly Carboniferous in age, but possibly includes the Sakmarian stage. The Yüchuan s.l. included Carboniferous, but here it is restricted to the Lower-Middle Permian rocks.

No stratigraphic break or discordance is known among these formations, while the Yüchuan and Chilin formations (s.l.) and the Ertaokou and possibly the

Heitai formations are partly duplicated to one another in age. In other words there is no sharp discordance among them.

These formations are chiefly composed of sandstone, shale and limestone, and conglomeratic sediments are uncommon whereas volcanic breccia is contained in the Ertaokou series, and tuff and tuffaceous rock occur at various horizons. They are as a whole thick sediments in the Mongolian geosyncline within which volcanic eruptions have taken place at times.

They are mostly roof-pendants on the Triassic granite batholith. The pendants are aligned on the granitized terrain in parallel to the northeast trend and these formations dip in various degrees, although little is known of their folded structure.

The Touman formation containing marine faunas and land floras is distributed on the Korean and Manchurian sides of the Touman river. With the marked contrast to the preceding formations it comprises a large amount of conglomerates and fanglomerates which contain granitic boulders and also reworked pebbles and black sapropelic mud facies like the Permian Usuginu conglomerate in Japan, and black slate like the Upper Permian Toyoma slate. These rock facies combined with the appearance of plant beds reveal the unstable epoch of the sedimentary basin and the surrounding land. The Touman formation was folded and intruded by granite after the crustal deformation. Therefore its base is unexposed in the area.

The Gedinnian-Silurian Nichuiho formation in the Lesser Khingan range and the Coblenzian-Silurian Lukuo formation in the Great Khingan range overlie the Older Palaeozoic group which is partly metamorphosed. The Devonian system in these ranges is a thick geosynclinal sediment, 6,500 to 8,000 m thick, and composed of shaly and sandy rocks, carbonates and volcanics. It is basic to acidic, but conglomerate is uncommon, although it contains abundant granitic rocks near Chinshuei, North Manchuria.

The Givetian was the inundation epoch in the Devonian period when the Heitai sea probably flooded the Mashan series in East Manchuria. The sea, however, later retreated and the outline of the sedimentary basin was modified during the late Devonian period. In the Great Khingan range the Devonian is overlain by the Tournaisian Hungshueishan formation unconformably (?), although the stratigraphic break between them is small because the *Clymenia* limestone occurs near the top of the Devonian sequence. The Lower Carboniferous on the Manchurian side of the Argun river begins with a thin basal conglomerate bed, overlying the metamorphosed Older Palaeozoic, while the Devonian of North Manchurian plateau is overlain by the Lower Permian. The Lower Carboniferous formation known in some places of the Great and Lesser Khingan ranges is 1,000 m thick or less and similar to the Devonian in the inclusion of pyroclastic material. Little is known of the Middle and Upper Carboniferous formations in the ranges.

The Permian formation possibly extending into the Uralian is distributed extensively in the Great Khingan range and adjacent areas. It is composed not only of terrigenous sediments but also of carbonates, andesite, agglomerate, tuff and other volcanic material. Its base is unknown, but the Lower Permian formation exposed at Dabussumnor is several thousand meters thick, and conglomerate and conglomeratic sandstone occur frequently.

The West Ujimuchin formation is a link between the Jisu Honguer formation in Suiyuan, Inner Mongolia and the Yüchuan formation in East Manchuria, all containing similar Lower Permian faunas, but lacking fusulinids. The Middle or Upper Permian fusulinid limestones are on the other hand known from the central part of the Great Khingan range.

An angular unconformity is known to exist between the West Ujimuchin and the Middle(?) Permian Dabussumnor formations. Another conspicuous feature is the existence of naiads and land plants in the Upper Permian formation. Judging from these facts the early Permian sea spread equatorially through the Great Khingan range, but later retreated allowing extensive areas of land to emerge. Such an emergence took place by means of crustal movement as indicated by the angular discordance and frequent intercalations of conglomerate in the West Ujimuchin formation.

G. Triassic Formations

The Manmo group is intruded at many places by the Triassic granite. The Triassic system was thought to have been unrepresented in Manchuria. Recently, however, it was found in the Natanhataling range in the eastern part of Heilungchiang province that the Upper Triassic Chingchiang formation, 3,000 m thick, is composed of variegate tuff, diabase, shale and sandstone and yields *Entomonotis ochtica* (Keyserling). It overlies the Palaeozoic unconformably and is overlain by the Jurassic Sanyang formation conformably (Chao Chike, Chen Chu-chen and Liang Hsi-luo, 1964).

All other Mesozoic formations are lacustrine sediments in intermontane basins whose basement are already well consolidated by the Mongolian granite batholith. They may be tilted, undulated and faulted by later movements, but scarcely folded. One of the oldest among them is found at Heitingshan in the central part of the Great Khingan range. It is a coal-bearing formation containing Older Mesozoic conchostracan remains (Kobayashi, 1951).

In short, it can be said for this part of the Mongolian folded mountains that the geosynclinal period has continued from Middle Silurian to Carboniferous, but the Permian is the orogenic period which continued to the Triassic before the Noric age. The Manchurian terrain culminated in the Older Mesozoic caused by the invasion of granitic magma.

H. The Basement Complex

The older rocks in Manchuria can be classified into the Manmo and Infra-Manmo groups and the Pre-Cambrian basement complex beside intrusive rocks. Ahnert (1927) suggested Pre-Cambrian for granite and gneiss to the southwest of the Hanka lake and Archaean for crystalline schists and granite in the Lesser Khingan range. As mentioned later, the former rocks on the east side of the lake are known to be overlain by the Sinian and Cambrian formations. In the Wantashan on the west side of the lake there is the Mashan series denominated by ASANO (1940), because its typical display is found near Mashan, Titao in the eastern part of Chilin province. It is composed of granulite, mica schist, crystalline limestone and dolomite, pyroxene-hornblende-plagioclase gneiss, garnet-bearing granite-gneiss and so forth among which granulite is predominant and graphite and sillimanite are deposited in the series. ASANO noted that it is lithologically comparable to the lower Liaoho system in South Manchuria.

Gneissose granite in the Laochangkuang-Sueiling range running parallel to the Wantashan from Chilin to the northeast was recently estimated to be as old as 600 million years (HUANG et al., 1965). The Chinese geologists classified the pre-Sinian metamorphic rocks in northeastern Manchuria into three groups as follows:

III. Upper Proterozoic Hsingtung group, about 2,800 m thick; quartzite, marble, gneiss, etc.

.........Unconformity (?).........

II. Lower Proterozoic Heilungchiang group, about 11,500 m thick; green schist, mica schist, quartzite, marble, etc.

.........Unconformity (?).........

I. Archaean(?) Mashan group, 3,000–6,000 m thick; various crystalline schists and gneiss.

According to YAMASHITA (1935), HARAGUCHI (1937) and OHKI (1959) the pre-Devonian sequence in Ch'i-kan district, Northwest Manchuria is as follows:

Silur-Ordovician(?) limestone and clayslate.

Ordovician-Cambrian(?) massive limestone with intercalation of clayslate.

Lower Cambrian(?) clayslate and sandstone in alternation.

.........Disconformity.........

Sinian along the A-Pa ho (river) and the Uron river; sandstone with clayslate in the upper part and hematite-bearing quartzite in the lower part.

.........Unconformity.........

Pre-Sinian granite-gneiss with mice schist lenses.

There is, however, no palaeontological evidence for these older Palaeozoic formations. On the other hand, it is noteworthy that *Ptilophyllum cutchense(?)*, *Taeniopteris*, *Equisetites* and *Podozamites lanceolatus* were identified by KAWASAKI among the fossil plants collected at Ch'eongjin and Yeonjin, northeast Korea in an older rock formation including mica schist and chlorite schist which were previously thought Palaeozoic or Pre-Cambrian (SHIMAMURA, 1933).

Our knowledge about the Infra-Manmo group and the Pre-Cambrian basement complex is still too meager in Central and North Manchuria to get a general concept of the Eo-Palaeozoic Mongolian geosyncline and the Pre-Cambrian basement of the geosyncline. Nevertheless, it is certain that the Mongolian geosyncline had extended in the Ordovician period as far as the central part of the Great Khingan range from the north and there were some patches of the Pre-Cambrian basement complex in the geosyncline, the Hanka massif, for example.

III. The Epirogeneses of the Hwangho Basin

The so-called Chungchao massif by HUANG extends from North China to Korea and South Manchuria. Older sediments were accumulated on the massif in the area which I called the Hwangho basin. As shown in Table 2, a conspicuous distinction in the stratigraphic sequence between the Hwangho basin and the Mongolian geosyncline exists in that it is largely broken by the Middle Palaeozoic emergence in the former, while there is no such a break in the latter. Another important distinction is the intrageosynclinal volcanism which took place repeatedly in the Mongolian geosyncline, whereas volcanic material is almost negligible in the sediments of the Hwangho basin, even when contained.

Table 2. Comparison between the stratigraphic sequences of the Mongolian Geosyncline and the Hwangho basin.

Geological age	Mongolian geosyncline	Hwangho basin
Lower Jurassic	Neritic-Paralic sediments	Daedong series
Upper Triassic		
Middle Triassic	Upper Manmo group	P'yeongan group
Lower Triassic		
Permian		
Carboniferous	Lower Manmo group	
Devonian		(Cheongseongni series)
Silurian		(Silurian boulders)
Ordovician	Infra-Manmo group	Korean group
Cambrian		
Sinian		Sinian group

The Chungchao massif was not such a simple *Urkraton* as the Laurentia, but a part of the Koreo-Manchurian Heterogen which is a heterogeneous aggregate of kratonic and quasi-kratonic blocks and various geosynclines with or without intrageosynclinal volcanism. Heterogen is, therefore, the antonym of simple monotonous Homogen as exemplified by such megakratons as Laurentia, Angara and Russia.

The total thickness of the sediments in the Koreo-Chinese heterogen is considerably different among the Shansi and Ordos blocks on the western side of the Chungchao massif and the Taitzuho, Liaotung-Pyeongnan and Okche'eon troughs aligned from north to south on the eastern side. I have already given a detailed account of the areal variation of the thickness of the Korean group in previous papers (1966, 1967 and 1968). The variation is far greater in the Sinian system.

Table 3. The Stratigraphic sequences and their thickness for the four subsiding zones in South Manchuria and Korea.

Geological Age \ Subsiding Zone	Tiehling (6300 m)	Taitzuho (2400 m)	P'yeongnam (10300 m)	Okch'eon (5500 m)
Lower Triassic	—	—	P'yeongan (1500 m)	P'yeongan (3500 m)
Permo-Carboniferous	—	Taitzuho (800 m)	P'yeongan (1500 m)	P'yeongan (3500 m)
Middle Palaeozoic	—	—	—	—
Cambro-Ordovician	—	Korean (1000 m)	Korean (1100 m)	Korean (2000 m)
Sinian	Fanho (6300 m) —	— Hsiho (600 m)	Sangweon (7700 m)	—

Four subsiding zones and five elevating ones alternate from north to south in the eastern part of the Chungchao massif. The four sedimentary zones are quite different in the stratigraphic sequence and also in the thickness of the contemporaneous formation, notwithstanding the fact that the Sinian, Korean and P'yeongan formations are generally para-unconformable to one another and their clino-unconformable contact is found exceptionally at a few small spots mostly in the marginal part of the Hwangho basin.

The Hwangho basin has suffered from the Middle Triassic disturbance called Shorin or Songnim through which all of these older formations were deformed, but the mode of crustal deformation was quite different between the sedimentary basins and sinking troughs. Generally speaking, the crustal deformation was gentle in the thin sediments of the labile basin, while it was severe in the thick sediments of the sinking trough. It was particularly strong in the P'yeongnam zone where the older Mesozoic Songnim phase was paroxysmal. The P'yeongan and older formations, some 10 km in total thickness, were strongly folded and thrust as detailed in my papers on the geology of Korea and South Manchuria (1953, 1956, 1967, 1969). The complicate geologic structure thus produced can hardly be seen in the mantle on any kraton.

The Triassic disturbance was especially important for the tectonic of eastern Asia in that not only the difference between these positive and negative zones or areas within the so-called Chungchao massif was greatly reduced or even nullified, but also the massif was united with the zone of the Mongolian folded mountains by the Triassic granitic batholith, leaving the Amur and Sikhote Alin geosynclines. Since the late Triassic epoch many new intermontane basins of different sizes were brought to being in the vase terrain of eastern Asia from Mongolia to Indochina regardless of the previous tectonic units.

In the Hwangho basin the sea had retreated in the late Ordovician but invaded the basin again in the middle Carboniferous. In repeated oscillations, the sea extensively flooded the basin till the middle Permian. After the retreat of the Permian sea, nonmarine sediments accumulated in the subsiding areas. Some areas emerged in the late Permian, whereas sedimentation continued in some other places till the early or middle Triassic period.

There was a long period of land in the middle Palaeozoic era, but Korea was an exception where local marine ingressions in this interval took place in the Silurian at one time and in the Devonian period at another as indicated by the Silurian derived fossils in limestone boulders of the Kyeomipo limestone conglomerate near Kyeomipo, about 30 km south of Pyeongyang and the Devonian *Disphyllum* limestone lenses in Sungheon district, North Korea and Tanyang, South Korea.

The Kyeomipo limestone conglomerate.—In 1932 Ozaki discovered fossiliferous limestones contained in a conglomerate bed at Songnim-ni adjacent to the northeast of Kyeomipo, Hwanghae-do. As a result of studies with Shimizu and Obata he reported the occurrence of the Silurian deposit in North Korea, denominating the conglomerate as Kyeomipo limestone conglomerate. Subsequently, YABE and SUGIYAMA (1937) added two stromatoporoids, *Clathrodictyon vesiculosum* NICH. & MUIR and *C. salairicum* YAVORSKY, to this Silurian fauna.

The geology of the area has been investigated by ICHIMURA (1927), SHIMAMURA (1929) and KOBAYASHI (1930). Because the Older Mesozoic Daedong series was found to overlie the *Coreanoceras*-bearing Lower Ordovician Songnim limestone clino-unconformably in the Songnim-myeon, I have emphasized the crucial importance of the crustal deformation indicated by this discordance, naming it Shorin, i.e., Songnim disturbance. This was later thoroughly proved at the Pyeongyang coal field and other places to be the most important orogeny of the

List 5. The Fauna of the Kyeomipo Limestone Conglomerate described by SHIMIZU, OZAKI and OBATA, 1934

Original Designation	Comments
(OZAKI, 1934)	
Amplexus spp. a and b	
Calophyllum ? sp. indet.	*Strombodes* (?) sp.
Storthygophyllum ? sp. indet.	
Cystiphyllum cf. *siluriense* LONDSALE	
Cystiphyllum sp. indet.	*Tryplasma* sp. ?
Heliolites sp.	
Plasmopora follis EDW. & HEIME	
Plasmopora nakamurai OZAKI	*Plasmopora* cf. *rudis* (Sil.)
Propora cf. *magnifica* POCTA	
Propora yabei OZAKI	*Propora* cf. *affinis* (Sil.)
Propora cf. *affinis* (BILLINGS)	
Koreanopora proporoides OZAKI	*Propora* sp.
Favosites cf. *gotlandicus* LAM.	*Corrugatopora koshuensis*
Favosites cf. *forbesi* EDW. & HEIME	
Favosites coreanicus OZAKI	Cylindrical *Favosites* group
Favosites kennihoensis OZAKI	Geographical varieties of *Favosites gotlandicus*
F. kennihoensis var. *regularis* OZAKI	
Favosites shimizui OZAKI	*Parafavosites shimizui* (OZAKI), Up. Silur.
Favosites minor OZAKI	*Parafavosites minor* (OZAKI), Low-Mid. Silur
Palaeofavosites aspera D.ORB.	*Palaeofavosites* sp. ? Low.-Mid. Silur.
Alveolites ? sp.	
Sapporipora favositoides OZAKI	
Syringopora bifurcata D'ORB.	
Syringopora sp. nov. ?	
Halysites escharoides FISH.-BENZ.	*Quepora ozakii* HAMADA Mid. Ordov.-Low. Silur.
Halysites sindoensis OZAKI	} Variation of *Quepora*
Halisites sapporiensis OZAKI	} *sindoensis* ?
Quepora cf. *sindoensis* (OZAKI)	} Mid. Ord.-Low. Silur.
(SHIMIZU and OBATA, 1934)	
Spyroceras cf. *microtextile* FOERSTE	
Sactoceras ozakii SHIMIZU and OBATA	
Huronia sp.	*Ormoceras nanum-O. harioi* group. Mid. Ord. Toufangian
Gomphoceras sp.	*Gomphoceras* ???

Liaotung-Pyeongnam trough (NAKAMURA, MATSUSHITA, KOBATAKE and IKEBE, 1957; KOBAYASHI, 1969).

Because the Daedong series is the Molasse of the Songnim orogeny, its basal conglomerate is greatly variable in facies and thickness. I have examined the Kyeomipo limestone conglomerate again carefully with the result it was ascertained that the Kyeomipo limestone conglomerate is not a Silurian sediment as they reported, but a special facies of the basal conglomerate of the Daedong series in which various limestone boulders were contained. OZAKI, SHIMIZU and OBATA separated the Daedong series from the Kyeomipo limestone conglomerate by faults, but it is actually traceable laterally as well as upward for some distance from the limestone-rich boulder conglomerate to conglomeratic sandstone containing well rounded pebbles and cobbles of various clastic rocks and this in turn into sandstone and shale beds in the higher part of the Daedong series. Its Older Mesozoic age or probably Upper Triassic—Lower Jurassic age was determined by fossil land plants and conchostracans, respectively, by KAWASAKI (1935) and KOBAYASHI (1951). Lately, NOVOJILOV and KAPEL'KA (1960) found a conchostracan faunule of the similar age in Central Asia.

During my reexamination I found Lower Ordovician *Coreanoceras* limestone, Middle Cambrian trilobite-bearing limestone, Lower Cambrian *Girvanella* limestone and *Redlichia* shale in the limestone conglomerate. In tracing the conglomerate to the northeast from Songnim-ni along the base of the Daedong series, it was seen to thin out (KOBAYASHI, 1935).

Many questions were raised about the identification of the so-called Silurian fossils. Insofar as I can judge it is certain that SHIMIZU and OBATA's *Huronia* sp. is an imperfect specimen belonging to the Toufangian *Ormoceras nanam—O. harioi* group. TEICHERT (1935) denied their *Gomphoceras* sp. There is no cephalopod in their collection which is typical of the Silurian fauna.

WEISSERMEL (1935), HILL and STUMM (1956) and HAMADA (1960) have questioned OZAKI's identification of the corals. According to HAMADA there are some Middle and Upper Ordovician forms as well as some Lower and Upper Silurian ones. Thus, various fossils from Upper Ordovician to Upper Silurian in age were included in their Silurian fossils.

Another question is the origin of the Kyeomipo limestone conglomerate. The thickness of the Korean group from the *Redlichia* shale to the Toufangian limestone is estimated there to be about 1,900 m thick and the Silurian formation of unknown thickness must have capped the group para-unconformably. Because the limestone-conglomerate contains various fossils derived from these three Eo-Palaeozoic systems and because these fossiliferous large boulders of the conglomerate belong to the early metaorogenic sediment, the Eo-Palaeozoic formations have begun to be deformed by the Songnim disturbance presumably with high dip and were all exposed, forming cliffs. The conglomerate in question accumulated near a cliff of the Silurio-Ordovician limestones a part of which would have been a talus debris, as the large limestone boulders were the size of a man's head or even larger and not well rounded. Because the limestone-conglomerate directly overlies the Lower Ordovician limestone and because the *Girvanella* and trilobite limestones and *Redlichia* shale are small pieces and uncommon members of the conglomerate at Songnim-ni, it is probable that the Lower and Middle Cambrian materials were transported for some distance (1950).

YABE (1940) claimed that the Silurian sediment should be found somewhere in Korea because the sediment must have been intercalated between the Korean and Pyeongan groups in the Daedong age. Until now, however, no Silurian sediment has been found either in Korea or in other part of the Hwangho basin, notwithstanding the contention that the Silurian formation in question was such an intercalation. Therefore, the question lies in the distribution and thickness of the Silurian formation. In other words, it was presumably so thin and its distribution so restricted that it was easily eroded out. If this presumption be acceptable, it would not be accidental that the Silurian derived fossils were found on the edge of the Hwangho basin, because it is probable that the embryonic subsidence of this synclinal basin had taken place already in the Silurian period which invited the formation of a local shallow sea.

Devonian Cheongseongni Series:—In the Korean peninsula the *Disphyllum* limestone is known from the following two localities:

(a) Imoktong, Cheongseongni, Sinchang-myeon, Suncheon-kun, Pyeongan-namdo, North Korea.

(b) Kosuri, Kumko-myeon, Tangyang-kun, Chungcheon-bukto, South Korea.

YABE and SUGIYAMA (1940) distinguished *Disphyllum* sp., *Phacellophyllum* sp., *Phillipsastrea* sp. and *Syringopora* sp. in OZAKI's collection from the limestone at locality (a) and suggested late Middle Devonian for their age. This limestone lies in the middle part of the so-called Cheongseongni series, 250–300 m thick, composed of limestone and shale beside the basal conglomerate overlying the Ordovician limestone disconformably.

The series is directly overlain by the Jido or Sadong series of the Pyeongan (Heian) system. In other words, it is located just in place of the Hongjeom (Koten) series in the general stratigraphic sequence in Korea.

Disphyllum sp. and *Phillipsastrea* sp. were collected by SUZUKI at locality (b) in a limestone near the base of the red shale and limestone series which used to be referred to as the Hongjeom series (YABE and SUZUKI, 1955).

As stated already, *Disphyllum* is known from Ertaokou, Chilin province, Northeast China and widely distributed in the Middle and Upper Devonian strate in South China, in provinces of Yunnan, Kueichow, Kuansi and Hunan. Therefore, these coralline limestones in Korea must be Devonian in age.

The relation between the Cheongseongni and Hongjeom series at these localities is an important question. Another question is whether the Devonian strata are very local or whether they are widely distributed in the Hwangho basin. The above two localities in the Pyeongan and Okcheon zones are all that is so far actually known of the Devonian marine ingression into the vast Hwangho basin. Recently it was reported that the Yemi lime-breccia, 70–160 m thick, Geseong shale, about 50 m thick and the Geseong limestone, 60–120 m thick, are intercalated between the Korean and Pyeongan groups in the Yemi district as the sole exception within the Taebaegsan region, South Korea, although their age is indeterminable (Geol. Surv. Korea, 1962). Recently the Silurian and Devonian systems were said to be clearly represented in South Korea in the Okch'eon metamorphic group, but no new palaeontological evidence was afforded to confirm their ages (Cheng et al., 1969).

The Silurian and Devonian ingressions in Korea are two exceptional events. In the Hwangho basin the Korean and Pyeongan groups are generally para-unconformable and the Toufangian limestone is found at the top of the former. The latter group begins with the Moscovian in the eastern part of the basin, while in the west the Lower Permian Taiyuan series lies directly on the Ordovician formation and the marine facies is lacking on the northwestern margin of the basin. Therefore, it is certain that the Permo-Carboniferous sea flooded into the Hwangho basin from the southeast side through the Pyeongnam and Okcheon troughs in Korea and probably the Shankiangan depression in Central China.

As mentioned above, the Taitzuho group of South Manchuria generally overlies the Korean group para-unconformably in the Hwangho basin, but there are a few exceptions in the northern periphery of the basin. Kiritani (1942) and Choh (Chang, 1943) found in the Nanpiao coal field in eastern Jehol that the Nanpiao coal-bearing series which yields *Lepidodendron* lies on the Toufangian para-unconformably at some places but overlies the Wanwanian (Basal Ordovician) and Cambrian formations clino-unconformably at some others. The phase of the crustal movement indicated by this discordance is known by the name "Nanpiao" (Kobayashi and Choh, 1942). A similar discordance was reported by K. C. Liu (1947) from the Yinghao coal field, Honan. In considering the age of the discordances to be between the Penchi (Moscovian) and the Taiyuan (Sakmarian) series, Chang (Choh, 1949) correlated this Uralian phase of movement with those of the Kumming phase in Yunnan and the Sakamoto phase in Japan.

Sugai (1948) on the other hand found in the Hsiaoshih coal field in the Taitzuho valley that the Penchi and Taiyuan (Huangchi) series are each marked off by a clino-unconformity at the base at a few places. More precisely, the Taitzuho group forms there an anticline and two synclines with equatorial axes, while a large synclinorium of the Korean group and Hsiho series beneath it has a meridional axis of folding.

In the valley of Miaokou, west of Hsiaoshih, the Ordovician formations strike from N to S and dips to the east with an angle of 10° to 20°. It forms a small syncline in a short distance before reaching the Tungho river. The Ordovician and Upper Cambrian formations in the valley are overlain clino-unconformably by the Moscovian Penchi series on the north side which strikes from E to W and dips 30° to 40° to the north. The Penchi overlies the Nanfen shale of the Sinian Hsiho series near 2 km NW of Hsiaoshih and the Lower Cambrian of Mataikou on the north bank of the Taitzuho river, north of Hsiaoshih, both clino-unconformably.

Another unconformity at the base of the Huangchi series is indicated by the fact that, overlapping the Penchi series toward the west from Miaokou, the Huangchi series rests directly on the Korean group possibly with a conglomerate bed at the base. It lies on the Sinian Nanfen shale on the north side of the valley and on the Lower Cambrian at Mataikou.

In the vicinity of Hsiehchiasueitzu the Nanfen shale on the north side is separated from the Korean group on the south side by a fault running from ENE to WSW. This fault is covered by the Taitzuho group. At a point 2 km south of Hsiaoshih another fault parallel to the preceding cuts the Taitzuho and Korean groups but the amount of displacement is quite different between the two groups. Therefore, SUGAI suggested that the faultings were repeated before and after the deposition of the Taitzuho group.

According to ONUKI (1967) the Lower Permian Taiyuan series unconformably overlies the Korean group in the Tatung coal field, Suiyang province and some places in the Tahangshan range, North China.

CHANG (1949) took the pre-Huangchi discordance for an indication of deformation in the Nanpiao phase and in proposing a new name, Hsiaoshih phase, for the pre-Penchi deformation he correlated it with the Weinan-Liukiang movement in Central and South China.

ONUKI on the other hand called the epirogenic emergence indicated by the para-unconformity between the Korean and Pyeongan groups as Tahang movement. At any rate, there were no strong orogeny in the Hwangho basin, comparable to the Caledonian or Variscan movement in Europe. In calling the emergence between Silurian and Devonian marine ingressions in Korea Suncheon phase, four movements can be distinguished in the Hwangho basin between the Toufangian and Taiyuan series as shown below, but even the Nanpiao and Hsiaoshih movements were epirogenic for the whole Hwangho basin and the above-mentioned angular discordances are negligible exceptions at a few points on the northern and southern margins of the basin.

Lower Permian Taiyuan series
..............Nanpiao phase
Moscovian Penchi series
..............Hsiaoshih phase
Devonian Cheongcheongni series
..............Suncheon phase
Sediments indicated by Silurian coralline limestone boulders
..............Tahang phase
Ordovician Tsinan limestone with the Toufangian series at the top.

It is well known at present that there was no strong crustal movement in the Hwangho basin between the Sinian and Cambrian periods and during the Cambrian and Ordovician periods, although there were epirogenic movements through which the outline of the sedimentary basin was modified. Such movements were repeated also during the sedimentation of the Pyeongan group. In North China the disconformities are found at some places between the Taiyuan and Shansi series, between the Shansi and Shihotzu (or Salachi) series and between the Shihhotze and Shihchifeng series. South Manchuria turned out land before the deposition of the Shihchifeng series. There was, however, no orogeny in the Hwangho basin in the Palaeozoic era. It was noted by KON'NO in the Penhsihu coal field that the Upper Permian Tsaichia series comprises in the basal part a conspicuous conglomerate facies which is comparable to the fanglomerate of the Touman formation. This conglomerate may be an indication of the sympathetic movement to the crustal movement of the Usuginu phase in the Mongolian geosyncline.

Assuming that the Shihnakan limestone of the Tachingshan range is a Sinian member, the northern margin of the Hwangho basin indicated by the distribution of the Sinian system does not deviate much from the Yenshan range and its eastern extension. The shoreline of the early Cambrian sea which is suggested by the distribution of salt pseudomorph extends from the Tatung coal field to Menchiang and Pataochiang in South Manchuria through Nanpiao, Jehol. Regarding the fossil record of the Korean group inhabitants at Wirnor 110 km northwest of Kalgan had Kushanian trilobites, but their true locality is unknown. The known northern distribution of the Cambro-Ordovician fossils of the Hwangho basin scarcely extends to the north beyond a line through Paotou, Chinshueiho and Tatung in Inner Mongolia, Ishun, Pingchuan and Linyuan in the Hopei-Jehol block and Liuho, Hueinan and Wusung in South Manchuria. This line is, I think, the approximate northern boundary of the basin (KOBAYASHI, 1967, 1969).

Incidentally, the Cambro-Ordovician Korean group is widely distributed in the Taitzuho tributaries and farther beyond the Yalu river in the Ch'osan, Kanggye and Huch'ang (Sosan, Kokai and Kosho) and other districts in the extreme north of Korea. Furthermore, it is noteworthy that Cambrian and Ordovician fossils are known to occur at the following localities (KOBAYASHI, 1966):

1. TOKUDA discovered Middle Ordovician Toufangian fossils at Shansungkang in Tunghau district.
2. KIRITANI collected early Middle Cambrian Tangshihan fossils at a locality north of Yangchiawan, Tatungkousun, Liuho-hsien, in the same district.
3. ASANO found Taitzuan, i.e., middle Middle Cambrian, fossils in the vicinity of Shuangkangtun, 20 km east of Hueinan.
4. SAITO collected some Ordovician fossils in the vicinity of Sungshuchen, Fusung.
5. ENDO (1944) described *Basiliella wusungensis* ENDO *B. chingkoutsuensis* ENDO from the Wuting formation near Chingkoutzu, Wusunghsien, Tunghua district.

6. ENDO (1944) reported the occurrence of the Tangshihan i.e. early Middle Cambrian brachiopods from the Pataochiang coal field, Tunghua-hsien.
These fossil localities are the northeasternmost ones of the Hwangho basin which suggest the shoreline of this part of the basin as shown in Fig. 2.

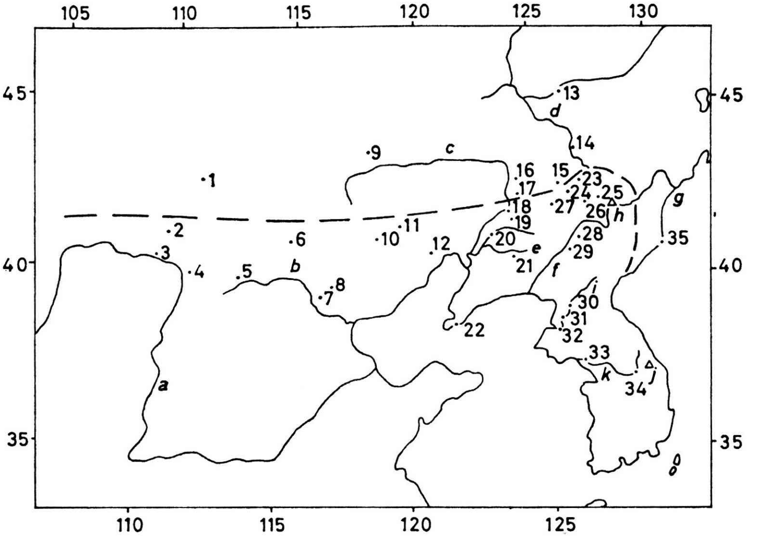

Fig. 2. Map showing the northern shoreline (broken line) of the Hwangho basin.

1. Jisu Honguer	13. Harbin	25. Wusung	c. Liaoho
2. Kuyang	14. Chilin	26. Mengchiang	d. Sungari
3. Paotou	15. Panshih	27. Liuho	e. Taitzuho
4. Chinshueiho	16. Ssupingchieh	28. Kanggyi	f. Yalu
5. Tatung	17. Kaiyuan	29. Ch'osan	g. Touman-chiang
6. Kalgan	18. Tiehling	30. Such'eon	h. Paektu-san
7. Peking	19. Tatientzu	31. P'yeongyang	Changpaishan
8. Ishun	20. Fengtien	32. Kyeomi'po	i. Taedonggang
9. Linsi	21. Hsiaoshih	33. Seoul	j. Taebaegsan
10. Pingchuan	22. Talien	34. Tangyang	k. Hangang
11. Linyuan	23. Huatien	a. Huangho	
12. Nanpiao	24. Hueinan	b. Sangkanho	

ASANO pointed out that a conspicuous shattered zone runs through Tatientzu, Hueinan and Huatien, although the mechanism and date of its origin are unknown. It is, however, evident that the boundary between the Hwangho basin and the Mongolian geosyncline located at a distance of about 45 km between Hueinan and Panshih where the Chilin formation exists in the latter.

IV. The Relation of the Manmo Group and its Substratum of Manchuria to the Pre-Jurassic Rocks in Transbaikalia and the Middle and Upper Amur Valley

Geological research has been greatly advanced in these neighbouring areas since the laying of the Siberian railway line in 1891–1916. After the time of proposal of the Manmo group, the stratigraphy of North Manchuria was illuminated by the knowledge on the contemporaneous formations adjacent on the north and east sides of Manchuria. Compilations by OBRUTSCHEW (1926), AHNERT (1926), RAUPACH (1934) and LEUCHS (1935) were sources important for figuring out the geological concept of the neighbourhoods. I learned of recent advancements achieved there from *Geologic Structure of USSR* by BELIAEVSKY et al. (1958), *Geological Maps of USSR* by NALIVIKIN et al. (1955, 1956) and many papers. Among the facts thus gathered, an especially important discovery was that of Cambrian fossils in Eastern Transbaikalia with which the whole Palaeozoic sequence was completed.

In 1942 I compared the Mesozoic stratigraphy of Transbaikalia clarified by TETIAEFF et al. (1931) to those of Japan and Koreo-Manchuria. As the result, I was astonished by the resemblance of the marine sequence of East Transbaikalia to the Mesozoic one of the Kitakami mountains, North Japan. Therefore, it was my interpretation that the Amur subgeosyncline which was brought about by the destruction of the Permo-Triassic folded mountains after the Triassic Akiyoshi orogeny was disturbed by the Sakawa cycle of orogeny. According to NAGIBINA (1956), Transbaikalia is now divisible into the Caledonian folded zone in the west, the Hercynian folded zone in the middle and the Mesozoic folded zone in the east.

The Upper Triassic and Lias-Dogger strata are the Molasse of the Triassic orogeny which attain 5,000 m and 2,500 m or more , respectively, in thickness in central and eastern Transbaikalia. The Upper Jurassic volcanic series, 1,500 to 1,600 m thick, is followed by the thick Cretaceous coal-bearing formation.

In the Amur-Okhotsk region the Upper Triassic—Lower Cretaceous clastic strata, estimated to be 5,000 to 7,000 m in total thickness, suffered from the late Mesozoic orogeny and related igneous activity. Vulcanicity occurred earlier in the west where it began in early or middle Jurassic and later in the eastern areas where it occurred in late Jurassic or later (NAGIBINA, 1958). Eastern Transbaikalia of the Mesozoic era is considered by KOZERENKO (1962) a typical relic geosyncline where the orogeny most culminated in the late Jurassic age. In the upper and middle Amur region, however, the orogeny attained its paroxysm in the Middle Cretaceous age.

Whether the early and middle Triassic sea reached as far as Transbaikalia may be open to question, although *Claraia*(?) was once found by WOINOWSKI–KRIEGER (1927) in boulders on the Bichiktui river near Nerchinsk. On the other hand, it is certain that marine Triassic formations from Skytic to Ladinic are present in the

Middle Amur valley and the Lesser Khingan range. However, no strong discordance is seen at the Permo-Triassic boundary. The Upper Triassic formation is on the contrary marked off by the conspicuous clino-unconformity from various older rocks all through the area from Transbaikalia to the west coast of the Okhotsk sea. Judging from these facts, it is incorrect to refer this region to the Hercynian folded zone because the crustal deformation culminated after the Hercynian cycle of orogeny had almost ceased in Central Europe, and it became paroxysmal in the Middle Triassic as evidenced by the thick Upper Triassic Molasse sediment.

Cambrian:—In East Transbaikalia an older formation called the Argun Complex is found near the Argun river. In 1957 KRUZIN has discovered archaeocyathids in the lower part of this complex. KOZERENKO, LOKERMAN and NAUMOVA (1960) classified the complex into 3 parts in descending order as follows:

3. Nerchinsk-Zavod limestone and dolomite, 1,100–1,500 m thick, Silur-Ordovician age: Wenlockian fossils contained in upper marl and clayslate beds.
2. Altachinsk slate and sandstone, 150–200 m thick, containing Ordovician and Cambrian microfossils.
1. Bystrinsk limestone and dolomite, 1,000 m thick, with Lower and Middle Cambrian archaeocyathids. Recently, *Redlichia* was found in the Sanash substage (REPINA, 1966).

In the Lesser Khingan range iron-ore bearing beds of 400 meter thickness overlie the eroded plane of the Sinian system and yield *Modioloides prisca* by which its Lower Cambrian age is suggested. The superjacent limestone and shale formation, 500–600 m thick, is referred to the Middle Cambrian.

Ordovician and Silurian:—KASANSKI (1914) reported the occurrence of the *Orthis* cf. *calligramma*-bearing Ordovician sandstone and the *Calymene blumenbachi*-bearing Silurian marly shale on the Omutunaya stream in the Upper Amur valley. Subsequently, WOINOWSKI–KRIEGER (1927) noted the Silurian or early Devonian age of the fossiliferous limestone near Gasimurski-Zavod. Recenty, LOCKERMAN (1957) identified 10 species in 9 genera of Wenlockian brachiopods, including *Tuvanella, Leptaena, Stegerhynchus*, etc. which were collected from the Nertchinsk-Zavod limestone and dolomite at Mt. Balagodatski. This formation is overlain by the Balagodatski siliceous and clayey formation of the Middle Devonian age with distinct discordance (KOZERENKO and LOKERMAN, 1958).

In the Upper Amur valley the Omutnaya series, 600 to 700 m thick, is composed of quartzite and greywacke and yields *Tuvanella gigantea* TCHERNY., *Leptaena rhomboidalis* WILCK. and so forth. This formation is overlain by the Lower Devonian without stratigraphic interruption.

Silurian exposures are found between Zeja and Silindji rivers as well as the Dep tributary. On the Nora between the above two rivers the Silurian formation is seen to overlie Pre-Cambrian crystalline schists transgressively (MAKARENKO, F. A., 1938).

Thus, the Wenlockian series belongs on one side to the Infra-Manmo group and on the other side to the Manmo group in which it continues upward to the Devonian as in the Ertaokou series. It is important to note that the Upper Silurian sea flooded the northern land of the Pre-Cambrian basement complex, because a similar flooding is presumed to have occurred on the south side of the Mongolian geosyncline at the base of the Ertaokou series.

Devonian:—In Transbaikalia and the Far East of the USSR, the Devonian is spread wider than the Silurian system. A stratigraphic break is recognized between them on the left bank of the Argun river (MODZALEVSKAYA, 1968). The Ildikan series, 600 m thick, along the Gasimour valley consists in ascending order of (1) crinoid limestone, (2) siliceous shale and sandstone beds and (3) limestone and sandy shale beds and corals, brachiopods, trilobites and other fossils are contained in the upper part.

In the Argun river area the Older Palaeozoic is clino-unconformably overlain by the Devonian whose lower 100 m consists of sandy and clayey limestones of Middle Devonian age. The middle 100 m is occupied by calcareous shale and sandstone, and Givetian bryozoans and brachiopods are found in the higher part. Some hundred meters in the still higher part is composed of conglomerate, limestone, etc. and is probably Upper Devonian in age.

Along to Urcha, Oldoi, Tyktaminda and Urakan rivers in the Upper Amur valley the Silur-Devonian formations are unbroken. The Devonian, 1,200–1,300 m thick, is composed of sandstone, limestone, slate, etc., and is rich in Gedinnian and Coblenzian fossils. KASANSKI (1915) distinguished (1) Coblenzian-Eifelian limestone and slate, (2) reef-facies bearing Middle Devonian limestone and marl and (3) Upper Devonian limestone. Lower Devonian rocks were found on the divide between the Urkan and Zeja and the Dep. Furthermore, Givetian brachiopods are contained in a formation of limestone, calcareous shale, sandstone and quartzite in the upper reaches of the Unma and Bidschan rivers on the east side of the Lesser Khingan range.

MODZALEVSKAYA (1968) pointed out that in Transbaikalia and the Far East of the USSR, the Lower and Middle Devonian is a thick marine formation which is composed of terrigenous sediments, calcareous rocks and volcanic material in which reef facies is well developed. The sequence continues as high as Givetian or lower Frasnian. The Devonian fauna is intimately related to those of Kazakhstan and the Altai and Sayan on one side and to the North American ones on the other and particularly the earlier faunas to those of the Helderbergian and Ulsterian ones and the middle one to the Hamilton fauna.

Carboniferous:—In the Gasimur tributaries in East Transbaikalia the Lower Carboniferous formation, 900 m thick, is composed of sandstone, shale and limestone and yields *Productus semireticulatus* and other fossils.

According to MODZALEVSKAYA, FREYDIN and GASTINTSEV (1963) the Lower Carboniferous Tiparani series of the Oldoi river in the Upper Amur valley which discordantly overlies the Silurian quartzite and sandstone as well as the Devonian clayslate and limestone consists of the following three parts:

3. Upper 800–900 m, chiefly built up of sandstone with shale intercalation; *Orthotetes keokuk* WELL. and other fossils.
2. Middle 350–400 m, chiefly sandstone but limestone in part; *Leptaena analoga* PHILL. and other brachiopods and crinoids abundant.
1. Lower 200 m composed of sandstone and conglomerate; *Rhipidomella* aff. *burlingtonensis* HALL and other fossils.

The series ranges from upper Tournaisian to Visean; lower and middle Tournaisian is apparently absent. Its sediments were supplied mostly from the northern Palaeozoic and Sinian terrains, but a part is presumably derived from Pre-Cambrian crystalline schists further north. Its fauna is allied to that of Kazakhstan on the west side and on the other to the Osagian fauna of the Mississippi valley, North America; for example, the Burlington and Keokuk faunas. This area therefore must have been on the trans-Pacific route of migration.

Marine fossils are found further in the Lower Carboniferous shale and sandstone beds near the junction of the Urka and the Zeja rivers. Plant remains in clayslate and sandstone beds on the Urka river are considered either Upper Carboniferous or Permian in age.

Near Chabarowsk in the Middle Amur valley the Carboniferous system is classified by MIKLUCHO–MOKLAJ and SSAWTSCHENKO (1962) into the following three series:

3. Ulunskaja series, 1,200–1,300 m thick, Gzhelian-Moscovian in age, composed of siltstone, shale, limestone, diabase and spilite; *Triticites schwageriniformis* and *Montiparus montiparus* contained in upper part and *Profusulinella ovata* in lower part.
2. Iolinskaja series, 1,100–1,300 m thick, Bashkirian-Dinantian; sandy and clayey shales, limestone, spilite, diabasic porphyrite; Bashkirian foraminifers in the upper part.
1. Niranskaja series in Kur-Urmijsk district; ranging from Devonian to basal Carboniferous.

Like the lower Manmo group in Manchuria the Upper Devonian, especially the Famennian and lower Tournaisian, is probably absent in the Upper Amur valley and Transbaikalia because of the regressive movement at the transition between the two periods. It is a remarkable fact that marine Middle and Upper Carboniferous sediments are totally absent in these areas as in the North Manchurian plateau. However, if one comes down as far as Chabarowsk, a continuous sequence of the Carboniferous system below the Orenburgian which merges down into the Devonian and contains Middle and Upper Carboniferous fossils in this section can be seen. If the Chabarowsk Carboniferous is combined with the Chilin formation, an excellent Carboniferous sequence in the axial part of the Mongolian geosyncline would be available. This orientation of the Carboniferous geosyncline is in support of the facts on the intrageosynclinal volcanism as indicated by spilite and diabasic rocks.

Permian:—In East Transbaikalia this system occurs in Chiron and Borzin districts, where in the former it overlies the Onon metamorphosed slates clino-unconformably (KULIKOV and TULOKHONOV, 1958). The Chiron formation, 400–900 m thick, begins with basal conglomerate, breccia and sandstone. Merging upward into sandstone and siltstone beds it is associated with granite porphyry, porphyrite and tuff. In age it is not older than Artinskian. The next is the Urgadyi conglomerate, sandstone and siltstone beds, 400 m thick, containing *Dielasma plana* MASL. and other Kungurian fossils. The upper or Berein formation, 500 m thick, consists of siltstone and sandstone, but having conglomerate at the base and yields the Kazanian fossils.

The Permian formations of the Chiron and Borzin districts are correlated as shown in a table below (KULIKOV, 1959). The Permian faunas of the districts are allied to the northern faunas, Siberian faunas, for example, and distributed to the west into North Mongolia, but they are quite different from the South Mongolian faunas.

Chiron district	Borzin district
Berein beds	Borzin sandstone, 869 m thick
	Belektsui sandstone, graywacke, ca. 400 m thick
Urgadyi beds	Kharanosk sandstone, shale, 600 m thick
Chiron beds	Kundoi shale, sandstone, conglomerate, 845 m thick

In West Transbaikalia the Permian Gitai series begins with the basal conglomerate which overlies granite and folded Middle Palaeozoic strata and contains granitic rocks. Its lower 100–150 m is composed of conglomerate and arkose, and the upper 100–150 m of sandstone and siltstone.

In the Lesser Khingan range the Upper Permian, 2,500 m thick, chiefly composed of conglomerate, tuffite, sandstone and clayslate, is divided by GLUSHKOV (1962) into the following three units in descending order.

3. Sereduikhino sandstone, 1,000 m thick, containing ammonites of the *Timorites* zone.
2. Balstovo shale and sandstone beds, 700 m thick, intercalating thin beds of limestone, porphyry and tuff and yielding *Paraceltites* cf. *altudensis* in the middle and brachiopods and pelecypods in the upper part.
1. Ungun beds of conglomerate, tuff, sandstone and shale containing *Callipteris sahni*, 800 m thick.

The Permian near Chabarowsk consists of sandstone, breccia, clayslate, calcareous sandstone and limestone, and yields Radiolaria, *Spirifer (Munella) supramosquiensis*, *Neoschwagerina*, and various other fossils (MASSLENIKOV, 1937). Recently, MIKUCHO-MAKLAY and SSAWTSCHENKO (1962) distinguished the Permian conformably lying on the Upper Carboniferous Uluskaja series into the following formations.

6. Dshiakunjskaya shale, 650 m or less, Tatarian (Pamirian) to Kazanian (Murgabian).
5. Utanskaja shale with limestone and basic tuff, 640–890 m thick.
4. Jarapskaya conglomerate, sandstone and shale beds, 1,100–1,200 m thick, *Spirifer* cf. *nitiensis*, etc. therein.
3. Sanarskaja beds similar to 2 and 1 in lithology, lying clino-unconformably on acidic volcanic rocks, non-fossiliferous, but presumably Lower Permian.
2. Kukanskaja of Artinskian age, containing *Pseudofusulina vulgaris*.
1. Uljkuljskaja series, 850–1,700 m thick, composed of siltstone, clayslate, sandstone and some limestone and aplite, and containing *Schwagerina* and other Sakmarian foraminifers.

As seen in the Chabarowsk district the Permo-Carboniferous formations are conformable at their systematic boundary in the axial part of the Mongolian geosyncline, but a discordance is recognized between the Middle and Lower Permian which would be nearly coeval with the discordance between the Ujimuchin and West Dabussumnor formations. The Permian from Sakmarian to Tatarian in this district is all marine and contains spilite and other volcanic and pyroclastic rocks indicating the intrageosynclinal volcanism.

In the Lesser Khingan range on the other hand the Upper Permian formation yields land plants in the lower part.

In Transbaikalia there were probably crustal deformations during the Middle and Upper Carboniferous and Sakmarian times because the Permian formation lies on granite and folded and metamorphosed sedimentaries, although the age of these underlying rocks is still questionable. Because the Permian fauna of Transbaikalia from Artinskian to Kazanian is allied to the boreal faunas, there may have been land between Transbaikalia and the Middle Amur valley.

The common occurrences of conglomerates in various horizons combined with Middle Permian discordances indicate the crustal unstability which was strong and extensive in the part of Eastern Asia in the Permian period.

Lower and Middle Triassic:—According to Boleylev and Okunev (1967) the Triassic formation overlies the Upper Permian in the Lesser Khingan range disconformably and both are deformed. They are overlain by the Lower Cretaceous lava and intruded by granite. Its sequence is as follows:

Ladinic *Daonella* beds, 350 m thick or more.

Anisic sandstone, 500 m thick, containing *Paraceratites*, *Ptychites*, etc., Olenekian, 770–1,100 m thick.

4. Siltstone and sandstone containing *Claraia* and *Eumorphotis*.
3. *Dieneroceras*-bearing sandstone, Columbitan.
2. Sandstone and siltstone with *Anasibirites* and *Flemingites*, Owenitan.
1. Conglomerate and sandstone.

Induan, 350 m thick, composed of siltstone and sandstone; basal conglomerate containing granite and quartzporphyry; *Meekoceras* and others contained, Gyronitan.

In Khektin and Vandan areas in the Middle Amur valley there is no stratigraphic break between the Upper Permian and the Lower and Middle Triassic formation containing *Leiophyllites* and *Ptychites* (BOBYLEV, SALUN, SHEVYREV, 1963).

Near Chita, Transbaikalia the Lower Triassic formation, 500 to 600 m thick, containing acidic and intermediate volcanic rocks overlies granite and is overlain by a Jurassic conglomerate. Its tuffaceous shale along the Klilka river yields such Older Mesozoic plants as *Pecopteris crenulata* PRYN., *Tersiella* sp. and *Sphaenobaiera* sp.

Upper Triassic:—In the Shilka, Amazar and Galakan tributaries in the Upper Amur valley the Upper Triassic formation is composed of lower sandstone beds 200 m thick and upper siltstone beds 100 m thick, and contains *Monotis scutiformis*, *M. ochotica* and *M. zabaikalica* which indicate upper Carnic-Noric age. It overlies Silurian and Devonian strata with remarkable discordance (GORZHEVSKY and SHASHKIN, 1960).

In East Transbaikalia the Upper Triassic formation which is composed of sandstone, shale, conglomerate and some limestone, and overlies Permian and older formations attains 5,000 m in thickness. The Carnic beds yield *Halobia* ex. gr. *zitteli* LINDSTRÖM in the Onon drainage near the Mongolian frontier and *Monotis scutiformis* between the Aga and Ingoda rivers further in the west. Noric *M. ochtica* and *M. zabaikalica* are widely distributed in Transbaikalia. The Noric sandstone and shale beds with the basal conglomerate measure 1,500 m in thickness along the Shilka river (SCHENFILY and TSCHAZKIS, 1964).

The most important stratigraphic boundary is recognized now between the Middle and Upper Triassic formations, instead of between the Upper Permian and Lower Triassic formations which are found together in the geosyncline and conformable in its axial part. Except for the plant beds near Chita, the Lower and Middle Triassic sediments are probably absent in the Upper Amur valley and Transbaikalia, while the Carnic sea ingressed as far as the Mongolian frontier south of Chita. The sea flooded more widely in the Noric epoch. The clastic sediments which accumulated as thick as 5,000 m in the short time from Carnic to Noric must have been post-orogenic sediments on the still unstable ground. In other words, the Akiyoshi orogeny must have been paroxysmal in the middle Triassic epoch in this part of the Mongolian geosyncline.

Pre-Cambrian:—Finally, the older metamorphic rocks in the Khingan-Urmi region are considered Pre-Cambrian. Garnetiferous gneiss is predominant in the Archaean(?) Urmi series, more than 1,500 m thick, to which quartzite is added. The metamorphosed Proterozoic complex consists of two series. The lower or Amur series, 2,500 to 3,000 m thick, is composed of hornblende mica schist, thick quartzite and porphyrite in the lower part and mica schist, mica-hornblende schist and marble in the upper part. The upper or Soiouznoye series is composed of crystalline schists 1,600 m thick intercalating marble lenses in its lower part, graphite-bearing marble, quartzite and mica schist in the middle 2,000 to 2,500 m and graphite-bearing schist and marble in the upper 700 m. The superjacent Sinian system consists of the following 3 series in ascending order.

1. Ditour series, 1,000 m thick, limestone, dolomite, quartzite, etc.
2. Igintcha series, 1,500 m thick, chiefly sandy and shaly beds.
3. Mourdandava series, 800 m thick, dolomite in main.

The last series appears to be overlain by the Lower Cambrian conformably.

The older rocks in the terrain from East Transbaikalia to the Middle Amur valley can be classified into the following four stratigraphic units.

1. Pre-Cambrian metamorphosed basement complex.
2. Infra-Manmo group from Sinian to Middle Silurian.
3. Lower Manmo group from Middle or Upper Silurian to Carboniferous.
4. Upper Manmo group from Permian to Ladinic.

Summary:—According to KOZERENKO (1962) the Infra-Manmo group in East Transbaikalia which suffered from Caledonian orogenies is a thick sedimentary series ranging from 6 or 7 km to 9 or 10 km in thickness and forming brachysynclines and brachyanticlines and in which granite has intruded at the axial zone. The Middle Palaeozoic of 2 or 3 km thickness constituted a geosyncline and a geanticline. According to NAGIBINA (1956) the northern geosyncline was running through Daurien, Upper Amur valley, Uda and Shantarsk and the southern geanticline through the Argun, Tchickoi, Tukuringro and Dschagdinsk. In comparison with the former, the stratigraphic sequence was discontinuous and coarse rock-facies predominant in the latter zone. Magmatism took place between the two zones. The above differentiation of the northern terrain of the Mongolian geosyncline might be a large primary folding of the Lower Manmo group in the geosyncline.

As a result of the crustal movements the Middle and Upper Carboniferous sediments as well as the Lower and Middle Triassic ones are absent or undeveloped in the stretch from Transbaikalia to the Upper Amur valley, and the Permian sediments filled up the Kryinsk-Borsja Mulde. The movements were certainly stronger in the terrain than in the middle and southern parts of the Mongolian geosyncline.

The Upper Manmo group is well developed in the Lesser Khingan range and the Middle Amur valley. There the Permian can be divided into two parts and the Upper Permian is transgressive. There was no crustal deformation at the transition between the Permian and Triassic periods except for a marine regression as indicated by disconformity or erosion-unconformity. The Lower and Middle Triassic is the Flysch of the Akiyoshi orogeny and the Upper Triassic its Molasse which is a tremendously thick clastic formation.

A correlation of these formations to those of Manchuria is tentatively made and shown in Table 4. (See page 50).

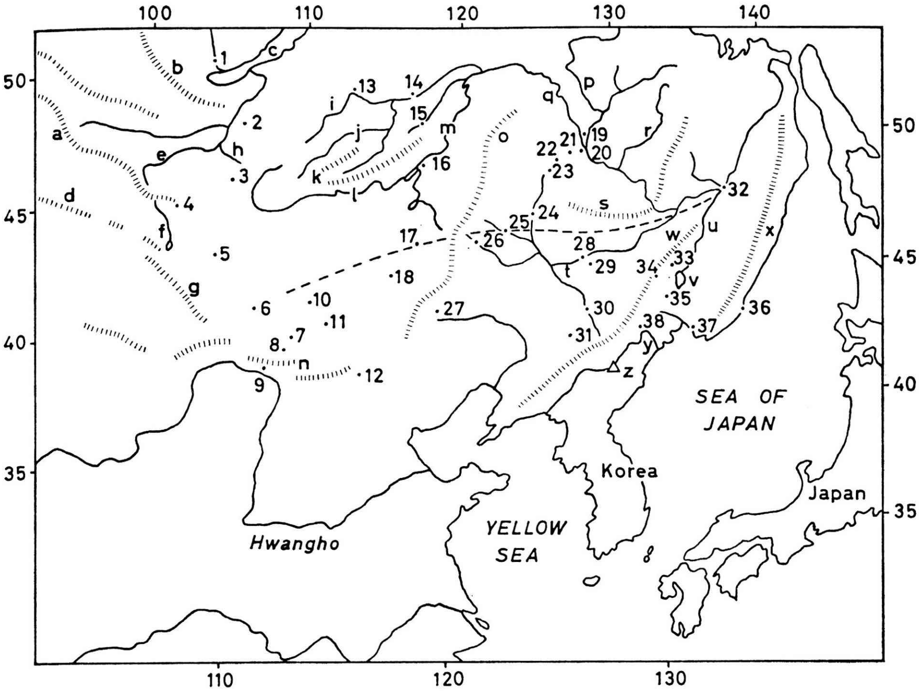

Fig. 3. Map showing the subsiding axis of the Mongolian geosyncline in the Permo-Carboniferous period.

1. Irktsk
2. Maimatchen
3. Urga, Uran Bator
4. Tsetsenwan
5. Sair Usu
6. Totoshan
7. Jisu Honguer
8. Beiyin Obo
9. Paotou
10. Iren
11. Pankiang
12. Kalgan
13. Chita
14. Nertchinsk
15. Gasimur
16. Manchouri
17. West Ujimuchin
18. Dabussum-nor
19. Blagovestchensk
20. Heiho
21. Nichuiho
22. Houlungmen
23. Nengkiang, Mergen
24. Tsitsihar
25. Djalaitewanfu
26. Soron, Solum
27. Linsi
28. Harbin
29. Yüchuan
30. Chilin, Kirin
31. Panshih
32. Chabarowsk
33. Mishan
34. Mashan
35. Grodekov
36. Olga
37. Vladiostok
38. Kaishantun

a. Khangai Mts.
b. East Sayan Mts.
c. Baikal lake
d. Altai Mts.
e. Orkan R.
f. Orgin gol
g. Gruben Saikan
h. Sharan gol
i. Ingoda R.
j. Onon R.
k. Kentei Mts.
l. Kerulen R.
m. Argun R.
n. Inshan Mts.
o. Great Khingan range
p. Seja R.
q. Upper Amur valley
r. Bureya R.
s. Lesser Khingan range
t. Sungari R.
u. Ussuri R.
v. Hanka lake
w. Wantashan range
x. Sikhte Alin range
y. Touman R.
z. Paiktu shan, Changpai shan

Broken Line: Geosynclinal Axis

V. The Relation of the Manmo Group and its Substratum of Manchuria to the Triassic and Older Rocks in Eastern Mongolia

In Geology of Mongolia by BERKEY and MORRIS (1927) the Taishan and Wutai metamorphic groups constitute the basement complex of Mongolia. The Khangai graywacke series which was referred to the Sinian lies on them. All of these are intruded by granite of the Mongolian batholith. Later, Permo-Carboniferous seas spread into the area and various sedimentary beds were deposited.

An important problem arises, however, in referring the Khangai series to the Sinian system typical in China which is quite different from the Khangai series in lithology. Therefore, GRABAU (1931), TEILHARD DE CHARDIN (1935), MACCAVEEW (1935), TCHAIKOVSKY (1935), ALEKSEICHIK (1947) and KOBAYASHI (1948) have expressed their opinions against the above conclusion.

A good display of the Khangai graywacke series is found in the Kentei and Khangai mountains, respectively, to the east and west of Urga (i.e., Ulaan Baator). In his reconnaissance in Mongolia, 1892–94, OBRUTSCHEW referred a graywacke and slate formation between Maimaichen and Urga to the Upper Proterozoic. Subsequently, in 1915, Ussov found in the Kentei mountains that the Barchin series composed of slate, limestone and graywacke with intrusion of granodiorite, is overlain by a graywacke series. Graywacke and slate are two main constituents of the latter, but porphyrite and tuff are associated with them. Ussov considered the Barchin series to be Lower Proterozoic and the Graywacke series Upper Proterozoic. However, he recognized also the gradual merging of the former with the latter.

The principal reasons for referring the Khangai series to the Proterozoic were negative. More precisely, limestone common in the Lower Proterozoic in Siberia is not found in the Khangai and coal measures often contained in the Upper Palaeozoic in Siberia are not found in it. On the contrary, it is noteworthy that in 1892 OBRUTSCHEW found Older Palaeozoic(?) fossils at Sharangol and later bryozoans and brachiopods of presumably Upper Devonian or Lower Carboniferous age in a formation consisting of shale, sandstone and conglomerate. These finds suggest that the Khangai or Barchin series may still be Palaeozoic at least in part.

OBRUTSCHEW reported that a marine Palaeozoic formation along a tributary of the Tchikoi river was found to lie on the steeply inclined Graywacke series. KUPLETZKY (1926) found that in the western part of the Togos mountains the basal conglomerate of the Graywacke series overlies the strongly disturbed Barchin series composed chiefly of slate with intercalation of thin limestone layers and intruded by porphyrite and granodiorite. TSCHAIKOVSKY (1935) stated that the two series are in most places difficult to distinguish from each other. On TSCHAIKOVSKY's geological map of Northwest Mongolia the Barchin series is in close association with granite. Therefore it is probable that at least a part of the Barchin series may be the metamorphosed facies of the Graywacke series. The extension of the two series in Transbaikalia beyond the international boundary is referred to as unclassified Palaeozoic on the Geological Maps of the USSR. The inclusion of granite in the basal conglomerate and a large amount of arkose sandstone in the Khangai series of the Togos mountains show that certain granite is older than the Khangai series. TCHAIKOVSKY discovered Carboniferous marine fossils in the series.

According to KUPLETZKY and TCHAIKOVSKY there are two plant beds in the western Kentei mountains near Urga, one containing Tungussian plants and the other yielding *Pleuromeia* typical of the Buntsandstein. Therefore, they are Permo-Triassic continental sediments. Between Tsenkirngol and Tugulguti-nuru there are two plant beds each having a basal conglomerate and the lower one overlies the Graywacke series unconformably. Furthermore, an epoch of crustal deformation and igneous activity may have intervened at the interval between the Khangai and Barchin series.

The Khangai series, as suggested by its name, extends westward from the Kentei mountains into the Khangai mountains. It was noted by LEVEDEVA at Hariste of the latter mountains that yellow limestone containing Kazanian *Murchisonia inprolineata* and other fossils is overlain by yellow sandstone conformably. It rests on a sandstone and shale formation from which it is separated by angular discordance.

According to MACCAVEEW (1944) older rocks in Central Mongolia can be classified into the following three series in ascending order.

1. The Vzolinsk series composed of micaceous siliceous shale, arkose sandstone and micaceous calcareous shale.
2. Gruben Saiban series composed of coarse-grained green sandstone and fossiliferous siliceous limestone.
3. The Shanhai series composed of thin bedded shale and siliceous pebble-bearing conglomerate.

Because the Vzolinsk series is characterized by arkose and shale, it matches the Khangai series best in lithology among the three series. If so correlated, it appears probable that the Gruben Saiban limestone and sandstone formation may be Carboniferous or Permian.

Southwest of Urga, Central Mongolia, the Mongolian Altai is represented by two rows of horst mountains. The Ike Bogdo, Baga Bogdo and Arste Bogdo belong to the northern row while the Gruben Saikan and Golobal'n Ula are the southern horsts. These mountains consist of granite, crystalline schist, phyllite and graywacke in addition to quartzite, phyllitic conglomerate, diorite, serpentine and so forth. The metamorphic rocks of igneous origin were once referred to as the Taishan complex, those of sedimentary origin to the Wutai and the graywacke to the Sinian by BERKEY and MORRIS. No evidence, however, which could decide their stratigraphic relation and ages has ever been found. On the other hand, Devonian or Dinantian marine fossils were found at Gruben Saikan. Devonian fossils in the Adshi Bogdo and Silurian(?) fossils at Kobdo in the west. At a place about 20 miles southwest of Sair Usu *Gigantella* and other fossils are contained in Carboniferous limestone, and sandstone and conglomerate beds, 45 m thick, exist at the base of this formation. GRABAU (1931) described a copious Lower Permian fauna from Jisu Honguer in further south in Inner Mongolia. The Jisu

Honguer formation overlies the Arbun Khoyer formation which is strongly folded and intruded by Oshigo granite. Thus, there are probably Middle and Upper Palaeozoic formations, but there is no evidence to definitely show Pre-Cambrian age for the Khangai series. ALEKSEICHIK (1947) is of opinion that the Khangai series is a formation deposited in a closed basin in the Upper Silurian or Devonian period.

In the present knowledge the archaeocyathid-bearing Lower Cambrian formation exists in the Kerulen river basin in the southwest extension of East Transbaikalia (MARRINOV, 1966).

The Ortsog suite in the Central Gobi block is a lithologically persistent carbonate formation, about 1,800 m thick, with the basal conglomerate, 50 m or thicker. It contains *Osagia* and other stromatoliths and oncoliths and considered Sinian or Riphean. Overlain by the suite with angular discordance there are still older metamorphic rocks which constitute the basement of the block (BORZAKOVSKY, SUYETENKOV and KHRAPOV, 1968).

Ordovician:—Such Middle to Upper Ordovician corals as *Cryptophyllum*, *Liopora*, *Proheliolites*, *Saffordophyllum* and *Nyctopora* were recently discovered in a variegated terrigenous carbonate formation near Delgar, northeast of Sayn Shanda. It merges into a volcanic terrigenous greenstone complex, 3,000 m thick, on the southeast side in which Middle Ordovician microfossils were found in the vicinity of Mt. Buhatyn Barun Obo. Further south near Mt. Tabun Hara Obo the Ordovician is unconformably overlain by the fossiliferous Silurian formation (BORZAKOVSKY, SUYETENKOV and KHRAPOV, 1968).

Silurina:—WU Wang-shih (1958) described *Entelophyllum* aff. *yassense* (ETHERIDGE), *Heliolites interstinctus* (L.) and other Middle Silurian corals from a limestone 2,500 m below the Carboniferous limestone near Beiyin Obo, Suiyuan, Inner Mongolia.

Devonian:—As IWANOW (1950) classified older rocks in Northeast Mongolia into Pre-Cambrian metamorphics, Middle Palaeozoic formations and Upper Palaeozoic acidic volcanic rocks, the Devonian formation is widely distributed in the Kentei mountains. According to BOBROV (1961), the Lower Devonian occurs near Transbaikalia in the Nukutdatnsk anticline and Bailzik district in the Upper Onon tributary where in the latter the basal conglomerate, 150 m thick, overlies phyllites and mica schists discordantly. Above the conglomerate follow sandstone and arkose beds, 150 m thick, and then volcanic and pyroclastic sediments, 350 m thick. In the former area brachiopod-rich limestone lenses are intercalated at the middle part of the phyllitic shale and arkose sandstone formation, 1,000 m thick. The early Devonian fauna there is allied to those of Western Mongolia, the Altai mountains and North America.

The Middle Devonian formation is chiefly composed of terrigenous sediments, but in association with tuff and reef-limestone. It is distributed from the eastern part of the Kentei mountains to Goshu-Kholbo-Ula, 190 km to the south of Urga and as far as Bargin Obo in the north and Sayn Shanda near the Inner and Outer

Mongolian border in the south. At Goshu-Kholbo-Ula it begins with a thick basal conglomerate bed overlying older rocks unconformably and its thickness measures about 860 m. Its upper part contains Givetian brachiopods related to the Maysk fauna of Kazakhstan and the Hamilton of North America (BOBROV and MODZALEVSKAYA, 1961, 1964). The Upper Devonian is found near the Middle Devonian at Khutul Nur in the eastern Kentei mountains.

Mucrospirifer cf. *ales* (KHALFIN) and other Middle Devonian brachiopods are found also at several places in Inner Mongolia. In the northeastern vicinity of Iren, Hsilinkecha-meng, the Devonian formation, 300 m thick, is built up of conglomerate in the lower part but is sandstone and shale in which some limestone is interbedded in the remaining main part (WANG YÜ and YÜ Chang-min, 1964).

A graben surrounded by older Palaeozoic metamorphic rocks was introduced at Khara-Ayrak, 350 km southeast of Urga, by a block movement after the Givetian transgression. The lacustrine formation in this depression is 1,000 m in total thickness. Its lower half is composed of arkose, sandstone, porphyrite and conglomerate beside the basal conglomerate, and yields *Lepidodendron*, *Porodendron*, *Prolepidodendron* and other plants including spores which are considered late Devonian or earliest Carboniferous. The upper half of the formation is an acidic volcanic formation (MARINOV, KHRABOV and KHUBULDIKOV, 1959).

Permo-Carboniferous:—During the Central Asiatic Expeditions, 1922–23, by the American Museum of Natural History, *Michellinia*, *Gigantella giganteus* and other Lower Carboniferous fossils were discovered at Sair Usu in limestone of a formation composed chiefly of shale and clayslate beside some conglomerate and limestone. Subsequently, J. S. LEE (1927) reported the occurrence of *Fusulinella bocki* MÖLLER and other Moscovian fusulinids at a locality 200 km north of Kalgan.

Recently, CHÜ Tzu-yun (1959) found *Lithostrotion irregulare* var. *asiatica* and other Visean fossils in a limestone-clayslate formation, 500 m thick, near Paichiatien, Aohan-chi and southeast of Wutuntaohaichen, Wengshoutechi (YANG Kingchih, SHENG, S. T., WU Wang-shih and LU Lin-huang, 1964).

Recently, SUYETENKO (1968) reported the occurrence of *Eostaffella* and various other foraminifers in a range from Visean to Namurian or possibly Bashkirian in limestones of a graywacke and siliceous sandstone formation, 150 m thick, near Totoshan, southeastern Outer Mongolia. Limestones in a graywacke and tuffaceous sandstone in its vicinity yield foraminifers of Moscovian to Lower Permian age and Upper Permian bryozoans and brachiopods.

T. S. SHENG (1958) described fusulinids of the *Triticites* zone and the *Pseudoschwagerina* zone from Lalaotu and Amushan, respectively, to the southwest of Beiyin Obo, Inner Mongolia.

The Jisu Honguer formation, 100 m thick, in Wulanchapumen commences with the basal conglomerate, followed by thick sandstone and limestone beds in which the *Marginifera*, *Enteletes* and *Hemiptychia* zones are distinguished. The next highest is 200 m limestone with chert in the basal part in which are known the *Streptorhynchus broilii* zone, *Spiriferella* zone, *Camarophoria* zone, *Streptorhynchus* *kayseri* zone and the *Spirifer moosakhailensis* zone. Furthermore, the *Lyttonia* zone, *Martinia* zone, *Orthotychia* zone and the *Productus humboldti* zone are found in the greenish grey shale beds at the top which intercalate limestones. GRABAU (1931) described 4 coral species, 2 bryozoans, 99 brachiopods, 17 pelecypods and 18 gastropods from the formation, and correlated the Jisu Honguer fauna to the Middle *Productus* limestone of the Salt Range and the *Schwagerina* (i.e., *Pseudoschwagerina*) zone of Russia. Accordingly, its age is Sakmarian and the West Ujimuchin fauna is its correlative. According to GRABAU, nearly all species of the Jisu Honguer fauna were identifiable with the Indian or Russian ones. The dwarfing of these species, however, suggests their being inhabitants in an embayment which presumably opened its mouth in the east in the Pacific ocean.

According to BOBROV and KOTLYAR (1963) the Kazanian formation is distributed from the Borzya district, Transbaikalia to the Tsenkhin-gol district, south of Urga through Ul'dza-gol in Northeast Mongolia. Its basal fanglomerate on the older rocks contains large boulders 1 m across. It consists of not only clastic sediments, but also acidic volcanic materials and attains a thickness of 2,000 m in the southwest and more than 3,000 m in the northeast which suggests a subsiding axis in the late Permian period. Its fauna rich in brachiopods in association with pelecypods is allied to those of the Ural and Siberia. It is probable that the North Mongolian sea with the boreal fauna was separated from the South Mongolian sea with the austral fauna by a land barrier which was produced by the early Permian movement.

Permo-Triassic:—In the Khangai plateau the Permo-Triassic formation, 300 m or thicker, in the upper Ongin-gol overlies older rocks clino-unconformably with conglomerate at the base. It consists of coarse clastic rocks, sandstone and shale, and conglomeratic sediments and false-beddings are commonly met with. In the Orkhon river section the shale and sandstone in the middle part yields *Paracalamites*, *Noeggeratiopsis*, *Yuccites* and others whose age is considered in the range from late Permian to early Triassic (AMANTOV and RADCHENKO, 1959).

Mongolian Batholith:—BERKEY and MORRIS (1927) considered that a great batholithic invasion has taken place into the Sinian Khangai series and older rocks before the deposition of the Permian Jisu Honguer series and probably of the Carboniferous Sair Usu series.

TEILHARD DE CHARDIN (1940) on the other hand classified granites of Mongolia and Sintsiang or Chinese Turkestan into late Carboniferous Tienshan granite and late Permian Mongolian granite, and claimed that the intrusion of granite is, broadly speaking, earlier in the west than in the east. Permian(?) limestones containing crinoids and corals at Tairnor south of Iren and at Hatlyn Sam southeast of Pankiang are recrystallized due to the contact effect of granitic intrusion. They are overlain by a siliceous marl and conglomerate formation which is uneffected by the intrusion and contains Jurassic(?) wood stems. The Gobi slate in Mongolia and Linsi slate in the southern Khingan range which belong to his Khangai facies are all intruded by the granite.

In Manchuria the Chilin and Touman formations which the latter includes Upper Permian are extensively intruded by granite. This granite batholith is covered by Mesozoic formations which are generally called Jurassic or Cretaceous. In the vicinity of Vladivostok the Lower Triassic formation overlies granite and its basal conglomerate contains granite boulders. Therefore, the batholithic granite must be Permo-Triassic in age.

TCHAIKOVSKY (1935) distinguished two kinds of granites in Northeast Mongolia. One is his Bain Uransky type which is rosy semi-idiomorphic medium-grained granite with broad aplitic marginal facies. The other called the Jan Shabrisky type contains large phenocrysts of microcline. Their field relationship is unknown. The former is thought to be late Jurassic because it is intrusive into porphyritic lava and conglomerate which covers the Upper Palaeozoic formation. The latter type of granite is said to resemble Cretaceous and Tertiary granitic rock in Transbaikalia. As noted elsewhere (KOBAYASHI, 1942), Jurassic and later granite and porphyry were reported to occur from Transbaikalia to Udaland.

The major part of the granite batholith in Southeast Mongolia and Central Manchuria and probably North Manchuria, however, must be a product of the Permo-Triassic intrusion because strongly folded Permian and older formations are roof-pendants on the Mongolian granite batholith, while Jurassic and later formations which overlie this already granitized basement are simply undulated and cut by faults.

The following absolute ages of Mongolian igneous rocks were estimated by the argon method (BOBROV, POLEWAJA and SPRINZSON, 1961).

1. Older biotite granite in East Mongolia...419–450 million years
2. Chuchtuinsk granite...315 million years
3. Dorinchonsk granite...210–220 million years
4. Newer granite of Modoto...140 million years
5. Uchetuin-Daba volcanic rock...290–300 million years
6. Volcanic rock of Judosdyr district...150–183 million years

Summary:—In spite of my search in recent references, the facts which I could gather on the Pre-Jurassic geology of East Mongolia are imcomplete. As stated above, I could not find many salient facts on the Pre-Cambrian geology. Because the Khangai series has been in chaos, the finds of archaeocyathids and Ordovician fossils in East Mongolia cover just the outset of the Infra-Manmo stratigraphy of this region.

The Middle Silurian coralline limestone of Beiyin Obo, like that of the Ertaokou series, appears to be a member of the Lower Manmo group. The Devonian and Carboniferous systems are on the contrary wide spread in Inner and Outer Mongolia. In Northeast Mongolia the Manmo group begins with the Lower Devonian basal conglomerate. The sea was most transgressive in the Middle Devonian but became regressive after the Givetian inundation phase till at length the region wholly emerged except for the Khara-Ayrak graben where lacustrine sediments were accumulated.

Table 4. Correlation of the Manmo Group in Manchuria and adjacent Areas.

Formation and Age		East Mongolia South	East Mongolia North	Transbaikalia	Upper Amur Lesser Khingan	North & Central Great Khingan
Upper Manmo	Triassic			Marine Upper Triassic		
			Pleuromeia	Plant beds	Middle Triassic Lower Triassic	
	Permian		R. Orkan	Berein	Sereduikhino Balastov Ungun	Hahai
			Kazanian	Ungadui		Soron
		Jisu Honguer		Chiron		Shilaiyao
Lower Manmo	Carboniferous	Lalaotou				
		Totoshan				
		Sair Usu	Khara-Ayrak	Lower Carbon.	Tiparani	Lower Carbon.
	Devonian	Mid. Devon	Up. Devon Mid. Devon Low. Devon	Ildikan	Middle Upper Devon.	Taminshan Huolungmen
					Silur-Devonian	Nichuiho
	Silurian	Beiyin Obo		Nerchinsk-Zavod		
Infra-Manmo	Ordovician	Ordovician		Altachinsk	Omutnaya	Suluho
	Cambrian		Archaeocyathid	Bystrinsk		Halahaho
	Sinian		Ortsag			

Formation and Age		Manchuria NE Korea: East Manchuria		Middle Amur	Far East, USSR: South Primoria	Far East, USSR: Sikhote Alin	Orogenic Phase, Japan
Upper Manmo	Triassic			Upper Triassic	Upper Triassic		Akiyoshi
				Middle Triassic	Ladinic		
					Anisic		
				Lower Triassic	Lower Triassic		Tate
	Permian		Touman	Dshiakunjskaya	Sitzinsk		
				Utanskaya			
		Kaishantun		Jarapskaya		Basleoian	
				Sanarskaya	Kaluzinsk	Kazanian	Usuginu
				Kukanskaya	Lyudanzinsk		
		Yüchuan			Chandalazsk	Lower Permian	
Lower Manmo	Carboniferous	Panshih	Chilin	Uljkulskaya			Sakamoto
				Ulunskaya		Yuzagolsk	
		Mincheng		Iolinskaya		*Fusulinella*	
		Luchuan		Niranskaya		*Millerella*	Shizu
	Devonian	Hetai					
					Calymene horizon	Plant beds	
		Ertaokou					
Infra-Manmo	Silurian						
	Ordovician						
	Cambrian						
	Sinian						

The marine transgression was renewed following the Visean age and the Carboniferous sea caused extensive flooding in the middle and southern parts of the region, but the northern part probably emerged. Volcanism was violent in the Devonian period but declined in the Carboniferous period.

The foraminiferan and nonforaminiferan biofacies are distinguishable in the Permo-Carboniferous formation. The former ranges from Visean to Lower Permian as recognized by the fusulinacean zones. It is most developed along the boundary between Inner and Outer Mongolia and extends eastward to the Middle Amur valley through the central part of the Great Khingan range. Brachiopods and corals are two leading members in the latter biofacies and the copious Jisu Honguer fauna is traceable from Inner Mongolia to the East Manchurian mountainous land and further to the east into the maritime region of the USSR.

In North Mongolia the Kazanian sea has ingressed from the north probably through Transbaikalia. The distribution of the Kazanian sedimentary patches with their great thickness and boulder-bearing basal conglomerate show as a whole their being orogenic sediments in the growing syncline. This conclusion is in support of the fact on the repeated occurrences of conglomerates in the Permian sequence of the Chiron district which record the repetition of folding, causing topographic rejuvenescence. The Permian and especially the Middle Permian was a time of unstability for the Mongolian geosyncline as indicated by various stratigraphic discordances in its eastern part and the development of conglomerate and fanglomerate.

In the region from East Mongolia to the Far East of the USSR the oldest land flora are the Devonian plants of the southern Sikhote Alins (KRASILOV, 1968). The next oldest is the flora of the Khara-Ayrak graben. It is followed by the Moscovian(?) plants of the Chilin formation near Mingcheng, East Manchuria on which, however, no palaeobotanical study has been done. Permian plants are recorded from some places of the region, namely Tungussian(?) plants of the Nalaika coal measures, Late Permian spores of Tabu-Tologoj coal-measures, Late Permian-Lower Triassic plants of the Orkhan river in Mongolia and the Middle Permian *Callipteris sahni* of the Lesser Khingan, *Comia* of Ichun, the Kaishantun flora, and many other plants in the Touman area of Korea and South Primoria which will be mentioned later. Combined with the Hahai naiad fauna they show an extensive emergence of the geosyncline in the Permian period. At the same time, most of these plants belong to the Kuznetsk flora except for the Kaishantun flora which indicates the northeastern limit of the Cathaysian phytoprovince. The junction of the two provinces is at the Nanshan or Kilianshan where the invasion by the Cathaysian flora took place first followed by invasion of the northern flora. If there was any barrier to the dispersal of land plants, it extended from west to east between Inner and Outer Mongolia and between Central and South Manchuria.

The land flora declined in the Triassic period, although *Pleuromeia*(?) of the Kentei mountains may be a link between *Pleuromeias* in the east in south Primoria and the Agma river basin, the Yakut ASSR, and in the west in northeastern

Kazakhstan, southern Ferghana, Mangyshlak, the Urals, the Russian platform near Rybinsk and Germany (SREBRODOL'SKAYA, 1966). Additional Lower Triassic plants are known from Transbaikalia. Little is known, however, of the Triassic stratigraphy of East Mongolia. The Older Mesozoic conglomerates of Tsetsenwan, Central Mongolia is a basin deposit on a basement that has already been oronized.

As already mentioned, the so-called older granite was intruded in the Silurian at about the boundary between the Infra-Manmo and Manmo groups. The Middle Carboniferous Chuchtinsk granite was probably related to the extensive emergence of North Mongolia, although actual evidence is still meager for the late Dinantian orogeny (DORNFELD, 1968). The extensive area of the Mongolian geosyncline covering East Mongolia and Central and North Manchuria was not well consolidated until the emplacement of the Triassic granite to which the Middle Triassic Dorinchonsk granite belongs.

VI. The Triassic and Older Formations and Rocks of South Primoria, USSR Compared with the Older Stratigraphic Sequences in Japan and Manchuria

One important fact is that the Cambrian formation overlies the Ussuri-Hanka block which is thought to be the ancient nucleus of Primoria. The Pre-Cambrian rocks of the block are classified into three groups. The oldest rocks are crystalline schists, mica gneiss and mica-sillimanite gneiss which are considered as old as Archean. The Lower Proterozoic Poutita series is chiefly composed of various green schists and basic igneous rocks and the Upper Proterozoic Spas series, 1,000 m thick, of quartzite, mica schist and porphyroids. KOBLIN (1960) estimated the thickness of the Proterozoic formations to be more than 2,500 m.

The Lower Cambrian, 2,500 to 3,000 m thick, consists chiefly of fossiliferous limestone, dolomite and shale and the Middle Cambrian of conglomerate and breccia. In 1949 KROPATHOKIN discovered archaeocyathids in these carbonates. YAKOBLOV (1961) distinguished the Cambrian sediments into the limestone-slate series, limestone-conglomerate series, slate series, calcareous slate series and the slate-limestone series, in ascending order where the fourth is discordant to the fifth series. *Coscinocyathus* and *Ajacicyathus* are contained in the first and *Ethmophyllum* in the fourth series. Spilite and keratophyre in these series show that they are thick orthogeosynclinal sediments.

Recently *Calymene* was found on the Kordonka bank, southwest of Grodekovsk, South Primoria, and the trilobite is considered Lower Devonian in age (MAXIMOVA and ORGANOVA, 1959). The relation of this *Calymene* shale to the *Calymene*-bearing limestone of Hsiaosuiho and the *Calymene*-bearing shale of Omutunaya is a subject which ought to be taken up for study.

There is no record of the history from Upper Cambrian to Silurian. Nevertheless, a remakable fact is that the N–S to NW tectonic trend is predominant in the Infra-Manmo structure indicated by the Sinian-Cambrian sediments is quite discordance to the NE trend prevalent in the tectonics and morphology of the Sikhote Alin mountains.

Devonian plants were discovered recently in the Danubikhe river, Tudagou river and other areas in the southwesternmost part of the Sikhote Alin near Vladivostok (KRASILOV, 1968). The oldest marine fossil horizon is the *Millerella* zone of the Avvakureska basin. There the Moscovian formation containing *Fusulina* and *Fusulinella* overlies the upper Visean with the basal conglomerate, and the second oldest is the *Triticites*-bearing Uralian (ZHAMOIDA, PODGORNAIA and SOSINA, 1958). The Yuzagolsk formation of the Turchi peninsula yields *Lepidodendron* and its age is considered either Upper Carboniferous or Lower Permian.

The Permian system is extensive from the middle and southern parts of the mountains to the Ussuri-Suifung lowland. The Lower Permian is represented on the west side by a thick continental formation, 2,500 m thick, comprising arkose and coal measures, and yields *Noeggeratiopsis theodori*, *Lepidodendron occulis-felis*, *Cordaites*, etc. On the east side it is chiefly composed of shale and volcanic rocks, and contains *Pseudofusulina* and *Misellina* in the lower and *Cancellina* and *Neoschwagerina* in the upper part.

The Permian sequence terminates at the marine Kazanian in the Olga-Tetyukinsk district and the Basleoian containing *Timorites* and *Callipteris* in the Churki-Kursk district. The Upper Permian formation is on the contrary well developed in South Primoria, attaining a thickness of 3,000 m. It is classified into 4 formations the lower three of which are composed of grey limestone, siltstone, various sandstones and volcanic rocks all of which are marine. They are named in ascending order as follows:

Chandalazsk formation with *Lyttonia*, *Richthofenia*, etc.
Lyudyanzinsk formation containing *Neospirifer moosakhailensis*, etc.
Kaluzinsk formation containing *Fenestella cyclofenestrata*, etc.

The Sitzinsk formation at the top is a coal- and conglomerate-bearing rock and yields *Sphenopteris tenuis*, *Pecopteris anthriscifolia*, *Supaia*, *Noeggeratiopsis*, *Somaropsis*, *Glottophyllum*, etc. Because these plants belong to the Kuznetsk flora, the phytopalaeogeographic boundary between the Angara and Cathaysian provinces should be drawn between here and Kaishantun. JONGMANS (1942) expressed the opinion that the Permian flora of South Primoria is closely related to that of the Upper Kolchugino series in the Kuznetsk basin, while ELIASHEVICH once correlated it with the lower Gondwana flora in India. Because the Kaishantun flora is Kazanian in age according to KON'NO, it is evidently older than the Stizinsk flora.

The above-mentioned marine Permo-Carboniferous formations and faunas form the link between the Mongolian and Chichibu geosynclines. In the inclusion of volcanic materials the Permian of South Primoria well agrees with that of the Inner Zone of Southwest Japan (KOBAYASHI, 1941, TAKAI et al., 1963).

The marine Lower and Middle Triassic stages are well represented in South Primoria. The granite-bearing basal conglomerate of the Skytic stage is 2–150 m thick and transgressively overlies the Permian and also granite. Incidentally, the

Shmakovsk granite in South Primoria which intrudes the Upper Permian formation is dated late Permian by the argon method. The sandstone, shale and calcareous sandstone beds on the conglomerate yield Induan as well as Olenekian ammonoids and pelecypods. *Lonchorhynchus* and *Pleuromeia* were discovered in the Olenekian substage. The Skytic and Anisic stages are about 250 m and 500 to 700 m, respectively, in thickness. The latter consists of sandstone and siltstone and contains *Ptychites, Ussurites* and so forth. The Ladinic stage, 400 to 800 m thick, is also composed of sandstone and siltstone and yields *Daonella, Ptychites* and *Neocalamites*. North of Vladivostok it overlies the Permian directly.

These Triassic formations are so closely allied to the Skyto-Anisic Inai series and the Ladinic Zohoin series in the Japanese islands in the lithofacies and biofacies that they show an embayment opened toward the Pacific basin through Japan. The great thickness of these formations shows strong subsidence related to the growth of the prorogenic synclines and anticlines. The subsidence was stronger in Japan than Primoria insofar as can be judged from the thickness which attains 3,500 m and 500 m respectively, for the Inai and Zohoin series, i.e., 4,000 m in total (TAKAI et al., 1962).

With the marked contrast in the restricted distribution of the Ladinic and older marine Triassic formations, the Upper Triassic formations are wide-spread in the Far East of the USSR from the Dzugdur mountains to South Primoria. The strong discordance at the base indicates the Akiyoshi orogeny.

The Noric or late Noric age was the time of inundation followed by the extensive Rhaetic emergence. The lower Carnic sediments are limited to South Primoria where the shelly and plant-bearing facies alternate as follows:

Upper *Pseudomonotis* beds, 100–200 m thick; *Monotis ochotica*, etc.
Upper Mongugai beds, 250–400 m thick; *Neocalamites, Cladophlebis*, etc.
Lower *Pseudomonotis* beds, 400–500 m thick; *Monotis scutiformis*, etc.
Lower Mongugai beds, 500–800 m thick; *Neocalamites, Taeniopteris*, etc.

Like in Japan, the Lower and Middle Triassic marine sediments and the Upper Triassic paralic ones are the Flysch and Molasse, respectively, with regard to the Akiyoshi orogeny. The latter is comparable with the Miné series in the Inner Zone of Southwest Japan with reference to the great thickness and variation of facies. The inclusion of pyroclastic materials in the Upper Triassic sediments in South Primoria indicates the metaorogenic volcanism on the hinterland of the Akiyoshi folded mountains. The Upper Triassic Akiyoshi Molasse is most typical in Yamaguchi Prefecture where it consists of the Ladino-Carnic Atsu series, 2,000 to 2,300 m thick, and the Carnic and Noric Miné series, 7,000 m or more in thickness. It is interesting to see through this tremendous sequence of the Miné series the facies change from the neritic lower part to the paralic upper part through the limnic middle part (TOKUYAMA, 1962).

The Permo-Carboniferous and Triassic sequence of South Primoria is more similar to that of Japan, particularly of the continental side of West Japan than to that of adjacent East Manchuria and Northeast Korea where the Triassic sediments are totally absent. In these adjacent areas the Permian formations are intruded by the Triassic granite at many places, while the Permian fanglomerate contains granite boulders.

VII. Conclusion: The Akiyoshi Orogeny of the Mongolian Geosyncline

The intracontinental megageosyncline of Asia (1953) was extended between the Angara megakraton and the Koreo–Chinese heterogen from Central Asia to the Far East of the USSR through Central and North Manchuria with a breadth of about 1,000 km. It may be divisible into two wings in Central Mongolia, approximately N 105° E or a longitude through Urga. While the western wing runs from NW or WNW to SE or ESE, the eastern wing extends in the NE or ENE direction. The Great and Lesser Khingan ranges are diagonal to the eastern wing, whereas the Manmo group is distributed through the wing without interruption by these ranges.

Judging from the Cretaceous Sungari series in the Central Manchurian basin (Kobayashi, 1942) it can be concluded that the Great and Lesser Khingan ranges were produced by the late Mesozoic disturbance, destroying the folded belt of the Manmo group.

Setting aside the Proterozoic Stanovoi zone between the Aldan shield and the Mongolian geosyncline, the pre-Sinian rocks are exposed as patches in the northern part of the Great Khingan range, eastern part of the Lesser Khingan range, around the Hanka lake in the Ussuri-Suifung lowland, in the Wantashan and so forth. Their origin is not yet well understood, but they suggest that the structure of the Mongolian geosyncline was complicated.

Broadly speaking, however, it appears to be important for the intracontinental megageosyncline of Asia that the oronization was earlier in the western than the eastern wing as well as earlier on the inner or Siberian side than the outer or Chinese side. In other words, the oronizing trend in the Sinian and later periods was centrifugal from the Angara urkraton but centripetal to the Pacific basin within this megatectonic belt.

The Eo-Palaeozoic and Sinian formations are extensive in the western wing from the Sayan to the Altai range and their stratigraphy has become quite advanced in recent years. As noted by Vologdin already in 1937, the Cambrian of these mountains is different from the same system of the Middle Siberian platform in the great thickness and profusion of volcanic material. Volcanism was related to the crustal deformation in the late Cambrian and early Ordovician which Kouzmin called the Salair movements in 1928.

The fossiliferous Cambrian formation is known to exist in Transbaikalia, the Lesser Khingan range and the Hanka lake area where it is underlain by the Sinian formation. Spilite and keratophyre of the third area show the intrageosynclinal volcanism. Although the three Older Palaeozoic systems are present in the first area, little is as yet known of the Ordovician system except for its occurrences in the Haluha river area and probably in the upper Amur valley.

Judging from the known distribution the flooring of the Cambrian sea occurred from Transbaikalia to the Hanka area, but the Gobia was largely emergent on its southwest side until the Ordovician period.

The Argun complex in East Transbaikalia reaches as high as the Wenlockian series, while the Middle Silurian limestones in East Manchuria and Suiyuan, Inner Mongolia are the oldest fossiliferous horizon of the Manmo group. Therefore it is presumable that there was a crustal movement during the Silurian period through which the northern side of the Mongolian geosyncline was deformed, and the sea widely flooded toward the Gobian land on the south side.

The lower Manmo group unconformably overlies the slightly metamorphosed Infra-Manmo group in North Manchuria. In Northeast Mongolia the Lower Devonian basal conglomerate contains phyllites and mica schists. The Devonian conglomerate of Houlungmen has granite boulders possibly derived from the contemporaneous plutonic rock group which includes the older biotite granite of East Mongolia which are 419–450 million years old. The Devonian formations contain volcanic material at various horizons and reef limestones are well developed in the middle part. The transgression reached the inundation phase in the Givetian age. The sea lingering in the early Famennian in North Manchuria, extensively retreated from the geocyncline at the transition between the Devonian and Carboniferous periods. In the Khara Ayrak graben 350 km to the southeast of Urga a plant-bearing lacustrine formation deposited at this interval which is the oldest continental facies of the group is found.

The Permo-Carboniferous formation near Chabarowsk, however, continues down to the Devonian gradually, but was broken by the Middle Permian discordance. It contains spilite, diabase and other volcanic materials. The Carboniferous and Permian formations of similar facies are wide spread in the Sikhote Alins and East Manchuria and traceable into the borderland between Inner and Outer Mongolia. Coralline limestones mostly of the Visean age and Visean to Middle Permian fusulinid limestones are common members. The Jisu Honguer fauna comprising various marine invertebrates but no fusulinid is distributed extensively in the Lower Permian in the area from Inner Mongolia to East Manchuria through the Great Khingan range.

The Lower Carboniferous patches are known in North Manchuria and Transbaikalia. The Tiparani series is one of them which overlies the Silurian in the Upper Amur valley. I could, however, find no record of its presence in Northeast Mongolia. Furthermore, the higher Carboniferous formations of marine facies appear to be totally absent in the northern side of these areas. Therefore, the northern side of the geosyncline became most probably emergent at that time. The upheaval was probably related to the intrusion of granite as represented by the Chuchtuinsk granite in Mongolia. There is, however, no orogenic facies in the Carboniferous formations on the other side as summarized above.

With remarkable contrast to the Carboniferous period, the Permian was a period of unstability as indicated by the discordance between the West Ujimuchin and Dabussumnor formations and other discordances, and the development of conglomerates and fanglomerates in the middle part of the system.

In the Kazanian age a marine ingression took place into North Mongolia from the Transbaikalian embayment. This boreal fauna suggests a barrier which separated the northern sea from the southern one. Is it too far fetched to speculate that the barrier was land that appeared as a result of Permian orogeny? After the retreat of the sea the late Permian plant and naiad beds were deposited in North Mongolia and the Great Khingan range, and Lower Triassic plant beds in Transbaikalia and in Northeast Mongolia.

In the Lesser Khingan range the Upper Permian marine formation is overlain by the Lower and Middle Triassic with erosion-unconformity, but the two systems are accumulated in the Middle Amur valley without any interruption. In South Primoria the Skytic conglomerate containing granite boulders overlies the Permian granitic mass and north of Vladiostock the Ladinic *Daonella* beds are found to overlie the Permian transgressively.

It is a remarkable fact that Mongolia and Manchuria were already emergent in the late Permian and the Triassic period and that the sea has not entered the area since then. The Lower and Middle Triassic formations are still prorogenic Flyschtype sediments but their distribution agrees better with the Upper Triassic and probably the Upper Permian than with the Lower Permian formation. The Middle Permian is intermediate.

The Upper Triassic formations in Transbaikalia, the Upper Amur valley, the Lesser Khingan range and South Primoria are all typical metaorogenic sediments which are nerito-paralic and greatly variable in facies and thickness, up to several thousand meters. In the north there was a narrow embayment extending as far as Transbaikalia and in the south the shoreline ran down along the international boundary toward South Primoria.

In 1942, I compared the above Permo-Triassic sequence to that of Japan and noted the following:

(1) The palaeontological hiatus between the Moscovian and Sakmarian fossil beds suggests a movement of the Uralian Sakamoto phase.

(2) The Middle Permian Usuginu phase of movements is fully indicated by the discordances, development of conglomerate and the change from the marine facies to the nonmarine plant and naiad beds.

(3) The Tate phase of regression is indicated by the discordance at the base of the Skytic stage.

(4) The Middle Triassic Akiyoshi disturbance is shown by the unconformity at the base of the Upper Triassic and the change of the sedimentation from Flysch to Molasse.

In South Primoria there is Permian granite, and the Skytic conglomerate lying on granite contains granite boulders. The Middle Permian conglomerate of the

Touman formation also contains granite boulders, but the formation having the Upper Permian *Lepidolina* zone is intruded by granite whose age must be post-Permian. The Chilin and Touman formations are all roof-pendants on the Triassic or Permo-Triassic granite which is very extensive in Central and North Manchuria and East Mongolia. Its Mongolian member is the Triassic Dorinchonsk granite. The granite largely oronized the Mongolian geosyncline and fused this orogenic zone with the Chungchao block of the Koreo-Chinese heterogen.

The later continental sediments in basins were faulted or undulated but not strongly folded. The Jurassic(?) Tsetsenwan formation is one of the oldest in Central Mongolia. There are such basin deposits in Manchuria which are generally considered Jurassic or Cretaceous. The oldest of them at Taheishan in the Great Khingan range contains Conchostracan remains of the same group with those of the Daido (or Daedong) series in Korea whose age ranges from Upper Triassic to Lower Jurassic. Although I do not go any further in treating the subject here, the chronology of the nonmarine older Mesozoic formations determined by land plants requires a thorough revision, because it is now well ascertained that the Rhaeto-Liassic type floras flourished in Eastern Asia already in the Carnic age (KOBAYASHI, 1938, 1942).

The relations of the stratigraphic sequence and geographic distribution between the Manmo and Infra-Manmo groups suggest that the middle Silurian movement are of prime importance to the eastern part of the intracontinental geosyncline of Asia, although much remains to be studied on this crustal movement in future.

As noted above, palaeogeography was quite different between the Devonian and Carboniferous periods. While the Devonian system is wide spread from north to south, the Carboniferous, and especially the Upper Carboniferous which is poorly represented on the north side, is well developed in the central and southern parts. Therefore, it is certain that the northern side of the Devonian geosyncline became emergent in the Carboniferous period. The geanticlinal culmination of this side may be related to the intrusion of the Carboniferous Chuchtuinsk and allied granites. To decipher the post-Devonian crustal deformation, however, the importance of dating of the folded substratum discordantly lying beneath the Carboniferous or Permian formation is crucial, because the deformation of the substratum could be the effect of the Middle Silurian movement if it belongs to the Infra-Manmo group.

One aspect that can hardly be overlooked is that the Carboniferous sequence in the central and southern parts is only slightly broken. It shows that the subsidence was not interrupted in the axial zone even at the beginning or end of the period. It is mostly composed of fine terrigenous sediments and carbonate rocks in addition to volcanic material which was produced by repeated intrageosynclinal volcanism. No typical orogenic facies is seen among them. There was neither the Bretonian nor any later Carboniferous phase of movement in this part of the Mongolian geosyncline. Sometimes it is called late Variscan, but insofar as Central and North Manchuria is concerned, this late Variscan means Pseudo-Variscan because it is post-true-Variscan. Because the orogenic movements were repeated during the Permo-Triassic period after the Saalic phase of the Hercynian orogenic cycle, the Akiyoshi cycle of the Mongolian geosyncline should not be confused with the Hercynian or Variscan cycle of Central Europe. Such a distinction is important in clarifying the time displacement of the cycle between the two sides of the Eurasiatic continent.

SCHÖNEMANN (1929) emphasized the late Mesozoic orogeneses for the Mongolio-Amur folded belt, but as I have pointed out already (1942), the Amur folded belt is in my opinion the final product of a subgeosyncline which was brought about in Transbaikalia and its eastern extension by the destruction of the northern side of the Mongolian orogenic zone immediately after the Akiyoshi orogeny. The Upper Triassic Molasse with regard to this orogeny is the oldest sediment of the Amur subgeosyncline. The Mesozoic structure of Eastern Transbaikalia which TAETIAEFF and his cooperators have clarified is the product of the Sakawa orogenic cycle which is characterized by the differential movement between the Upper Triassic and later subgeosynclinal material on one side and their substratum on the other. In this sense this late Mesozoic folded belt is superimposed on the Mongolian orogenic zone, as YANSHIN (1964) claimed. In Manchuria, however, there is no such subgeosynclines but intermontane basins which suffered later block movements. The Sikhote Alin mountains appear to me to be a polycyclic folded belt having the Akiyoshi folds at the axis. In this sense the Sikhote Alin geosyncline may be said a relic of the Mongolian geosyncline which was placed there by migration of the geosynclinal axis. Most of the crustal movements culminated there later than the Amur belt.

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* Abbreviations
Doklady: Doklady Acad. Nauk, SSSR, Earth Sci. Sections.
Trans.: English translation published by the American Geological Institute.
Zentralbl.: Zentralbl. für Geol. und Pal.

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Earthquakes in Manchuria

Win INOUYE

I. General View of the Earthquakes in Manchuria

It is said that earthquakes originate mainly from the folded mountain zones which were formed by the Cretaceous and Tertiary orogenic movements, so many earthquakes do not occur in Manchuria which has been relatively stable in the recent geological age. According to NIINOMY and MURATA, only 68 earthquakes have been recorded from 2 A.D. to 1888 A.D. Of these, the following three earthquakes were destructive.

(1) 1774: Tieh-ling district, Mukden Prov.
(2) 1855 (Dec. 11): Mukden—Chin-chou district, Mukden Prov.
(3) 1859: Niu-chuang—Kai-ping district, Mukden Prov.

During the period of 26 years from 1904 when meteorological observation was begun at Dairen to 1930, 20 earthquakes were felt in Dairen, Ying-kou, Port Arthur, and Mukden.

Since the Central Meteorological Observatory was established in Chang-chun and meteorological observation was begun throughout Manchuria, earthquakes have been precisely recorded, but instrumental observation was not satisfactory. According to the Monthly Report of the Central Meteorological Observatory of Manchoukuo from 1935 to 1941, even in the years when no destructive earthquakes occurred several felt earthquakes were recorded. The earthquake in the districts of Kai-lu in West Hsing-an Province and Tung-liao in South Hsing-an Province on January 19, 1940, seems to have caused a little damage. The earthquake in Hsiung-yo-cheng, Mukden Province on August 5, 1940 and the earthquake in Sui-hua, Pin-chiang Province on May 6, 1941 were destructive earthquakes which rarely occur in Manchuria.

According to the Richter-Gutenberg magniude scale, the magnitudes, M, of these earthquakes are as follows: the earthquake in Kai-lu and Tung-liao, $M=5.9$; the earthquake in Hsiung-yo-cheng, $M=6.3$; and the earthquake in Sui-hua, $M=6.7$. The energy of each of these earthquakes is 4×10^{22}, 2×10^{23}, and 1×10^{24} erg, respectively. These values, though rough, can be used as standards when comparing the magnitudes of these earthquakes. That is, the Sui-hua earthquake was about five times as large as the Hsiung-yo-cheng earthquake, and the Hsiung-yo-cheng earthquake was about five times as large as the Kai-lu and Tung-liao earthquakes.

In Japan, more than 1,200 felt earthquakes are recorded every year, and a destructive earthquake occurs at the rate of one a year. Compared with Japan, the occurrence of earthquakes in Manchuria is very infrequent. In the Tōnankai earthquake of 1944 and the Tokachi-oki earthquake of 1952 $M=8.0$, in the Kwantō earthquake of 1923 and the Nankaidō earthquake of 1946, $M=8.2$, and in the Sanriku-oki earthquake of 1933, $M=8.5$. Compared with these earthquakes, the magnitudes of destructive earthquakes in Manchuria are small. The destructive earthquakes which occurred in Manchuria in recent years, namely, the Hsiung-yo-cheng earthquake and the Sui-hua earthquake, will be outlined below.

II. The Hsiung-yo-cheng Earthquake of August 5, 1940

According to the Monthly Report of the Central Meteorological observatory of Manchoukuo, this earthquake can be summarized as follows:

(a) Damage

The damage was very severe in the area extending from Hsi-erhtai-tsu in the west to Erh-tao-ho in the east; the center of the affected area was the Chiu-chai Station of the South Manchurian Railway and its vicinity. Mud-brick houses were mainly damaged, and in some villages more than 50 percent of these houses were totally demolished. According to the investigation by the Kai-ping Prefectural Office, the damage and casualties were as follows:

Table 1. Statistics on Damages and Casualties.

Village or town	Houses		Killed	Injured
	Totally demolished	Partially demolished		
Chiu-chai	740	4,261	—	2
Lung-men-tang	135	917	—	—
Kang-ning-pu	59	448	1	2
Hsiung-yo-cheng	—	1,030	—	—
Kuei-chou	138	1,131	—	—
Hsiang-huang-chi	—	56	—	—
Shuang-tai-tsu	34	52	—	—
Fang-shen-kou	43	281	1	3
Huan-chia-pu	—	92	—	—
Chien-chia-tun	41	1,128	—	—
Total	1,190	9,396	2	7

No remarkable topographical change took place except in the low damp ground near the coast of Hsiang-lan-chi village where fissures from which water spouted were formed; and several small fissures were reported in some places. It is said that well water became slightly turbid at the time of the earthquake, but it became clear before long. There were no unusual signs in the hot spring at Hsiung-yo-cheng.

(b) Seismological observation

The seismic intensity observed at various meteorological offices was as follows:

III: Ying-kou, An-shan
II: Chin-chou, Lien-shan-kuan, Fu-shun
I: Mukden, Chin-feng, Chang-chun, Fu-shen, Kai-lu, Liao-yang, I-hsien, Hsing-cheng, Pyong-yang

This earthquake was felt even in Chang-chun which was 500 km from the epicenter. The results of instrumental observations are shown in Table 2.

Table 2. The Results of Seismological Observations.

Locality	Time of occurrence	Duration of preliminary tremors	Maximum amplitude micron
Ying-kou	$18^h\ 55^m\ 18^s$	8.0^s	—
Pi-tsu-wo	18 54 54	11.0	—
Dairen	18 55 32	18.0	980
Port Arthur	18 55 35	20.8	—
Mukden	18 55 58	29.2	1650
Hsin-ching	18 56 18	57.1	31
Yen-chi	— — —	78.0	330
Pyong-yang, Chosen	18 55 57	—	—
Inchon, 〃	18 56 16	—	—
Seoul, 〃	18 56 18	—	—
Singalli, 〃	18 56 55	—	—
Taegu, 〃	18 57 06	—	—

Based on these results of observations, the epicenter of this earthquake was judged to be located at a point abaut 10 km southwest of Hsiung-yo-cheng, precisely speaking, 122.1° E, 40.1° N. Based on the time of occurrence and the duration of preliminary tremors at each place, the time of occurrence at the hypocenter was estimated at $18^h55^m6^s$.

The depth of the hypocenter is considered to have been less than 10 km, which is very shallow, so, if it is assumed that the depth of the hypocenter is 0 and if the previously mentioned times of occurrence are adopted, the travel time curves of the P-wave and the S-wave shown in Fig. 1 are obtained. In this graph only the observation values from the observatories in Manchuria were adopted, and the values from Mukden and Pi-tsu-o were excluded, as they were considered untrustworthy. The black dots on the graph are the values observed at Chang-tung in the cases of the Chi-lin earthquake of June 1, 1937, and the Sui-hua earthquake of

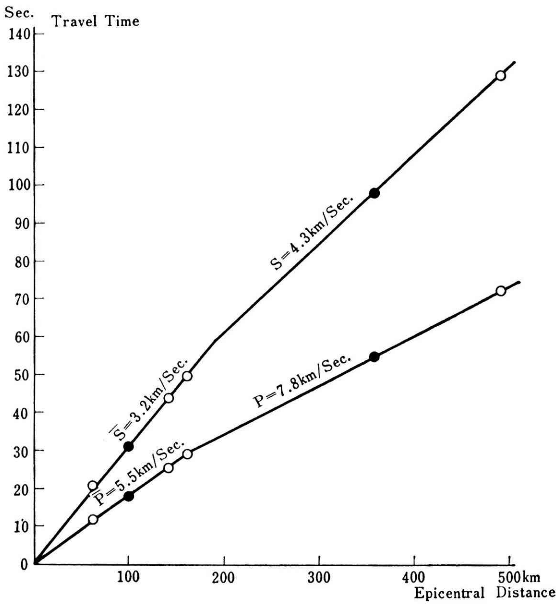

Fig. 1. Time-distance curve.

May 6, 1941. These were plotted for reference. In the cases of these earthquakes, the time of occurrence at the hypocenter of each earthquake was obtained from the time of occurrence and the duration of preliminary tremors at each place, and it was considered that the hypocenters of the two earthquakes were very shallow.

As seen in the graph, there were not many observation values, so the graph has little value. But, if the points are connected with straight lines, two straight lines can be obtained for both the S-wave and P-wave. The velocity of the earthquake waves can be determined from the inclination of these straight lines. That is, in the upper layer the velocity of the P-wave was 5.5 km/sec and that of the S-wave 3.2 km/sec, while in the lower layer the velocity of the P-wave and the S-wave was 7.8 km/sec and 4.3 km/sec, respectively. If these travel time curves are trustworthy, the thickness of the earth's crust must be 35 km, but it is regrettable that these values are not very trustworthy.

(c) The magnitude of the Earthquake

The Richter-Gutenberg magnitude scale, which expresses the magnitude of earthquakes, has recently become practical and has come into general use. This is a method to determine the magnitude of earthquakes by a function on the maximum amplitude of earthquake motion, and at the same time it serves to clarify the relationship between the magnitude and the toal energy of earthquake waves. Consequently, the magnitude of earthquakes can be compared based on the amount of energy of the earthquakes.

According to a study by TSUBOI, the relationship between the magnitude, M, and the maximum amplitude, A (unit; micron), in the epicentral distance $\triangle$ (unit; 100 km) is represented by the following formula,

$$M = 0.20\ \triangle - 0.67 \log A - 3.80\ (\triangle < 5)$$

$$M = 0.03\ \triangle - 0.61 \log A - 5.00\ (\triangle > 5).$$

The mean magnitude of this earthquake based on the observation values at Dairen, Yen-chi, Mukden, and Chang-chun and calculated by this formula was $M = 6.3$.

The relationship between the magnitude, M, and the energy of the earthquake, E, has been given by Gutenberg in the following formula,

$$\log E = 12 + 1.8\ M.$$

If the value M is substituted in the above formula,

$$E = 2 \times 10^{23}\ \mathrm{erg}.$$

That is, the magnitude of this earthquake is considered to be almost the same as that of the destructive earthquake which occurred in the valley of the Chikuma River northeast of Nagano city on July 15, 1941.

(d) Foreshocks and Aftershocks

A foreshock occurred 10 to 30 minutes before the principal shock, and it was felt everywhere in the vicinity of Hsiung-yo-cheng. According to the Hsiung-yo-cheng Police Station 69 aftershocks occurred in August, 33 in September, 5 in October, 5 in November, and 1 in December.

The magnitudes of the main aftershocks calculated on the basis of the maximum amplitude recorded at Ying-kou were as follows:

Sept. 14, $11^h\ 36^m$	$M = 4.9$
Sept. 17, $14^h\ 10^m$	$M = 4.9$
Sept. 21, $16^h\ 10^m$	$M = 4.6$
Nov. 5, $15^h\ 08^m$	$M = 5.1$
Nov. 22, $22^h\ 01^m$	$M = 4.9$

That is, the magnitudes of the main aftershocks are smaller than the magnitude of the principal shock by more than 1 for the value of M. That the magnitude was smaller by 1 means that the energy was about 1/60.

III. The Sui-hua Earthquake of May 6, 1941

(a) Seismological Observation

The earthquake which originated from a point near Sui-hua on May 6, 1941 at about $0^h\ 18^m$ was a large earthquake which occurs very rarely in Manchuria. According to the Chang-chun Meteorological Observatory, the time of occurrence was $0^h\ 19^m\ 12.8^s$, the duration of preliminary tremors 43 seconds, and the epicentral distance 375 km. Assuming the Poisson's ratio to be 0.27, the time of occurrence at the hypocenter was $0^h\ 18^m\ 18^s$. Based on the time of occurrence at Dairen ($\triangle = 995$ kg) and Seoul ($\triangle = 1040$ km), and assuming the depth of the hypocenter to be 0, according to the travel time table prepared by WADATI, SAGISAKA, and MASUDA, the calculated time of occurrence at the hypocenter was $0^h\ 18^m\ 18.5^s$. The epicenter was estimated to be 127° 04′E, 46° 42′N from the results of field observations in the meizoseismic area, though the epicenter could not accurately be determined by instrumental observation. The hypocenter was considered to be shallower than 10 km from the extent of the meizoseismic area.

(b) The Magnitude of the Earthquake

The maximum amplitude in each place in Manchuria was 620 microns in Chang-chun, 690 microns in Mukden, 453 microns in Yen-chi, and 323 microns in Ying-kou. If the magnitude of this earthquake is calculated on the basis of these amplitudes and by using TSUBOI's formula, the result is $M=6.7$. Consequently, $E=1\times10^{24}$ erg. In short, the magnitude of this earthquake was of the same degree as that of the Tajima earthquake on May 23, 1925, the Nishi-saitama earthquake on September 21, 1931, and the Imaichi earthquake on December 26, 1949.

(c) Aftershocks

Two minutes after the principal shock the first aftershock occurred and it was followed by six aftershocks on that day. Table 3 shows the number of aftershocks recorded at the prefectural office of Sui-hua.

Table 3. The Number of Aftershocks.

Date	Number	Date	Number
May 6	6	May 10	1
〃 7	4	〃 11	0
〃 8	1	〃 12	1
〃 9	2	〃 13	3

On June 3, when I arrived in the town of Sui-hua, it was said that two aftershocks were felt. On the night of June 6, I felt two slight shocks.

(d) Damage

The meizoseismic area was a diluvial tableland 230 to 250 m in altitude with a point 10 km northeast of Sui-hua town as the center. Figure 2 shows the percentage of totally demolished houses in this area. As seen in the figure, the area where houses were totally demolished was an elliptical area 17 km E–W and 25 km N–S.

According to the statistics prepared by the authorities of Sui-hua prefecture, main damage was limited to one town and four villages as shown in Table 4.

Houses in this area are poorly built brick houses and thatched houses. The latter are wooden-framed houses with walls of sun-dried bricks called tu-pi-tzu. Therefore, the relationship between the intensity and damage to dokaku (sun-dried

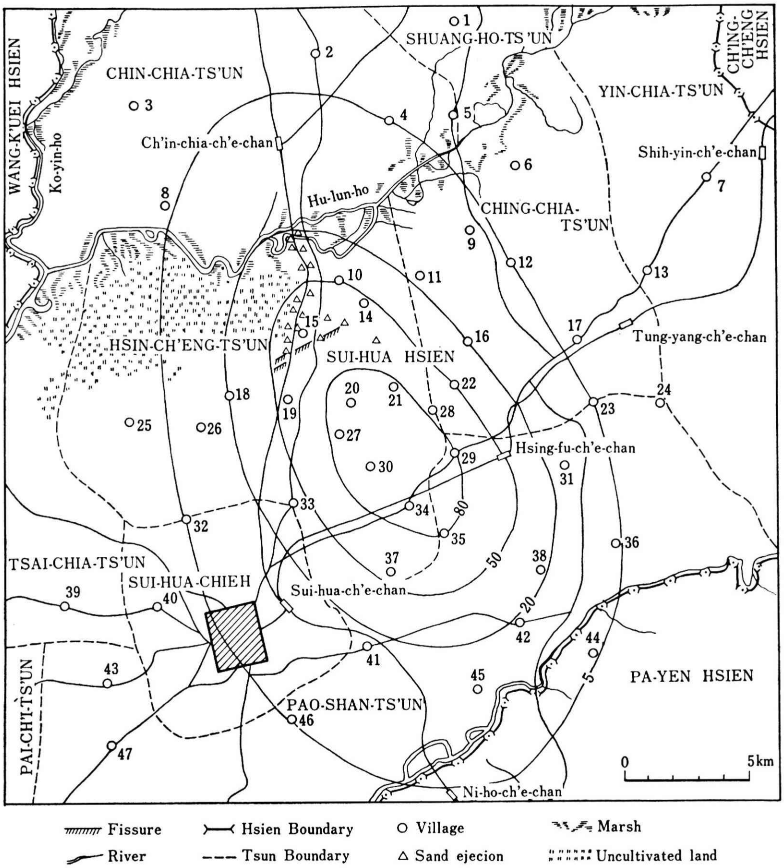

Fig. 2. Percentage of totally damaged houses in the Sui-hua area.

1 Kuo-chia-tien
2 Wang-ch'ing-shui
3 Yang-chia-yu-fang
4 San-hsing-t'un
5 Wu-ch'ang-lung-t'un
6 Chiao-wo-p'u
7 Lan-chia-wa-tzu
8 Hsiao-tung-t'un
9 Pei-chang-wo-p'u
10 Niang-niang-miao
11 Kao-chia-tien
12 Liang-hai-tzu
13 Ta-p'ing-ling
14 Chu-chia-wo-p'u
15 Ting-chia-sui-tzu
16 Hsiao-chang-wo-p'u
17 San-men-chang-t'un
18 Huang-chia
19 Erh-tao-kou
20 Hsiao-hsin-ch'eng-wo-p'u
21 Ta-hsin-ch'eng-wo-p'u
22 Ta-chang-wo-p'u
23 Chien-ching-ho
24 Hsing-chia-t'un
25 Hsi-fu-ch'un-ling
26 Ta-fang-shen
27 Tiao-yü-t'oi
28 Meng-chia-wo-p'u
29 Huang-fien-te-t'un
30 Huang-chia-kou
31 San-chia-wei-tzu
32 Hsü-chia-fen-fang
33 Lan-feng-ch'ih
34 T'ung-chia-wo-p'u
35 Hsiao-fang-shen-kou
36 Meng-chia-kao-tzu
37 Sheng-chia-wo-p'u
38 Erh-lung-shan
39 Hsi-ch'ang-fa-t'un
40 Hsi-ssu-p'ing-chieh
41 Tung-wan-fa-t'un
42 Kung-hsing-fu
43 Ying-chia-wo-p'u
44 Hou-chou-feng-lu
45 Chia-pao-t'un
46 Lang-chia-choi
47 Fan-chia-t'un

Table 4. Statistics on Damage.

Town and village	Population before earthquake		Damaged houses	Casualties
	Houses	People		Killed
Sui-hua town	9,711	57,546	353	32
Hsin-cheng village	1,569	10,619	269	63
Yen-lin village	1,408	10,386	103	15
Chin-ho village	1,714	12,190	109	9
Chin-chia village	1,708	11,054	24	1
Total	16,110	101,795	858	120

Town and village	Casualties		Houses	
	Severaly injured	Slightly injured	Totally demolished	Partially demolished
			Pangtsu	Pangtsu
Sui-hua town	6	16	71	3,337
Hsin-cheng village	33	45	1,067	18
Yen-lin village	12	28	483	439
Chin-lin village	20	30	310	349
Chin-chia village	3	10	19	35
Total	74	129	1,950	4,178

brick) houses in Taiwan, as investigated by Ryūtarō TAKAHASHI, can be applied to this case.

According to MONONOBE, 50 percent of Japanese modern houses are totally demolished when the acceleration of earthquake motion reaches 450 gals. According to TAKAHASHI, 50 percent of dokaku (sun-dried brick) houses are totally destroyed by the acceleration of 300 gals.

There are very few data from which the acceleration of earthquake motion in the meizoseismic area can be known, but the results of KAWASUMI's field observations are as follows:

Based on the damage to an iron bridge on the Hu-lan River north of Sui-hua, the fissures produced in the railway banking, the sinuous buckling of rails, and quantities of sand forced up through the cracks in the alluvial land, KAWASUMI estimated the acceleration of earthquake motion in the vicinity to have been about 300 gals. Glass bottles, tableware, and other vessels fell from shelves in the town of Sui-hua. An iron incense-burner in the courtyard of the mausoleum of Emperor Sheng-tsung rotated, at the same time it was displaced 4 cm to the northeast and the lid fell to the northeast. Moreover, the upper part of the double granite pedestal of the incense-burner was displaced to the east by about one cm.

The ratio of the acceleration that causes these movements to gravity is almost equal to the friction coefficient. So the acceleration in the town of Sui-hua is estimated to have been about 250 gals.

Not only the hypocenter of this earthquake was shallow but in the case of the above-mentioned poorly-built houses damage of quite a different type is produced from a slight difference in intensity. It has been considered that the damage from this earthquake was limited to a small area for these reasons.

(e) Topographic Changes and Ground Water

It seems that there was no topographic change directly related to the mechanism of occurrence of the earthquake. Fissures were produced in the skirt of a hill situated on the boundary between the tablelands of Hsiang-chia-wei-tzu and Wan-ho-fu and the marshy land on the Hu-lan River, and great quantities of sand and water were ejected at several places from the fissures. Moreover, sand was ejected here and there on both sides about 30 m from the railway track south of the iron bridge on the Hu-lan River, and sand ejection occurred as far as the vicinity of the hill.

(f) Mechanism of Occurrence of the Earthquake

The distribution of "Push" and "Pull" of the initial motion instrumentally observed is of great use in clarifying the mechanism of occurrence of an earthquake. In the case of this earthquake the initial motion was observed in Nagano and Kobe, both which are situated southeast of the epicenter, and the intitial motion was "Pull" in both places. These data are insufficient for the clarification of the mechanism of earthquake occurrence. But it is not illogical to consider that the hypocenter was subjected to pressure from the northwest and southeast and tension to the northeast and southwest. The epicenter of this earthquake corresponds approximately with the center of a circle including the arc of the Japanese Islands, so the epicentral distance of the station in Japan is almost equal, i.e., 1,200 to 1,600 km. If it is admitted that of the maximum motion observed at each station, the seismic motion of short duration was caused by the S-wave and that of long duration by the surface wave, the S-wave was large in Nagasaki, Fukuoka, and Kumamoto all of which are situated south of the epicenter, and in Aomori and Mizusawa which are east of the epicenter. But in Osaka, which is southeast of the epicenter, the S-wave was small. On the contrary, the surface wave was largest in Toyama southeast of the epicenter.

In the case of the quadrant-type distribution of initial motion it is theoretically expected that the S-wave is large in places which correspond with the nodal line, while the surface wave is large in places which correspond with the loop. In the case of the Sui-hua earthquake the mechanism of occurrence can be explained as follows: first, the E–W and N–S nodal lines of initial motion at the epicenter are drawn. In the four quadrants thus obtained, the initial motion was "Pull" in the NW and SE quadrants, and "Push" in the NE and SW quadrants.

In this case, if the hypocenter was subjected to horizontal shearing force, either of the E–W and N–S nodal lines must be a fault line. If fracture occurred at the

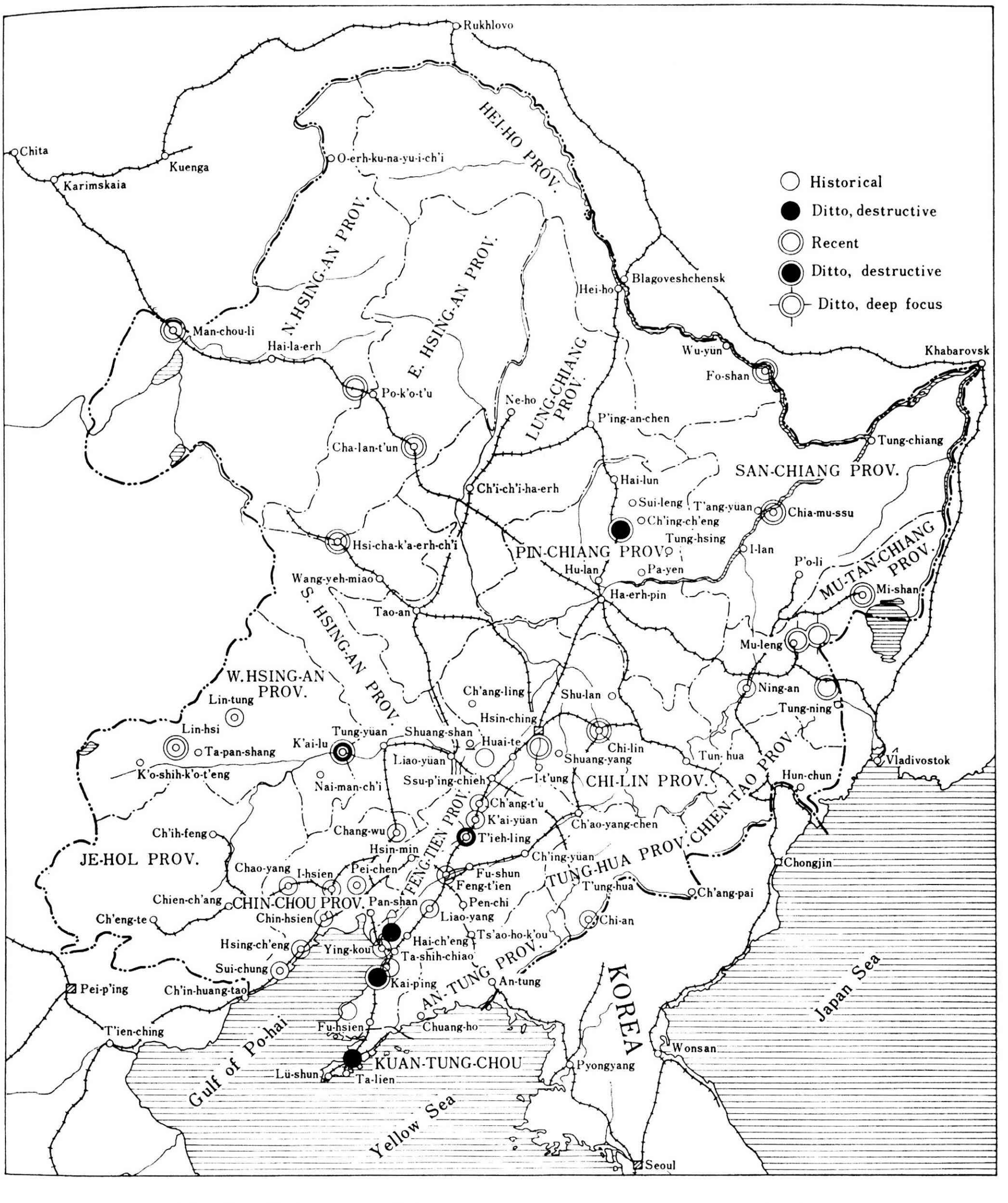

Fig. 3. Epicenters of the earthquakes occurred in Manchuria.

hypocenter as a result of tension, the direction of the fault line must be northwest or southeast; and it is also probable that magma intruded through the fault line.

The area where houses were severely damaged in the direction of northwest and southeast, and the result of magnetic survey carried out by the writer in the vicinity of the epicenter after the earthquake revealed that an axis of large vertical magnetic force ran in the above-mentioned direction. From these facts it is reasonable to assume the presence of a NW–SE fault line rather than a fault line running E–W or N–S.

The result of magnetic survey carried out by the writer in the disturbed area from June 5th to the 8th is shown in Table 5 as a reference. The datum point was established near a monument in the square in front the Sui-hua Station, and a comparative survey was made at this point before and after the survey.

Table 5. Anomaly of the Vertical Magnetic Force.

Locality	Observation value	Distance from the datum point		Anomaly
		To N	To E	
	γ			γ
Sui-ha	0	0 km	0 km	0
San-ho-tun	+ 31	2.2	0.2	+ 13
Tung-chia-wo-pu	+119	3.5	3.5	+102
Hsi-fang-shen-kou	+202	5.05	5.1	+177
Tien-chia-wo-pu	+242	6.25	7.2	+214
Tung-chin-i	+220	10.7	13.6	+176
Shih-in-i	+197	17.4	19.8	+118
Lan-feng-chih	+ 72	4.3	0.05	+ 37
Pi-chia-fen-fang	+150	7.65	0.55	+ 90
Wan-ho-fu	+212	10.7	0.95	+128

IV. Geographical Distribution of the Epicenters in Manchuria

In Manchuria few earthquakes occurred of which the epicenters were known. Figure 3 shows rough locations of the epicenters. Recent earthquakes are shown on the map by symbols different from those of historical earthquakes. The epicenters of historical earthquakes, with the exception of Tu-chi-an in Kao-kou-li, Tu-ning-an in Chin, and Lin-tung in Je-ho Province, are distributed in a row, i.e., Chin-chou, Fu-chou, Kai-ping, Nie-chuang, Liao-yang, Mukden, Tien-ling, Kai-yuan, Chang-tu, and Li-shu. There is another row of epicenters, i.e., Sui-chung, Hsing-cheng, Chin-chou, Pei-chen, I-chou, and Chang-wu.

Earthquakes that occurred in recent years have been distributed extensively in North Manchuria, so it is difficult to establish seismic zones. But, in the past, the Chin-chou earthquake and the Nie-chuang earthquake occurred in the zone extending from Chin-chou to Hsin-ching, and the Hsing-yo-cheng earthquake recently originated from that zone which seems to be a relatively active seismic zone.

In the vicinity of Mu-ling, Mu-tan-chiang Province, a very deep-focus earthquake takes place from time to time. From the distribution of "Push" and "Pull" of the initial motion of the deep-focus earthquakes on July 10, 1940, and on

January 11, 1946, it is inferred that the hypocenter was subjected to pressure on the NW–SE side and tension on the NE–SW side.

V. Conclusion

It is unfortunate that a thorough study on the earthquakes in Manchuria is impossible due to the deficiency of historical materials and incomplete instrumental observation.

A felt earthquake occurs only several times a year in Manchuria, and a destructive earthquake very rarely occurs. The number of earthquake occurrences in Manchuria is less than one percent of those in Japan.

The magnitudes of the destructive earthquakes which recently occurred in Manchuria were determined by using TSUBOI's formula as follows:

Kai-lu Tung-liao earthquake of January 19, 1940, $M=5.9$
Hsiung-yo-chen earthquake of August 5, 1940, $M=6.3$
Sui-hua earthquake of May 6, 1941, $M=6.7$

There are almost no data concerning the force which worked on the hypocenter. It has been inferred, however, that pressure worked on the NW–SE side and tension worked on the NE–SW side in the cases of the Sui-hua earthquake and the deep-focus earthquake which originated from the vicinity of Mu-ling.

The determined velocity of seismic waves based on scanty data is as follows: in the upper layer the velocity of the P-wave is 5.5 km/sec, and that of the S-wave 3.2 km/sec. In the lower layer the former is 7.8 km/sec and the latter 4.3 km/sec.

The historical information on the earthquakes in Manchuria has appeared in other publications, so only the earthquakes which occurred recently in Manchuria are tabulated below.

List of the Recent Earthquakes in Manchuria
(Japanese standard time)

(1) The earthquake which originated in the Hsing-an-ling Mountains on Dec. 4, 1936 at about $11^h\ 49^m$.

The intensity was III in Hsing-an. Though the earthquake was rather brisk, no damage was produced.

(2) The earthquake in Kuo-chia-tun south of Chang-chun of Feb. 18, 1937 at about $19^h\ 43^m$.

The earthquake was felt in Chang-chun. The time of occurrence in Pyongyang, Seoul, and Tae-gu was $19^h\ 44^m\ 50.2^s$, $19^h\ 45^m\ 37.6^s$, and $19^h\ 46^m\ 41.1^s$, respectively.

(3) The earthquake north of Chi-lin on June 11, 1937 at about $1^h\ 55^m$. A felt earthquake occurred in the drainage basin of the Sungari River north of Chi-lin. The intensity in Chang-chun and Harbin was I. The epicenter was located at a point in the drainage basin of the Second Sungari River (T.N.; the Sungari above Harbin) north of Chi-lin. This earthquake was followed by two small ones which

originated from the same point. The earthquake which occurred at 3 o'clock was not felt, and the intensity of the earthquake which took place at 6 o'clock was I at Chang-chun.

The result of seismological observation in Chang-chun is as follows:

Locality	Time of occurrence	Maximum amplitude			Period			Duration of preliminary tremors	Initial motion
		N	E	Z	N	E	Z		
Chang-chung	$01^h\ 56^m\ 10^s$	430	430	140	0.6^s	0.6^s	—	12.9^s	ENE, Down
〃	03 36 09	—	10	—	—	—	—	—	—
〃	06 00 33	—	90	—	—	0.5	—	—	ENE

The time of occurrence of this earthquake in Pyong-yang, Seoul, and In-chon was $1^h\ 57^m\ 30.6^s$, and $1^h\ 58^m\ 56.9^s$, respectively. The duration of preliminary tremors in Pyong-yang and Seoul was $1^m\ 60^s$ and $1^m\ 29.7^s$, respectively. From these results of observation the time of occurrence at the hypocenter was determined as $1^h\ 55^m\ 52^s$. The magnitude of this earthquake determined from the maximum amplitude in Chang-chun by using TSUBOI's formula is 5.75.

(4) The earthquake in Mi-shan on July 6, 1937.

(5) The earthquake in Lin-hsi on March 7, 1938 at about $21^h\ 57^m$. At first slight shocks were felt in Lin-hsi, then a subterranean noise which resembled the sound of a passing truck was heard, and after that sliding doors and others began to rattle with the vibration.

(6) The earthquake in Tung-ning and Sui-fen-ho on April 21, 1938 at about $20^h\ 20^m$.

The intensity of this earthquake was II in Sui-fen-ho and I in Tung-ning. In Sui-fen-ho and its vicinity a subterranean noise was heard, simultaneous with the shock, from the direction of southwest or west.

(7) On May 3, 1938, it seems that a local but considerably severe earthquake occurred in Fo-shan and its vicinity, Hei-ho Province. Details are unknown, however.

(8) At about $4^h\ 24^m$ on June 29, 1938, an earthquake occurred which was strong enough to vibrate houses in the Chia-mu-ssu district. But we have no details.

(9) An earthquake was instrumentally recorded in Chang-chun at $3^h\ 18^m$ on June 30, 1938. This earthquake seems to have been felt in some districts.

(10) An earthquake with an intensity of II was felt in So-lun at $20^h\ 48^m$ on January 24, 1939. Vibrations continued for about 20 seconds, and the oscilation of water in vessels was observed.

(11) The earthquake in Chan-lan-tun on Feb. 6, 1939 at about 14^h. An earthquake with an intensity of I was felt in Cha-lan-tun. According to the seismological observation in Chang-chun, the time of occurrence was $14^h\ 28^m\ 59.2^s$, and the duration of preliminary tremors was 58 seconds. Therefore, the distance

between Chang-chun and the epicenter must be 500 km, i.e., the epicenter is Cha-lan-tun.

(12) The earthquake in Manchouli on April 18, 1939.

(13) The earthquake in the drainage basin of the Liao-ho between Kai-lu and Tung-liao on January 19, 1940, at about 14^h 23^m.

This earthquake was felt throughout the western part of South Manchuria, and it seems that there was some damage in the epicentral area. The intensity was V in Kai-lu, III in Chin-feng and Pai-cheng, II in Chin-chou and I in Chang-chun and Mukden. The results of seismological observations in Mukden and Chang-chun were as follows:

Locality	Time of occurrence	Maximum amplitude			Period			Duration of preliminary tremors
		N	E	Z	N	E	Z	
Mukden	14^h 23^m 55.3^s	—	204	—	$—^s$	$—^s$	$—^s$	36.7^s
Chang-chun	14^h 24^m 29.7^s	227	269	152	1.1	1.1	0.9	56.2^s

The epicenter was located at a point 121°E, 43.5°N. The magnitude of this earthquake was determined from the maximum amplitude in Mukden and Chang-chun and by using Tsuboi's formula. The result is M=5.9.

(14) An earthquake with an intensity of I was felt in Cha-lan-tun at about 14^h 30^m on February 6, 1940.

(15) The unfelt earthquake in the vicinity of Chang-chun at about 14^h 4^m on March 24, 1940.

(16) An earthquake which had an intensity of I was felt in Lin-hsi at 5^h 34^m on May 27, 1940.

(17) The deep-focus earthquake in the vicinity of Mu-leng, Mu-tan-chiang Province on July 10, 1940, at about 14^h 51^m.

The epicenter was situated in 130.6°E, 44.8°N, i.e., in the vicinity of Mu-leng. At many weather stations in Japan the ScS wave was observed. From the ScS-wave, the depth of the hypocenter was estimated at 560 km. The intensity was I in Chang-chun, and II in Chong-jin and Na-nam, Chōsen. A zone of abnormal seismic intensity was observed in Japan proper. The intensity II was reported from Hakodate, Urakawa, and Hachinohe, and I from Wajima, Aomori, Obihiro, Miyako, Kushiro, Utsunomiya, Onahama, and Yokohama. The initial motion was "Pull" at all weather stations in Japan where this earthquake was observed, i.e., in Sapporo, Aomori, Sendai, Nagano, Kyoto, Fukuoka, In-chon, and Dairen, except for the "Push" motion in Nemuro and Shikuka. From the distribution of the "Pull" and "Push" of the initial motion it is inferred that the stress at the hypocenter was pressure on the NW–SE side and tension on the NE–SW side.

(18) The earthquake in Hsiung-yo-cheng on August 5, 1940 at about 18^h 55^m.

The epicenter of this earthquake lay at a point about 10 km southwest of Hsiung-yo-cheng, i.e., 122.1°E, 40.1°N. The time of occurrence at the hypocenter was $18^h\ 55^m\ 06^s$. According to the investigation by the Kai-ping Prefectural Office, two persons were killed, five were injured, and about 1,000 houses were totally demolished.

The intensity was III in Ying-kou and Pi-tsu-wo, II in Chin-chou, Lien-shan-kuan, Hsin-i-chou, and Dairen, and I in Chin-feng, Mukden, Chang-chun, and Pyong-yang. The magnitude of this earthquake was M=6.3.

(19) The earthquake in the Sui-hua district, North Manchuria, on May 6, 1941 at about $0^h\ 18^m$.

According to the investigation by the Sui-hua Prefectural Office, 122 persons were killed, 74 were severely injured, 129 were slightly injured, 1952 fang-tsu (T.N.: houses) were totally destroyed, and 4178 fang-tsu were partially destroyed. The magnitude of this earthquake was M=6.7, and the earthquake was of the same magnitude as the Nsihi-Saitama earthquake of Sept. 21, 1931.

(20) The deep-focus earthquake in the vicinity of Sui-fen-ho on Jan. 11, 1946, at about $10^h\ 35^m$.

The epicenter was assigned to a point 131°E, 45°N, and the focal depth was estimated at 600 km. Whether or not this earthquake was felt in the vicinity of the epicenter is unknown, but an earthquake with an intensity of I was abnormally felt in Hachinohe, Tokyo, Shizuoka, and Kashiwara. The initial motion was "Pull" at more than ten weather stations from Mori in Hokkaidō to Fukuoka in Kyūshū. Therefore, it is inferred that this earthquake was caused by the same stress that caused the deep-focus earthquake on July 10, 1940.

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Heavy Sand Deposits of Fergusonite and Columbite in the Kikune (Kukkun) Mine, Yŏnbaek-kun, Hwanghae-do, Korea

Toshiya MIYAZAWA

I. Introduction

The Kikune mine has been worked as a gold mine during the past years. Gold occurs in both the quartz veins and the placer deposits. In 1942 the mine produced 78 kg of gold, 20% of which was placer gold. Fergusonite was discovered in this placer deposit in 1940. Until the mineral was confirmed to be fergusonite by KINOSAKI, it had been an unknown mineral, relatively coarse-grained, dull lustrous, and of high specific gravity; and it had been very difficult to separate fergusonite from other heavy sands (black sands) during the dressing. At that time, the writer received a similar sample from the mine and found the coarser part of the sands to be rich in fergusonite.

From the time of the Sino-Japanese conflict to the end of World War II, investigation for rare element minerals was proceeded actively in Korea. The writer was in charge of the investigation and surveyed this mine. Since the first field survey in May, 1943, the writer has visited the mine 6 or 7 times, to be engaged in prospecting of the deposits until the termination of the war. During these years, prospecting by drilling was continued for more than 40 days, and the writer found the existence of columbite in addition to fergusonite. From these investigations, the deposits were proved to be workable and then the exploitation was undertaken. Monthly production of the heavy sands reached several hundred kilograms by the end of the war.

II. Location and Accessibility (Fig. 1)

The mine belonged to the Kikune Mining Co., Ltd. at that time, and the mine office was at Kŭmsal-li (Kukkun-dong), Haewŏl-myŏn, Yŏnbaek-kun, Hwanghae-do, about 10 km south of the Paegch'ŏn-onch'ŏn station on the Hwanghae railroad. The road between the mine office and this station is good for transportation by truck.

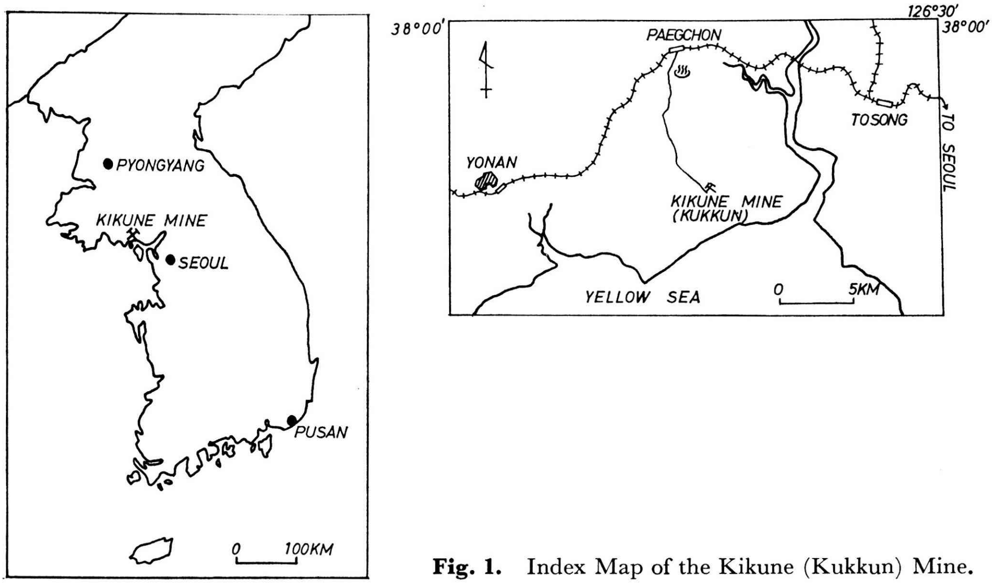

Fig. 1. Index Map of the Kikune (Kukkun) Mine.

The ore deposits are found in the Kŭmsal-li, Unsal-li and Songgye-ri regions.

III. Geology and Ore Deposits[5] (Figs. 2 and 3)

From both surface and subsurface investigations, the geology and the ore deposits of the mining area are summarized as follows:

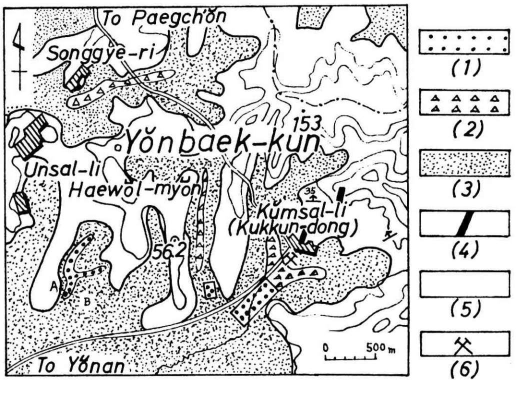

Fig. 2. Geologic Map of the Kikune Mine.

(1) Area for which the calculation of ore reserves was made.
(2) Old gold-mining site.
(3) Alluvium.
(4) Auriferous quartz vein.
(5) Gneiss, crystalline schists, granites and pegmatites.
(6) Mine office.

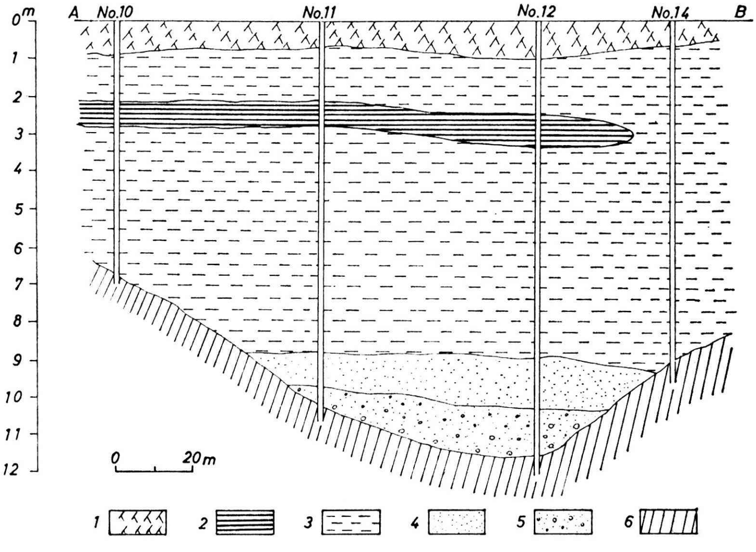

Fig. 3. Geologic Section along Line A–B of Fig. 2.

1. Overburden.
2. Peat bed.
3. Clay bed.
4. Sand bed.
5. Gravel bed.
6. Bed rock.

Gneiss and crystalline schists (including limestone)
Granites and pegmatites
Auriferous quartz veins
Alluvium (heavy sand deposits)

Gneiss is mainly granite gneiss. Crystalline schists are predominantly mica schist and quartz schist. These rocks trend east-west and dip gently (less than 50° in general) toward north. Gneiss and crystalline schists may be pre-Cambrian.

Of granites, biotite granite is predominant. Garnet-bearing granite and schistose granite are also found. The age of granites and pegmatites is unknown. The auriferous quartz veins cut all the above-described rocks in many places.

The alluvium consists of layers of overburden, peat, clay, sand and gravel in descending order. The thickness ranges from 4 m to 14 m within the surveyed area. Generally speaking, the alluvium in the lower reaches of the river of the area is thicker than that in the upper reaches. The alluvium is most extensive and thickest in the Kŭmsal-li region.

Though the alluvium is 4 m to 14 m thick, the heavy sands are concentrated in its lower part which is about 2 m thick; that is, they are contained in the basal auriferous gravel bed ("Kam" or "Kamt'o") and in the overlying gravel bed as well as in a part of the sand bed. In other words, the deposit is an alluvial deposit where fergusonite and columbite, together with placer gold, monazite, zircon, garnet, scheelite, ilmenite and magnetite, constitute the so-called heavy sand deposit.

As the surface of the bedrock is fairly even in the Kŭmsal-li region, the deposit extends roughly uniformly over a wide area, while in the Unsal-li region the bedrock is considerably rugged and the deposit is concentrated locally.

Of the constituent minerals of the heavy sand deposits, the ones with lower specific gravity such as monazite, zircon, garnet, ilmenite, rutile and magnetite are found in a considerable amount even in the upper part of the sand bed as well as in the gravel bed, while those with higher specific gravity such as gold, scheelite, fergusonite and columbite are usually restricted within the basal part and are smaller in amount.

IV. **Ores (Heavy Sands)**[5] (Tables 1 and 2)

The heavy sands consist chiefly of gold, monazite, zircon, garnet, scheelite, ilmenite, rutile, magnetite, fergusonite, columbite, etc., although the amount of each mineral, especially that of gold, fergusonite and columbite varies in some degree from region to region.

A. Placer Gold

The placer gold is concentrated in the auriferous gravel bed or "Kam", and occurs as granular, dendritic or flaky crystals. It is larger in size in the upper courses of the rivers in the surveyed area than in the lower courses. The largest nugget recently collected was about 41 gr in weight. The placer gold content in both the old claim and the heavy sand mining region averages about 7.5 gr per 3.3 m^2. The Kikune mine produced 78 kg of gold in 1942, 20% of which was from the placer deposit.

B. Monazite

Monazite occurs as brown to pale-brown crystals, granular or flattened parallel to a. The crystal planes such as a, m, x and v are observed. It attains to more than 2 cm in maximum size, although finer ones less than 1 mm are also abundant. The monazinte content of the heavy sands is roughly the same in each region, attaining a little over 12%. However, the content based on the grain size varies from region to region as shown in Table 1. The specific gravity of 15 samples was in the range of 5.0 to 5.31.

C. Zircon

The mineral occurs usually in good crystal form less than 1 mm in length. It is colorless, white, pale-brown or purplish. The zircon content of the heavy sands is about 10%.

D. Garnet

The distribution of garnet in each region is generally uniform. It is pink, red, or reddish-brown; finer grains are usually pink or red crystals with crystal plane e or n, while coarser ones are reddish-brown and commonly exhibit no distinct crystal forms.

The specific gravity measured on six samples was 3.43–3.76. The SiO_2 content of a sample of the reddish-brown kind from the Kŭmsal-li region was 37.80%. Many of the garnets are considered to be grossularite or andradite. The garnet content of the heavy sands is less than 5% at most.

E. Scheelite

The mineral was found first in the writer's investigation; it is amber-yellow, pale-brown or white. It attains to about 2 cm in maximum size and sometimes occurs as a crystal consisting of e on which striations are developed. The mineral is found in abundance generally in the coarser part of the heavy sands; e. g., in a sample collected from the Kŭmsal-li prospect, it was reported that the coarse grains over 14 mesh contained 4.8% scheelite.

F. Ilmenite and Rutile

Ilmenite occurs in two ways; (i) as a platy or granular crystal, (ii) as a single crystal combined with rutile.

In the case of (ii), the crystal occurs in a short columnar form of rutile, and ilmenite constitutes the outer part of that crystal. The boundary of the two minerals is irregular in general, and occasionally rutile is penetrated by veinlets of ilmenite. The ratio of the two composing minerals in a single crystal is unfixed, and, therefore, the specific gravity of the crystal is also inconstant, and generally shows the intermediate value between that of the two minerals; i.e., the value ranges from 4.4 to 4.6. The specific gravity of ilmenite of type (i) measured on three samples was 4.74–4.99. Ilmenite of type (i) is generally smaller in size than that of type (ii). The largest crystal of the latter attains to about 2 cm in length.

Ilmenite of the second type appears to be the alteration product from rutile; however, further studies may be necessary for determining whether all the ilmenite of the first type are also of the same origin. These minerals, comprising both of the two types, are contained in roughly equal amounts in the heavy sands in each region, attaining to about 60% on an average, which is the largest amount of all the mineral contents of the heavy sands.

G. Magnetite

Magnetite, together with zircon, occurs as the smallest crystal among the heavy sand minerals and is usually found as a granular crystal with the octahedral plane o. The magnetite content of the heavy sands is very low, less than 2% in maximum.

H. Fergusonite

The surface of the mineral is dark-gray to black and has almost no luster due to weathering which yields a gray to brown material along the cleavages; however, a fresh portion is black and exhibits a strong vitreous luster; H=6 (measured by KINOSAKI); streak pale-brown; radioactivity remarkable.

Fergusonite occurs as a columnar crystal, relatively larger in size as compared with the other heavy sand minerals, and attains a maximum of 3.2 cm in length and 1.4 cm in width, which may record the largest ever known in Korea. The crystal planes are c, g, s, and z; Sp. gr.=5.58–5.82 (measured by T. MIZUMA) (5.76 for a specimen studied by KINOSAKI). The slight difference in specific gravity as compared with the ordinary value for fergusonite may be due to a weathering product which adhered to the crystal surface. According to KINOSAKI[4)], the mineral is optically isotropic and the index of refraction is distinctively higher than 1.77. In a thin section the color is brown; but when it is heated to glowing white, the mineral becomes anisotropic and the refractive index becomes higher and higher.

The chemical composition of fergusonite is generally represented as R(Nb, Ta)O_4, where R=Y, Er, Ce, etc., although it is not consistent originally. Because of the high contents of Nb and Ta, fergusonite, together with columbite and tantalite, is regarded as the Nb and Ta ores; in addition, fergusonite is relatively rich in rare elements such as U, Ce, Y and Er, which are rarely contained in columbite and tantalite, so it may be considered as an ore of these elements. Thus, fergusonite has been referred to as the so-called rare element mineral which is found only very rarely in the world; and, in Korea, the deposit in the Kikune mine is the first occurrence worthy of being called a fergusonite deposit.

The chemical composition of fergusonite from the mine is tabulated below in comparison with those from Japan and other countries (only the main components are quoted).

Chemical Analysis of Fergusonite

Locality	Nb_2O_5	Ta_2O_5	UO_2	Y_2O_3	Er_2O_3	Ce_2O_3	ThO_2	CaO	H_2O
Kikune mine[2)]	31.1	17.4	8.4	33.5	-	1.5	3.4	2.6	-
Hakata, Iyo, Japan[3)]	44.97		3.14	40.39(Y_2O_3 etc.)			—	1.40	3.92
Greenland[1)]	44.45	6.30	2.58	24.87	9.81	7.64	—	0.61	1.49
Lockport, U.S.A.[1)]	48.73		0.25	46.24		4.24	—	—	1.65

As shown in the above table, fergusonite from the Kikune mine is characterized by high UO_2 content.

The fergusonite content of the heavy sands varies from region to region; e.g., the heavy sands in the Songgye-ri region contain only a very small amount of fergusonite, while those in the Kŭmsal-li and the Unsal-li regions similarly contain about 7% fergusonite. However, the fergusonite content in the latter two regions varies remarkably according to the grain size as shown in Tables 1 and 2. Fergusonite, generally speaking, occurs mostly in coarse-grained crystals and is rarely found in

Table 1. Composing Ratio of Principal Heavy Sand Minerals based on the Grain Size (gold is excluded).

(1) Kŭmsal-li (working face)

No.	Grain size (mesh)	Fergusonite	Columbite	Ilmenite and Rutile	Magnetite	Monazite	Zircon, Garnet, Scheelite, etc.
3	-28	27.0%	41.5%		4.5%	13.0%	14.0%
4	28-48	2.0	43.0		5.0	16.0	34.0
5	48-	0.0	9.1	65.2	0.7	10.0	15.0
Unsorted		7.0	7.0	60.0	2.0	12.0	11.8

Note: The value of 9.1% columbite in No. 5 was calculated from the chemical composition $Nb_2O_5+Ta_2O_5=4.40\%$. In fine-grained sands, fergusonite is generally much less than columbite.

(2) Kŭmsal-li (old pit of placer gold)

No.	Grain size (mesh)	Fergusonite	Columbite	Ilmenite, Rutile, Magnetite	Monazite	Zircon	Garnet, Scheelite, etc.
6	-14	13.0%	73.0%		12.0%	2.0%	
7	14-28	11.0	3.3	65.0	12.0	4.0	4.7
8	28-	2.0	3.3	65.0	12.0	12.0	5.7
Unsorted		6.3	4.5	64.2	12.0	8.0	4.0

Note: The fergusonite and columbite contents of both No. 7 and No. 8 are calculated in consideration of their chemical compositions.

(3) Kŭmsal-li (working face)

No.	Grain size (mesh)	Fergusonite	Columbite	Ilmenite, Rutile, Magnetite	Monazite	Zircon	Garnet, Scheelite, etc.
9	8	17.0%	61.0%		8.0%	14.0%	
10	8-14	8.0	77.0		8.0	7.0	
11	14-28	14.0	4.0	50.0	8.0	18.0	5.0
12	28-	3.0	6.0	48.0	20.0	20.0	3.0
Unsorted		8.0	6.0	53.0	14.0	13.0	6.0

Note: The fergusonite and columbite contents of both No. 11 and No. 12 are calculated in consideration of their compositions.

(4) Kŭmsal-li (working face)

No.	Grain size (mesh)	Fergusonite	Columbite	Ilmenite, Rutile, Magnetite	Monazite	Garnet	Scheelite	Zircon, etc.
13	-14	18.5%	59.3%		9.7%	7.7%	4.8%	0.0%
14	14-28	11.0	58.0		8.0	3.0	20.0	

Note: The fergusonite and columbite contents are roughly equal to those of (3).

fine sands less than 30 mesh. A sample from the Kŭmsal-li region contains about 27% fergusonite in its sand portion which is coarser than 28 mesh.

Fergusonite in the heavy sands occurs usually as a single crystal, but occasionally it is associated with quartz, monazite, or columbite. This fact gives us an important suggestion on the original occurrence of these rare element minerals; e.g., they were associated with one another in the primary ore deposits. In fact, in later days of the survey, the writer found a tourmaline pegmatite in a mountain region near the deposit and detected such minerals as fergusonite, monazite and columbite in it though in small amounts.

Table 2. Nb_2O_5+ Ta_2O_5, Fergusonite, and Columbite Contents.

Analysis No.	Sampling location	Heavy sand / Crude sands	Nb_2O_5+ Ta_2O_5 / Heavy sands	Fergusonite & columbite / Heavy sands	Fergusonite & columbite / Crude sands	Remarks
9130	Drill Kŭmsal-li No. 10	0.19%	2.25%	3.7%	0.0069%	The heavy sand analysed contains 30–50% light sand.
9133	Drill Unsal-li No. 12	0.61	1.80	2.9	0.0178	
9128	Drill East No. 3	0.04	1.40*	14.44	0.0055	*The content in the heavy sand
9129	Drill West No. 3	0.03	3.45*	12.65	0.0036	less than 30 mesh in grain size
9515	Drill (1)-5		4.40	9.1		Less than 48 mesh in grain size
9134	Drill (2)-7		8.15	14.3		14–28 mesh in grain size
9131	Drill (2)-8		3.60	5.3		Less than 28 mesh in grain size
9135	Drill (3)-11		8.00	18.0		14–28 mesh in grain size
9132	Drill (3)-12		4.80	9.0		Less than 28 mesh in grain size
	Drill Unsal-li No. 12			9.7		The value for fergusonite more than 28 mesh in grain size
	Drill (3) & (4)			12.0		The columbite content of the black sand more than 8 mesh in grain size

I. Columbite

Columbite in the district was discovered for the first time by the writer. It is black in color, blackish-brown in streak, and has a metallic luster.

The columbite content of the heavy sand also varies more or less from region to region, and the Songgye-ri region has the least of it. The columbite contents in both the Kŭmsal-li and Unsal-li regions are nearly equal, a little over 5% which is somewhat less than the value for fergusonite. Although a considerable amount of columbite is contained in the fine sand less than 30 mesh in grain size, occasionally attaining to about 5% of the heavy sand in the Kŭmsal-li region, it occurs often in coarse crystal or granular forms similar to fergusonite, and it was reported that the columbite content of the heavy sand more than 8 mesh in grain size attained to about 12% in some places in the Kŭmsal-li region.

The crystal is flat and platy, and attains a maximum length of about 1.5 cm. The crystal planes are a, b, c, n, m, and d(?).

The specific gravity measured on 17 specimens ranged from 5.31 to 7.14. Of them, the specific gravity of 10 specimens is less than 6; 5 specimens are 6–7; and 2 specimens are more than 7. Those having especially high specific gravity may possibly be tantalite, although they are grouped here tentatively as columbite because of lack of chemical data. In general, the ones with smaller specific gravity tend to have better crystal planes.

As mentioned above, columbite is often associated with fergusonite, but sometimes it is also associated with quartz and mica.

Columbite, as well as fergusonite, belongs to the so-called rare element mineral, and the world production of it is quite small. In Korea, there are only a few columbite deposits worthy of the name besides the Kikune mine, e.g., the Ŭngok mine in North P'yŏngan-do and the Tannok mine in Kangwŏn-do.

V. Ore Grade and Ore Reserves[5)]

A. Ore Grade

A dressing test was carried out using the Wilfley table at the Fuel and Ore Dressing Institute of the Mining and Engineering Bureau, the Government-General of Korea. The samples tested had been collected from drill holes and mining sites in both the Kŭmsal-li and the Unsal-li regions, and crushed into fine grains less than 30–40 mesh in size. The crude sand used in the test had once been washed and separated from the placer gold before it was desiccated, so it differs to some degree from the natural state. That is, the test material weighs about 60–70% as much as the sample of the natural state. The 30–40% diminution is due to the loss of clay and moisture.

Through the test dressing, it was clarified that the heavy sand content of the crude sand averages a little over 0.15% in Kŭmsal-li and a litter over 0.21% in Unsal-li. However, the heavy sand obtained in this test still contained 30–50% light sand, so the true percentage of the heavy sand in the crude sand may be safely estimated at about 0.10% equally in each region. The contents of the respective minerals in the heavy sands have already been listed; therefore, only the percentage of the principal constituents of the heavy sand are tabulated as follows:

1.	Fergusonite	0.007%
2.	Columbite	0.005
3.	Monazite	0.012
4.	Zircon	0.010
5.	Ilmenite and rutile	0.060

B. Ore Reserves

The reserves of the chief minerals in the investigated area (168,000 m²) were computed on the basis of the results of drilling, pit and trench tests, ore dressing test, and chemical analysis:

1.	Fergusonite	32.200 tons
2.	Columbite	23.000
3.	Monazite	55.200
4.	Zircon	46.000
5.	Ilmenite and rutile	276.000
6.	Gold	0.255
	Total	432.655

VI. Magnetic Concentration of Heavy Sands[6)]

A. Purpose

The heavy sand, as stated above, consists of a variety of minerals which differ in nature from one another. So, for exploiting the deposit, methods of mineral dressing should be considered first. If the dressing problem remained unsolved, one cannot expect to develop the deposit, even if the ore grade was high and the reserves were large.

The dressing problem of some heavy sand minerals has been solved by using the floatation and other methods; however, for such complex heavy sand as that which contains fergusonite and columbite, in addition to ordinary heavy sand minerals, no beneficial method seems to have been determined.

Under these conditions it was concluded that the magnetic concentration method should be tried at any rate and this method might solve the problem as in all probability. The primary object of employing this method was to separate columbite and fergusonite from ilmenite.

As to the magnetism of the minerals, only the data shown in Table 3 had been given at that time and the positions of columbite and fergusonite were not pointed out on the magnetic strength table.

Thus, using an assorter of the Research Institute of the Korea Mining Promo-

Table 3. Comparison of Magnetic Strength of Minerals

Mineral	Composition	Magnetic strength
Iron	Fe	100.00
Magnetite	$FeO \cdot Fe_2O_3$	40.18
Ilmenite	$FeO \cdot TiO_2$	24.70
Pyrrhotite	FeS	6.69
Hematite	Fe_2O_3	1.32
Zircon	$ZrO_2 \cdot SiO_2$	1.01
Limonite	$2Fe_2O_3 \cdot 3H_2O$	0.84
Corundum	Al_2O_3	0.83
Garnet	$3RO \cdot R_2O_3 \cdot 3SiO_2$*	0.40
Quartz	SiO_2	0.37
Rutile	TiO_2	0.37
Orthoclase	$K_2O \cdot Al_2O_3 \cdot 6SiO_2$	0.05

Note: * R=Ca, Mg, Fe, Mn.
R_2=Al, Fe, Mn, Cr, Ti.

tion Co., the writer obtained an interesting result (Table 4). The writer is greatly indebted to Mr. T. NAKANO, a technician of the Rare Element Section of the Mining Association of Korea, for his earnest effort and skillful technique which made the experiment successful.

B. Apparatus and Operation

The apparatus was the simplest one consisting of six wrought iron cores coiled 330 times with copper wire charged with direct current of 3.9 amperes and 100 volts (about 2,000 ampere turn). The mineral grains were sorted by electric bell vibrations which were adjusted by changing the distance between the electromagnet and the sample; the length of time operated was not considered. It was also reported that when the sample was fine-grained, the sorting would gain good results by using alternating current as well as direct current.

C. Sample

In the experiment, ten kinds of samples of various grain size from the Kŭmsal-li and Unsal-li regions were used. However, the record of only 4 kinds remains now, i.e., one 8–14 mesh, two 12–28 mesh, and one less than 48 mesh. The samples had been hand-sorted in advance at the mine, and they were rather high in grade for heavy sand. Care must be taken to select grains of uniform size as far as possible.

D. Results of Magnetic Concentration

The experiment was rather easy and good results were obtained as shown in Table 4. Especially, the writer unexpectedly succeeded in separating columbite

Table 4. Results of Magnetic Concentration.

Location	Unsal-li					
Grain size	8–14 mesh			14–28 mesh		
Magnetic strength	Mineral	%	Remarks (Percentages are those of the materials mixed in each heading mineral)	Mineral	%	Remarks (Percentages are those of the materials mixed in each heading mineral)
Strong	Magnetite	0.6	With limonite	Magnetite	1	Mostly magnetized limonite
	Ilmenite	40.1	Columbite 1.0%	Ilmenite	34	
	Columbite	21.8	Ilmenite (fine grain) 2.5% Fergusonite (coarse grain) 3.2% Limonite, monazite, zircon (coarse grain), etc. 8.7%			Ilmenite (fine grain) 4.1 Fergusonite 1.3 Limonite 12.9 Monazite, garnet, etc. 5.2 } 23.5%
	Fergusonite	4.5	Columbite 13.5% Monazite, etc. 27.0%	Fergusonite	14	Columbite 6.1% Monazite, etc. 39.4%
	Fergusonite	9.1	Monazite, garnet, etc. 41.6%	Monazite	13	Fergusonite 22.9%
	Monazite	6.8	Fergusonite 34.0%	Monazite	4	Fergusonite, reddish-brown 3.2% garnet, etc.
	Monazite	14.6	Fergusonite 19.7%	Zircon	5	Contains fergusonite, monazite, etc.; sorting unsatisfactory
Weak	Zircon	2.5	Contains rutile, etc.	Zircon, Quartz	15	Zircon 17.0%
		100.0			100.0	
	Columbite content of heavy sand ca. 19.3%			Columbite content of heavy sand ca. 11.6%		
	Fergusonite content 〃 〃 ca. 13.9%			Fergusonite 〃 〃 〃 ca. 11.0%		

and fergusonite from ilmenite—the highest aim of the work. The recovery percentage of both columbite and fergusonite was about 95%.

However, separation of hornblende from columbite, fergusonite or monazite was not so good in the samples below 40 mesh in grain size, but this is not a serious question because hornblede can be separated by the gravity method. Similarly the co-existence of quartz may also cause no serious question.

The garnet is classified into two kinds in regard to the magnetism; the stronger is pink or red and rich in iron, the weaker is reddish-brown and probably poor in iron.

As fergusonite occurs in columnar crystals, it was difficult to select grains of fergusonite which are uniform in size to grains of other minerals; accordingly, the separation of fergusonite from both monazite and reddish-brown garnet was disturbed. This, however, may probably be due to the irregularity of magnetism caused by weathering which fergusonite underwent to some degree; moreover, such minerals of indefinite chemical composition as fergusonite and columbite may

Kumsal-li					
14–28 mesh			Less than 48 mesh		
Mineral	%	Remarks (Percentages are those of the materials mixed in each heading mineral)	Mineral	%	Remarks (Percentages are those of the materials mixed in each heading mineral)
Magnetite	0.2	Mostly magnetized limonite	Magnetite	0.6	
Ilmenite	47.8	Contains a few red garnets	Ilmenite	41.2	Contains a few red garnets (coarse grain)
Red garnet	0.9	Ilmenite (fine grain) ca. 50% Columbite ca. 3.2%	Red garnet	5.6	Ilmenite (fine grain) ca. 40%
Columbite	13.1	Garnet, Fergusonite, Limonite, Rutile, Hornblends } 9.5%	Hornblende Columbite	0.9	Columbite ca. 30% Contains monazite and brown garnet
Monazite	4.5	Columbite, fergusonite 19.4% Reddish-brown garnet containing rutile 7.0%	Hornblende	2.8	Columbite, fergusonite, monazite 14.6% Reddish-brown garnet ca. 20%
Monazite	7.2	Fergusonite 8.7% Contains reddish-brown garnet, etc.	Monazite	9.1	Fergusonite 0.4% Contains hornblende and reddish-brown garnet
Reddish-brown garnet	1.9	Contains fergusonite, monazite, zircon, quartz, etc.	Reddish-brown garnet	4.4	Contains monazite, feldspar, quartz, etc.; sorting unsatisfactory
Zircon Quartz	24.4	Contains feldspar, mica, corundum, tourmaline, rutile, gold, etc.	Zircon Quartz	35.4	Zircon 4.5%
	100.0			100.0	
$(Nb,Ta)_2O_5=8.15\%$ (in heavy sand) (Analysed by T. Mizuma, Geol. Surv. Korea)					

differ in magnetic strength from one another even in the same kind of mineral species.

According to the result of this experiment, the magnetic strength of the heavy sand minerals may be arranged in order from the stronger to the weaker as follows:

Magnetite—ilmenite—pink or red garnet—columbite—fergusonite—monazite—reddish-brown garnet—zircon

As previously stated, some of ilmenite from this mine is believed to be an alteration product of rutile. Sometimes a single crystal of ilmenite having unalterd rutile in the core is found. Its magnetic strength varies according to the ratio of the two minerals composing a single crystal; generally speaking, the lower the degree of alteration, the weaker the magnetism, and the weaker ones, if not abundant, are found mixed with minerals whose magnetic strength is less than that of columbite.

The minerals are more easily sorted in proportion to the increase of the grain size. According to the result of the experiment, the minerals rich in iron are concluded to be stronger in magnetism. Though this may have been expected, it must be noticed that the positions of columbite and fergusonite were roughly determined on the magnetic strength table.

The experiment on the heavy sand of the Kikune mine is only a fundamental and preliminary one and the problems regarding the quantity of the sample and the time required for operations were not considered, so the writer does not think that the obtained results would point to an industrial success. Nevertheless, so far as the experiment is concerned, it may be considered to have succeeded in clarifying some unknown points, especially the possibility of separating columbite and fergusonite from rutile. Judging from the results of the experiment, even such complex heavy sand as that of the Kikune mine could possibly be sorted industrially into 4 classes, namely, (ilmenite, columbite), (fergusonite), (monazite), and (zircon), or at least into three classes such as (ilmenite, columbite), (fergusonite), and (monazite, zircon).

In conclusion, the best process for mineral dressing of such heavy sand as described here should be started with the sluicing or the table method and, if possible, it would be better to sieve the sand at the site of collection, to be followed by the magnetic concentration at the main dressing mill.

VII. Conclusion

Details pertaining to fergusonite and columbite are summarized as follows:

(1) The deposit is an alluvial deposit containing placer gold.

(2) Both fergusonite and columbite are the so-called rare element minerals and are found only rarely in the world. The Kikune mine is the first occurrence worthy of the name of a fergusonite deposit found in Korea. As for columbite, there are only a few other known occurrences except this mine, e.g., the Ŭngok mine in North P'yŏngan-do, the Tannok mine in Kangwŏn-do, etc.

(3) The fergusonite content in the heavy sand is about 7% and the columbite content is a little over 5%.

(4) Even in the limited area investigated, the ore reserves are estimated at about 55.2 tons, so the total reserves in the district would be rather large.

(5) Monthly production of heavy sands was several hundred kilograms by the end of the war.

(6) Mineral dressing is the problem to be considered in the future. According to the result of the writer's experiment, at least it is relatively simple to separate fergusonite and columbite from rutile.

In mineral dressing, it would be better to employ first the gravity method to concentrate the heavy sand, and afterwards magnetic concentration might be applied by using the electro-magnetic assorter.

(7) According to the result of the investigation of the deposit near the Kikune mine, it is most likely that new deposits will be discovered under the widely distributed alluvium in the uninvestigated area in the vicinity. The writer has found

a considerable amount of fergusonite and columbite in the heavy sand from the placer gold claim of the Totaku Yulp'o Mining Office (Yulp'o-dong, Munsal-li, Haewŏl-myŏn, Yōnbaek-kun) about 3 km northeast of the mine. Generally speaking, the heavy sand rich in placer gold appears to form a high grade deposit of fergusonite and columbite.

(8) The natural surface of fergusonite is remarkably dull in luster and the crystal is relatively coarse-grained as compared to other heavy sand minerals. On the other hand, the fine-grained columbite sands tend to be overlooked because of the difficulty in distinguishing it from ilmenite and other black minerals. If attention is given to this point in future investigations, heavy sand deposits as promising as that of this mine would possibly be discovered from other regions in Korea.

(9) At least some of the primary deposits of fergusonite and columbite would be pegmatites of unknown age in the mountain region near the mine. These pegmatites, although low in fergusonite and columbite contents according to the results of present investigation, should also be studied.

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Silver-Lead-Zinc Deposits in Manchuria

Kamezo MATSUDA

I. Preface

In 1939 an elaborate report was published by Prof. T. OGURA of Ryojun College of Engineering, concerning the silver-lead-zinc deposits in Manchuria. Six years after, the development work on these deposits proceeded remarkably well, and, as was predicted by Prof. OGURA, as a result there now exist several mines with a twenty thousand-ton monthly treating capacity.

I have been asked by the Committee to submit a report on the subject, owing to a change in the scheduled program of the project. However, inasmuch as I actually inspected only two mines at the time, the Yang-chia-chang-tzu Mine and the Tien-pao-shan Mine, and as I had no chance to contact the authors of detailed reports on each mine, it might be presumptuous of me to write such a report. Nevertheless, I have managed to compile this report based on material previously published by OGURA, and with some supplementation of new findings from the data on hand.

Messrs. M. YAMASHIMA and K. MURAYAMA provided valuable opinions concerning the Huan-jen and Hsiu-yen mines, for which I would like to express my grateful acknowledgement here.

II. Distribution of the Ore Deposits

According to the Manshu Kobutsu Chosa Hokoku (Research Report on Manchurian Minerals, an annual publication of the South Manchuria Railway Company), 310 mineral deposits of silver-lead-zinc category were found in Manchuria, and ranked next to gold deposits in number. There were 102 in Feng-tien province, 96 in An-tung province, 27 in Je-hol province, 21 in Hsing-an province, 19 in Tung-hua province, 17 in Chin-chou province, 16 in Chi-lin province, 6 in Kuan-tung Leased Territory, and 6 in Chien-tao province. They were clustered in such areas as the Tung-pien-tao block, the Triangular area of Feng-tien province, the Hei-an block, etc., and their main distributions were limited to the region south of an east-west line passing through the Lake Hsing-kai in the east and the Lake Ta-li in the west, or the line nearly in accord with lat. 44°N. That is, their distribution was grouped with that of the other metallic deposits including gold deposits. This was attributed to conditions such as poor population, flatness of topography, thick soil covers, etc., in northern Manchuria, which have prevented the opportunity for outcrop findings.

III. The History of the Discovery of Mineral Deposits

No available data is known to exist on the discovery of mineral deposits in Manchuria. It is said that many old prospects, which were scattered through the vicinities of Yang-chia-chang-tzu, Sung-shu-wu, Tiehling, Hai-cheng and Ching-cheng-tzu, were operated several hundred years ago by the natives of Kao-li in their search for sulphide ores as the source of sulphur. In the Chin dynasty, gold and coal mines were operated by Chinese in a region centering around Feng-tien, but they were all closed in the 18th year of Tao-Kuang (1838) by government order.

According to written records, the Chinese government in the Chien-feng and Tung-chih periods altered their policy in order to alleviate financial strains caused by frequent civil wars and stimulated operation of the mining industry. In the 6th year of Chien-feng, the Cheng-ping silver mine of Je-hol province was opened and became the biggest silver mine in Manchuria. Thus, 16 to 17 mines were in operation during the 25 years from the end of Tung-chih (1850) to the 25th year of Kuang-chu (1899) in the territory north of Ho-peh. The Geological Section of the South Manchuria Railway Company was established at Ta-lien in 1907, and from 1912 the Japanese exhorted the operation of metallic mines scattered throughout remote localities for more than ten years, but without success. The fact indicates that the situation for the Japanese in Manchuria was extremely difficult.

During the "Manchurian Incident" in 1931 mining operations were more or less suspended, but reopening of mining and prospecting work were resumed and saw for a while an increase beginning in 1936. Of the 310 known localities, most of them are either of difficult access or are poor in grade and reserve, and so exploitation has been carried out on only a score of deposits.

IV. Production

Very few written records are available on the production of the metallic mines in Manchuria. The important data are shown next page.

V. Geology

The metallic mineral deposits in Manchuria showed denser distribution in the region south of lat. 44°N, and this region could be further divided by the plain of Liao-ho into the eastern and the western parts. The eastern part included the

Name of Mine	Location	Production
Cheng-ping silver mine	Cheng-te, Je-hol	Annual production of Ag, 1,730 kg, about 1904–1922 (closed)
Kang-chia-chang-tzu	Tieh-ling, Feng-tien	Lead ore, 19 tons, 1909
Hsiao-tien-tzu-kou	Kai-yuan, Feng-tien	Lead ore, 18 tons, about 1915–16
Hsuan-ling-hou	Pen-chi, Feng-tien	Lead ore, 10 tons, about 1915–16
Kuan-men-shan	Tieh-ling, Feng-tien	Lead ore, 65 tons, 1916–20
Tien-pao-shan	Yen-chi, Chien-tao	Cu-bearing lead-zinc ore, 8,020 tons, 1917; 11,275 tons, 1918; 7,089 tons, 1919; and 10,157 tons, 1920 (The mine was restored in 1935 and has been processing 150∼300 t/d of mill feed)
Ching-cheng-tzu	Feng-cheng, Feng-tien	Lead ore, 340 tons, 1921; 1,000 tons, 1922; 500 tons, 1923; 2,640 tons, 1924; 2,823 tons, 1926; 462 tons, 1927; 366 tons, 1928; 1,450 tons, 1929. Lead metal, 3,500 tons, 1941; 7,500 tons, 1942; 5,500 tons, 1943; 5,500 tons, 1944. Milling capacity 15,000 t/m; mill feed grade was about Pb 9∼13%
Yin-tzu-kou	Lin-chiang, Tung-hua	Lead ore, 280 tons, 1926
Kuei-tzu-ha-ta	Hsin-ching, Feng-tien	Silver, 20 kg, 1932
Yang-chia-chang-tzu	Chin-hsi, Chin-chou	Lead ore, 269 tons, 1934; 1,490 tons, 1935; 307 tons, 1938. Lead concentrate, 2,623 tons, 1941. Lead, 4,715 tons, 1942; 1,500 tons, 1943; no output in 1944. Milling capacity 25,000 t/m; Pb 3.5%, Zn 4.8%

Huan-jen	Huan-jen, An-tung	Pb 1,000 tons, Zn 2,500 tons, Cu 10 tons, 1943; Pb 2,500 tons, Zn 3,500 tons, Cu 100 tons, 1944. Milling capacity 3,000 t/m, Pb 9%, Zn 15%
Hsiu-yen	Hsiu-yen, An-tung	Pb conc. 121 tons, 1941; Pb 6,500 tons, Zn conc. 20,000 tons, 1943; Pb 4,500 tons, Zn conc. 22,000 tons, 1944. Milling capacity 10,000 t/m; Pb 2~3%, Zn 12~13%

Kuan-tung Leased Territory, the Triangular area of Feng-tien province, the Tung-pien-tao area, the Hsi-an area, and the Chien-tao area; and the western part was the Je-hol area in which the Chin-chou area was also included.

The geology of the eastern part consists of a Precambrian system, Paleozoic and Mesozoic formations, and such igneous rocks as granite, diorite, diabase, quartz porphyry, rhyolite, porphyrite, andesite and basalt. The Precambrian system consists of gneisses and Proterozoic (or Liao-ho system) sedimentary rocks, and is distributed widely through the Kuan-tung Leased Territory to the Triangular area. A remarkable characteristic of the Liao-ho system is the prevalence of limestone and dolomite. The Cambro-Ordovician formation stretches through Fu-chou, which is situated to the west of the Kuan-tung Leased Territory, to the vicinity of Tai-tzu-ho, and consists of a complex of limestone and shale. The Permo-Carboniferous formation in southern Manchuria covered the Ordovician formation and formed the upper Paleozoic coal-field regions through Fu-chou to the basin of the Tai-tzu-ho River. They consist mainly of shale, sandstone, and coal-bearing series. In northern Manchuria the Chi-lin formation (hornfels, breccia and limestone) exists in the vicinity of Chi-lin, and the Tu-man formation near the Korean border.

The Jurassic formation forms minor basins in various localities. It consists of conglomerate, tuff, and sandstone, and with occasional coal-bearing beds. The Cretaceous formation is developed only in the areas of Pen-chi-hu, Chi-lin, and Chien-tao. Of the igneous rocks, the largest in distribution is probably granite. The principal ones are: that which is distributed through the southern part of the Triangular area to the southern part of the Tung-pien-tao with a length of 250 km from the southwest to the northeast; a circular district in the Hsi-an area; and that which extends through Chi-lin with a length of about 120 km from the southwest to the northeast. Of the granite groups, some would belong to the older geological ages. But the majority of them have provided contact metamorphism upon the Ordovician and Permo-Carboniferous formations, have intruded into the Chi-lin formation, and are covered with the Jurassic formation; and they have been considered as the intrusives at the end of Paleozoic era, and have a very close relationship with the localization of mineral deposits. Diorite and gabbro intrude as a sheet into the Proterozoic formation, and they also intrude into the Ordovician formation. Quartz porphyry and rhyolite may probably belong to the end of Mesozoic, although some of them are found as dike rock in the older formations.

Regarding the western part of southern Manchuria, the geology was found to be generally similar to the above-mentioned eastern part. But in the western part the development of the Mesozoic formations was regarded as more remarkable.

The Jurassic formation with important coal seams is found mainly in the northern districts of the western part. The Cretaceous formation is distributed through the southern half of Je-hol, and consists of remarkably developed pyroclastic sediments, and includes a complex of conglomerate, oil shale, green shale, etc. Igneous rocks are granite, diorite, rhyolite, andesite and porphyrite. The granite group intruded in two different ages, i.e., the Proterozoic and the intrusion at the end of Mesozoic due to the Yenshan crustal movement. The latter is deemed as having a close connection with the mineralization of the silver-lead-zinc deposits in Chin-chou province. Andesite and porphyrite were also erupted at the end of Mesozoic, and not infrequently they had connection with the formation of mineral deposits.

So far as it concernes the relation between the lithology and the mineralization of this category, of the deposits in about 75 localities 40 occur in limestone, 15 in gneiss and crystalline schist, 13 in granite and granite porphyry, 13 in quartzite and sandstone, and 4 in andesite and porphyrite. Namely, limestone is considered to have had a most important relation with the formation of ore deposits.

Although reports on the relation between the mineral deposit and the geological structure are not precise, they generally show a property of the fissure-filling veins in country rock. Frequently they exist metasomatically along the beddings of the strata, or sometimes occur as the metasomatic deposit at the intersection of the fissure systems. The direction of the fissure systems is not definite, but those found in the limestone should have a close relation with the intrusion of the igneous rock. A remarkable mineralization along faults is also seen frequently.

VI. The Ore Deposits

The silver-lead-zinc deposits are located mainly in the southern half of Manchuria, and the larger part belongs to the lead-zinc deposit of the world-type, but extremely big ones have not been found yet. Remarkably numerous ores were found in the limestone group and the deposits of vein type. At the time exploitation of only a few vein-type deposits had been started, and the ones being worked were predominantly of the contact-metasomatic deposit type. But, no deposit could have had more than 250,000 tons in ore reserve. In case of the contact-metasomatic deposit, there may have been an overlap of mineralization by not only pyrometasomatism but also by hydrothermal mineralization of the later stage, thereby resulting in variable deposit types with accompaniment of the metasomatic and vein deposits. With insufficient data on the research of the ore deposits, the ore minerals thus far determined were limited only to the easily recognizable ones. They were mainly of galena and sphalerite with the minor associations of pyrite, chalcopyrite, argentite, tetrahedrite, arsenopyrite, pyrrhotite, molybdenite, etc. The gangue minerals were dominantly calcite and quartz, with minor amounts of fluorite, barite, and siderite; and skarn minerals were found mainly in the contact-metasomatic deposits. The secondary minerals of lead and zinc ore, although they are rare in occurrence, were cerussite, anglesite, hemimorphite, and pyromorphite. Malachite and azurite were commonly found to be the secondary minerals of the copper ore. As the development of the oxidized zone was not so remarkable, mining operations were carried out in the primary ore zone.

A. Classification of Ore Deposits

From the origin and associated minerals, the deposits in Manchuria could be classified as follows. It is not certain, however, whether or not vein deposits contain a pegmatitic one. Some veins with a small amount of skarn minerals were provisionally put under contact-metasomatic deposits.

1. Contact-metasomatic deposits
2. Hydrothermal metasomatic deposits
3. Vein-type deposits (including fissure-filling and metasomatic veins)
   - (1) Quartz-calcite vein
     - (a) Lead-zinc-pyrite vein
     - (b) Lead-zinc vein
     - (c) Lead-pyrite vein
     - (d) Lead-copper vein
     - (e) Lead vein
     - (f) Silver-nickel-cobalt vein
     - (g) Silver vein
   - (2) Fluorite vein
     - (h) Lead-fluorite vein
   - (3) Barite vein
     - (i) Lead-barite vein

1. *Contact-Metasomatic Deposits*

Deposits of this type are found in the contact zone between the limestone-dolomite group and the intruding granite (or granite porphyry) or monzonite. Depending on the copper content the deposit may grade into a contact-metasomatic copper deposit. Even though the mineralization of lead and zinc minerals was poor, as in the case of the Yang-chia-chang-tzu Mine, the deposit was worked because of the minute but persistent existence of molybdenite in skarn zone. The deposit is accompanied by veins and metasomatic deposits of the later hydrothermal lead and zinc mineralization.

At the Yang-chia-chang-tzu Mine in Chin-hsi, Chin-chou province, the skarn zone contained magnetite, molybdenite, pyrite, fluorite, etc., and the country rock of limestone contained the lead and zinc deposits of hydrothermal metasomatism. A zonal arrangement of ore deposits from granite to the external part was seen there. The Sung-shu-wu Mine of the same area was also considered as a metasomatic vein with skarn minerals, and was considered as the extension of the Yang-chia-chang-tzu deposit.

The Tien-pao-shan Mine in Yen-chi, Chien-tao province, contained the contact-metasomatic deposit accompanied by hydrothermal disseminated deposits and veins. At the Huan-jen Mine in Huan-jen, An-tung province, banded and lens-like skarn ore bodies were found in the contact zone of monzonite.

The Ching-cheng-tzu Mine in Feng-cheng, An-tung province, was deemed a contact-metasomatic deposit, but the mine had comparatively poorly developed skarn ore deposits, and the later hydrothermal veins predominate.

The mineralized zone of the Yang-chia-chang-tzu Mine was the largest in size, with its length about 10 km from east to west, and the biggest part of the skarn zone had a length of over 1 km and a width of 100 m. The size of ore body in the Tien-pao-shan Mine, where the ore body forms a lenticular pipe, showed a length of 100 m and a maximum width of 20 m. The ore deposit at Ching-tsui-tzu, I-tung hsien, Chi-lin province, was said to be a contact-metasomatic deposit occurring between limestone and granite, accompanied by galena, fluorite, wollastonite and barite, but it required further investigation.

2. *Hydrothermal Metasomatic Deposits*

Hydrothermal metasomatic desposits are found mainly in limestone, forming irregular lenses or pipe-like masses.

At Kuan-ma-tsui-tzu, Pan-shih hsien, Chi-lin province, the deposit occurs along the bedding plane of limestone; at Yin-tzu-kou, Lin-chiang hsien, Tung-hua province, it was found to form lenticular bodies; and at Yang-chia-chang-tzu, Chin-hsi hsien, Chin-chou province, it formed spiral pipes at the intersecting points of the fissure system. So far as the size of ore body is concerned, the largest one was the above-mentioned pipe of the Yang-chia-chang-tzu, which had a diameter of 10 to 15 m, and its lower part was split into two platy bodies (each being 3 m wide and 30 m long). The ore consists mainly of galena, zincblende and pyrite, often with a small amount of chalcopyrite.

3. *Vein-Type Deposits*

There are two types of vein-type deposits; one is the fissure-filling type, and the other is the metasomatic type with a little gangue mineral and showing extreme swelling and pinching. Both are mesothermal or epithermal in character. The same mineralized zone would sometimes grade into a copper vein to form a copper deposit.

(1) Quartz-calcite vein. This is the most common type. Veins penetrating limestone are full of calcite. Veins of quartz, associated with siderite were found in the lead-zinc deposit of Hsuan-ling-hou, Pen-chi hsien, Feng-tien province. As for the mode of occurrence, some veins could be seen running parallel with the bedding plane or along the faults.

(a) *Lead-zinc-pyrite vein.* It is in many cases dominated by pyrite, and often contains chalcopyrite. The main localities are as follows:

Ching-cheng-tzu (Tien-nan-kou), Feng-cheng hsien, An-tung province.
Yang-chia-chang-tzu, Chin-hsi hsien, Chin-chou province.
Hsuan-ling-hou, Pen-chi hsien, Feng-tien province.
Kuang-tung-ling, Hsiu-yen hsien, An-tung province.

As for the size of the vein, the one at Yang-chia-chang-tzu was the biggest, with a maximum width of 6 m and a length of 150 m. The vein at Kuang-tung-ling was found in the granite and was often associated closely with acidic and basic dikes. At Hsuan-ling-hou, there was an auriferous quartz vein, with 5 to 10 gr/ton of gold. At the above-mentioned Kuang-tung-ling, the component minerals were chalcopyrite, specularite, quartz and chlorite, and were epithermal in character.

(b) *Lead-zinc vein.* It contains remarkably smaller amounts of pyrite than in the case of the above-mentioned (a). The main localities are as follows:

Kang-chia-chang-tzu, Hao-erh-shih and Kuan-men-shan, Tieh-ling hsien, Feng-tien province.
Chi-hsiang-yu, Pen-chi hsien, Feng-tien province.
Hsuan-ling-hou, Pen-chi hsien, Feng-tien province.
Hsiu-yen Mine (Chia-chia-pu-tzu), Hsiu-yen hsien, An-tung province.
Kuan-tung-ling, Hsiu-yen hsien, An-tung province.
Kuang-tung-kou, Chuang-ho hsien, An-tung province.
Cheng-ping Silver Mine (Yen-tung-shan), Cheng-te hsien, Je-hol province.

At the Cheng-ping Silver Mine, the ore veins were found in andesite area, and they contained galena and zincblende, with a small amount of chalcopyrite. There were 40 veins in all, of which the biggest one was 1.2 m in thickness and could attain 2.5 km in length. At the Hsiu-yen Mine, crystalline schists were country rocks in which the ore veins of a maximum thickness of 6 m and a length of several hundred meters were contained. They were metasomatic ore veins, filling the faults at the contacts of the porphyrite dike injected into the schists. The bonanza were connected by the veinlets of several centimeters thick.

(c) *Lead-pyrite vein.* It consists mainly of galena and pyrite. The main localities are as follows:

Ching-cheng-tzu (Ching-tzu-kou), San-tao-kou, Hsiao-pien-kou, Lan-chia-Kou, Miao-kou, Lu-chia-nan-kou and Ma-pao-kou in Feng-cheng hsien, An-tung province.
Tuan-piao, Fu hsien, Feng-tien province.
Tung-ta-kou, Hsin-ching hsien, Feng-tien province.

At the Ching-cheng-tzu Mine, the metasomatic ore veins, in association with several parallel veins, were found dominantly along with the dikes of diorite porphyrite and porphyrite, which were intruded into dolomite. The largest of the veins had a maximum thickness of 20 m and a length of 400 m, and often contained a small amount of pyrrhotite.

(d) *Lead-copper vein.* This type of vein contains a little more chalcopyrite than the above-mentioned (c). The main localities are as follows:

Su-tzu-ti-lu, Tieh-ling hsien, Feng-tien province.

Ching-cheng-tzu (San-tao-kou), Feng-cheng hsien, An-tung province.

The ore deposit at San-tao-kou was a stockwork deposit in dolomite. It showed a paragenesis of chalcopyrite-pyrite-galena-clacite, and seldom contained quartz as a gangue mineral.

(e) *Lead vein.* It consists mainly of galena, with a small amount of chalcopyrite. The localities are as follows:

Hsiao-tien-tzu-kou, Kai-yuan hsien, Feng-tien province.

Erh-tao-kou of Huang-pai-yu, Pen-chi hsien, Feng-tien province.

Ta-huang-pai-yu, Pen-chi hsien, Feng-tien province.

The deposit of Hsiao-tien-tzu-kou was a quartz vein in gneiss. The thickness of the vein was 1.3 m, and a length 350 m.

(f) *Silver-nickel-cobalt vein.* This type of vein was found only in the vicinity of Mu-chi, Hsin-ching hsien, Feng-tien province. It was a stockwork deposit in alaskite. The veinlet had a thickness of 0.5∼1.3 m and a length of 200 m. Ore minerals were löllingite, native silver, cobaltite, gersdorffite, erythrite, and arsenolite. A chemical analysis of the high grade ore showed Ag 26.14%, Ni 10.27%, Co 6.77%, As 18.67%, S 7.35% and Bi 0.42%.

A lead-zinc deposit was also found in the same locality, but it was not the same vein.

(g) *Silver vein.* It consists mainly of argenite and native silver, sometimes with a small amount of galena and chalcopyrite. The main localities are as follows:

Tien-pao-shan Mine (Tai-sheng vein), Yen-chi hsien, Chien-tao province.

Cheng-ping Silver Mine (Yen-tung-shan), Cheng-te hsien, Je-hol province.

Chi-lin-kou, Chi-chao-kou, Ta-hei-kou and Chi-jen-kou, Lan-ping hsien, Je-hol province.

Ya-pa-tien, Lung-hua hsien, Je-hol province.

Niu-chuan-tzu, Feng-ning hsien, Je-hol province.

At the Tien-pao-shan Mine, the Tai-sheng vein had a maximum thickness of 5 m and a length of 55 m, and a large amount of native silver, in thin folia, had been found within the oxidized zone which extended from the outcrop to a depth of 70 m below. As stated above, the Cheng-ping Silver Mine had been the largest silver producer of Manchuria. The ore veins in Je-hol were generally narrow fissure-filling veins in granite or gneiss area, of which the biggest one showed a thickness of 3 m and a length of 130 m.

(2) Fluorite vein. As the vein material, it contains fluorite, and a small amount of quartz.

(h) *Lead-fluorite vain.* It is a fluorite vein in granite-gneiss, and is located mainly in the district of Hai-cheng hsien and Kai-ping hsien of Feng-tien province. The main localities are as follows:

Lao-mu-kou, Hai-cheng hsien, Feng-tien province.
Pei-ssu-tao-kou, Kai-ping hsien, Feng-tien province.
Hsiu-yen Mine (Hsi-shan deposit), Hsiu-yen hsien, Feng-tien province.

The deposit of Pei-ssu-tao-kou contained a small amount of chalcopyrite and pyrite. The Hsi-shan deposit of the Hsiu-yen Mine had a width of 2–5 m and a length of over 1 km. The bonanza had a thickness of 5 m, and contained 35–40% fluorite and 2% Pb.

(3) Barite vein.

(i) *Lead-barite vein.* The vein material consists mainly of barite. The main localities are as follows:

Wang-chia-chuang, Chang-ling-ssu-hui, Kuan-tung Leased Territory.
Chien-hsien-shih, Chang-shan-ssu-hui, Kuan-tung Leased Territory.
Kuang-tung-tzu, Chi-an hsien, Tung-hua province.
Wan-pao-kai-tzu, Kuan-tien hsien, An-tung province.

The ore vein at Wan-pao-kai-tzu was found along the contact zone between quartz porphyry and porphyrite. The ore consists of galena, with a little chalcopyrite, pyrite and quartz. The mine was once exploited for copper. The deposit at Kuang-tung-tzu is a lenticular vein in limestone. The vein had a maximum thickness of 12 m and a length of 60 m. The ore consists mainly of galena and barite, accompanied by some chalcopyrite, bornite and zincblende.

Classification can be done according to the above-mentioned method. Meanwhile, Prof. OGURA made classifications of deposits at 75 localities in Manchuria according to the kind of country rocks, in which he separated out the overlapped mineralizations into each individual mineralization type. According to him, the contact-metasomatic deposits were found in 6 localities, the vein-type deposits in limestone in 31 localities, in granite or granite porphyry in 13 localities, in gneiss in 10 localities, in schist in 5 localities, and in the other rocks (quartzite, effusive rocks, etc.) in 12 localities.

B. Mode of Occurrence of the Minerals

Since only a few important deposits were investigated, the minerals described were not so numerous. Descriptions of the ore-forming minerals will be given here under the headings of the ore mineral, the skarn mineral, and the secondary mineral.

1. *The Ore Minerals*

(a) *Galena.* Galena is the principal ore mineral and it ranges in size from a minute granular to a coarse crystal sometimes attaining about 3 cm in diameter.

The so-called schistose galena was often found in the Hsiu-yen Mine. It showed a somewhat reddish luster and is said to have had a high silver content. Gelena from Manchuria was generally considered to be especially higher in silver content in fine grains than in coarser ones, but sometimes fine crystals of argentiferous tetrahedrite were found to constitute a close mixture with galena. The silver content of galena was in proportion to the lead content. Therefore, OGURA (1939), upon inspection of the analysis of 77 samples from various parts of Manchuria, made conversion of the lead content of samples into a lead content of 86.6% or an equivalent to galena, and the silver content was allocated by similar procedure, for comparison with each other. According to this study, the highest figure was shown by the galena from the Tien-pao-shan Mine with 33% Ag, while the majority of cases were between 0.10% and 0.29%.

The galena from the Ching-cheng-tzu Mine was also high in silver content, and so T. TATSUMI (1942) inspected the mode of occurrence of silver in the ore. The result showed that the silver content was fairly proportional to the lead content, or roughly 24.1 gr/ton toward 1% Pb. The ore contained mainly galena and tetrahedrite, and tetrahedrite was found encrusted with galena. TATSUMI calculated that the silver content in galena was equivalent to 16 gr/ton toward 1% Pb, and the silver content in tetrahedrite was estimated as about one-tenth of the copper amount. The results indicated that the galena from Ching-cheng-tzu was about two times higher than that of the preceding results, but there was a still pending problem as to the form and the mode of occurrence of silver in galena.

(b) *Zincblende.* This is also a principal ore mineral, and found in a larger amount than galena. Larger crystals of zincblende were as much as 2 cm in diameter, and they were dominantly of the black variety and rare in the brown variety. (Zincblende from the Kuang-tung-kou Mine in Chuang-ho hsien, An-tung province, was brownish in color and transparent.) Drop-like inclusions of chalcopyrite, with a diameter of less than 0.01 mm, are frequently found in the crystal of zincblende. The author found zincblende, in association with greenockite, at the outcrop of the Yang-chia-chang-tzu Mine.

(c) *Pyrite.* Pyrite, often in association with the above two minerals, was found in a larger amount. No information was obtained at the time for the variety belonging to marcasite.

(d) *Chalcopyrite.* This has often been found as an associated mineral with the ore. Irregular and massive chalcopyrite is scattering within the pyrite and galena ore.

(e) *Argentite.* This mineral is very rare in occurrence, and was found only at the Tien-pao-shan Mine of Chien-tao province, and at several spots in Lan-ping hsien, Je-hol province, but we have no reliable written information as to its nature.

(f) *Molybdenite.* Molybdenite was found at the Yang-chia-chang-tzu Mine and the Ching cheng-tzu Mine, as disseminated minute flakes in the skarn minerals. Molybdenite within the fissure was frequently found as dark-colored clayey film. Mill feed grade at the Yang-chia-chang-tzu Mine was about 0.5% MoS_2.

(g) *Arsenopyrite.* It is rare in occurrence. At the Yang-chia-chang-tzu Mine it was found as prismatic crystals 2–3 mm in size, forming stringer or dissemination within limestone. At the Ching-cheng-tzu Mine, the lead-pyrite veins were found to contain argentite and this mineral.

(h) *Pyrrhotite.* Sometimes this was found in the veins, and often also in the contact-metasomatic deposits. The examples are the mines of Yang-chia-chang-tzu, Huan-jen and Ching-cheng-tzu.

(i) *Magnetite.* It has been exclusively found in the contact-metasomatic deposits, but with small amounts. The localities are the Yang-chia-chang-tzu and the Huan-jen Mines.

(j) *Hematite.* Some of the lead-zinc-pyrite veins of the Kuang-tung-ling in Hsiu-yen hsien, An-tung province, contained quartz, chlorite and specularite. If it were micaceous hematite, they would have been considered as similar in nature to the gold- and silver-bearing chlorite-hematite veins in the vicinity of Osarizawa, Akita prefecture, Japan; the latter indicates special characteristics of the Tertiary mineralization in Japan.

2. *Skarn minerals*

Reddish brown garnet, hedenbergite, diopside, epidote, zoisite, tremolite and vesuvianite are the principal contact minerals. At the Ching-chang-tzu Mine, diopside, tremolite, forsterite and phlogopite were found in the country rock of dolomite; and cordierite was found in thermally metamorphosed schist. At the Ching-tsui-tzu Mine in I-tung hsien, Chi-lin province, wollastonite was formed in limestone.

3. *Gangue minerals*

The gangue minerals, of the ore deposits other than the contact-metasomatic deposits, are generally quartz and calcite. Calcite would be especially prominent if the country rock were limestone, and quartz would be the major one if the country rock were other than limestone.

Fluorite and barite are found often as the gangue mineral in association with quartz. Fluorite is violet or green in color, and often forms an octahedron of about 3 cm in diameter. Barite is white and prismatic, showing a fibrous structure. Siderite, in association with quartz, constitutes the gangue of the Hsuan-ling-hou Mine.

4. *Secondary minerals*

The oxidized zone of ore deposit would produce the following minerals.

(a) *Native silver.* Thin foil-like native silver was found in large amounts in the Ta-sheng vein of the Tien-pao-shan Mine, Chien-tao province.

(b) *Cerussite.* The prismatic crystals of about 1 mm in length were found at the Yang-chia-chang-tzu Mine.

(c) *Anglesite.* It was rarely found in the Yang-chia-chang-tzu Mine.

(d) *Hemimorphite.* At the Yang-chia-chang-tzu Mine, it formed white botryoidal aggregates within the veins.

(e) *Pyromorphite.* It has been exclusively found (as the pyromorphite vein in quartzite) in the Kuang-tung-shan area of Hua-tung-kou, Feng-tien province.

(f) *Malachite.*

(g) *Azurite.* Azurite, together with malachite, was encrusted on the surface of chalcopyrite, or found as stringers.

(h) *Gypsum.* It was often found in the deposits in limestone.

C. Succession of Minerals

Although there were no sufficient data as to the succession of ore and gangue minerals, Ogura (1939) summarized the studies that had been made on the deposits of several localities. According to this study, the succession of minerals, from early to later stages, should be as follows:

(1) Pyrite—sphalerite—galena—chalcopyrite—quartz—calcite.
(2) Pyrite—chalcopyrite—sphalerite—galena—quartz—calcite.
(3) Galena—fluorite—quartz.
(4) Barite—galena—quartz and barite (graphic intergrowth).

D. Distribution of the Oxidized Zone

The oxidized zones are poorly developed in general. They are accompanied by only a few secondary minerals. At Yang-chia-chang-tzu, the depth of the oxidized zone was less than 20 m. In the case of Tien-pao-shan, the depth of the oxidized zone within the contact-metasomatic deposit was less than 30 m; in some part of the vein-type deposit it may be as deep as 70 m from the outcrop. Mining of the oxidized zone had never been attempted.

E. Geological and Structural Control of Ore Deposits

In the case of the contact-metasomatic deposit, the development of the skarn zone is controlled by the shape of intrusives, and the high grade part is found as irregular veins or lenses within the skarn zone. In the case of the hydrothermal metasomatic deposit, the metasomatic action might have penetrated sometimes along the bedding plane of limestone, but the deposits appear mainly as pipe-like bodies at the intersection of the fissure systems.

Such deposits are also very irregular in shape, and some of the shapes are hardly explained either by the fissure system or by the structure of country rock, as exemplified well by the spiral pipe-like ore body at the Yang-chia-chang-tzu Mine. Generally speaking, the veins are developed chiefly along the dike-like intrusives, and they generally become metasomatic veins with very little gangue mineral and a remarkably lenticular shape, when they are found within the limestone group. The Ching-cheng-tzu Mine, which was studied by Tatsumi (1942) offered a good example showing abrupt changes for vein development by the nature of country rocks. Namely, the veins were swollen within the dolomite area, but they were sharply pinched upon entering into the schist area, and the galena content was also decreased. In some extreme cases, even the mineral association would be changed sharply; for instance, the lead and zinc vein would be changed into a pyrite-quartz vein or quartz-calcite vein, or might completely disappear. A similar relation is known where the veins have entered from dolomite into dike rocks.

F. Metallogenic Epoch

Plutonic intrusives such as granite or diorite are found frequently within the country rocks of the silver-lead-zinc deposits of Manchuria. Even though there may be no plutonic intrusives within the mining area, a close inspection through the area might often lead to the discovery of some minor intrusives differentiated from them. The acidic plutonic rocks are considered to have the closest relation to the localization of ore deposit. In the eastern area of the southern half of Manchuria, the principal age of the granite intrusions is considered to be the end of Paleozoic, or they might have intruded the Permo-Carboniferous formations and are covered with the Jurassic formation. While, in the western area of the southern half, the ore deposits have been found in schist, quartzite, and andesite; and the igneous activity, with a close relation to the formation of mineral deposit, is considered to be the Yenshan crustal movement of Cretaceous period.

VII. Summary

Silver-lead-zinc deposits in Manchuria show a denser distribution in the region south of the lat. 44°N, and the deposits exploited at the time were dominantly contact-metasomatic deposits. The vein-type deposits occupied nearly 90% of the total known localities, but they were small in scale. Generally the country rocks were dominantly limestone, and sometimes the mineral association showed a sharp change in its character, owing to the change in the nature of country rocks.

Among the silver ore veins, we can find an example of the silver-cobalt-nickel type. Regarding the silver content the galena at the Ching-cheng-tzu Mine showed about two times as much of any known result of the previous studies in Manchuria. The metallogenic age may be around the end of the Paleozoic in the eastern area of the southern half of Manchuria, whereas in the western area the age may be some time at the end of the Mesozoic, although further investigations are still necessary.

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Deposition and Metamorphism of Precambrian Banded Iron Ores in Manchuria

Takao SAKAMOTO

I. General Properties of the "Banded Iron Ores"

A. CLASSIFICATION

The "banded iron ores" in Manchuria and other regions can be classified as follows:

Table 1. Classification of "Banded Iron Ores."

Banded iron ores	Poor ores	Hematite-magnetite-quartz-schist	(1)
		Hematite-magnetite-quartz-schist or Magnetite-quartz-schist with Siderite, Chlorite, Gruenerite, Cummingtonite, Hornblende, Pyroxene, Garnet or Olivine	(2)
	Rich ores	Sedimentary——Hematite-magnetite-quartz-schist	(3)
		Hydrotherm——Magnetite-or Martite rock with Chlorite and Dolomite	(4)
		Weathering——Limonite, Hematite, Martite	(5)

The major part of the "banded iron ores" in Manchuria consists of a hematite-magnetite-quartz schist (1) or a poor ore with alternating bands of iron oxides and silica which corresponds to jaspilites in Lake Superior and Krivoy Rog, only recrystallized and with coarser grains. The rest of them consist of a finer banded poor ore with alternating bands of three components, i.e., iron oxides, silica and iron silicates (often iron carbonates). This second group occurs in thicker lamina of beds only in locally restricted areas, e.g., in Yuen-chien-shan and Ta-ku-shan areas at An-shan. Those poor ores which contain amphiboles, pyroxenes or olivines represent more highly metamorphosed members of group (2), and occur at Miao-erh-kou, Wai-tou-shan and to the south of Fu-shun, being accompanied with either mica schist or migmatite gneisses. Poor ores of this type are also found in the northern part of Krivoy Rog and in the Vermillion Range to the east of Mesabi, in the United States.

The rich ores of group (3) are found in the local area in Krivoy Rog and An-shan, but their mode of formation has not yet been determined. The big deposit in Brazil is thought to be in this class. The ores in group (4) are found in Krivoy Rog and Miao-erh-kou. The ores in group (5) forms exceedingly large deposits in the India, Krivoy Rog and Lake Superior districts. From the economic standpoint, the value of the "banded iron ores" throughout the world, rests in the class of rich ores of group (5).

B. Stratigraphy

The iron formations are found in the Precambrian Group of each continent, but do not cover all the Precambrian terrane. Their thickness is usually 100–200 meters, the maximum being 450 meters in the Lake Superior region. They are found at three horizons in the Keewatin and Huronian Systems. Although their age is considered Archaean in Fennoscandia and India, they are usually found among intermediate members between the most highly and least metamorphosed members of the Precambrian: e.g., among the Wu-t'ai System (Liao-ho Syst.) in N. China and Manchuria, the Saksagan System in Ukraina, the Jaturian and Kalevian in Fennoscandia and the Huronian in N. America.

There are iron ore beds in formations of later age, e.g., Wabana, Clinton and Oriskany in N. America, Minette in Europe, Oolitic in England, etc. But these are of an entirely different type, lacking in silica bands, and are much thinner when compared with those of the Precambrian Group. The "banded iron ores" are characteristic to the Precambrian Group, never in any later geological ages are formed similar iron ore beds.

Among highly metamorphosed deposits stratigraphical horizons could be decided only with difficulties owing to their lithological and structural features; while among little metamorphosed deposits they are extremely clear.

All over the world, the banded iron formations are formed in the Proterozoic Group when their stratigraphical position is known. Besides, it is a striking feature that they are always accompanied by a clayslate formation among the major Proterozoic cycle of quartzite, slate and calcareous rocks.

Table 2. Width of Bands and Diameter of Mineral Grains.

Ores	Width of "bands" (mm)	Diameter of mineral grains (mm)
2-component poor ores	finely banded 0.5–2	Iron-minerals ..0.005–0.3
	coarsely banded ..2–10	
3-component poor ores	silica bands 0.2–3	Quartz 0.05–0.5
	Fe oxide bands.... 0.2–2	
	chlorite bands 3–5.5	

C. The Banded Structure and the Grain Size of Component Minerals

The above diameters of mineral grains show those of ordinary hematite-magnetite-quartz schist or cummingtonite-magnetite schist in An-shan; while in jaspilites, grains are much smaller, but in higher metamorphosed ores, they become a little coarser.

It is a remarkable feature that such fine bands should be piled up in beds, showing regular cycles, and attain thickness of tens or even hundreds of meters without any interrupting beds of other clastic sediments.

Example of bands and regular cycles of three component poor ores are shown in Fig. 1.

Thickness - (mm)									Cycles
	Group				Individual				
Total	%	Quartz	Fe oxide	Fe silicates: Thüringite, Cummingtonite	Quartz	Fe oxide	Fe silicates: Thüringite, Cummingtonite	Acid - Alkali Complete Cycles: -	
11.2	45			5.0			5.0		IIIrd
	33		3.7		0.5, 0.2	1.0, 1.5			
	22	2.5			0.3, 1.5	0.7, 0.5			
15.1	37			5.5			5.5		IInd
	23		3.5		3.5, 0.7, 0.5	0.2, 1.2			
	40	6.1			0.7, 0.7	2.0, 0.1			
9.3	32			3.0			3.0		Ist
	30		2.8		1.5	2.5			
	38	3.5			1.5, 0.5	0.3			

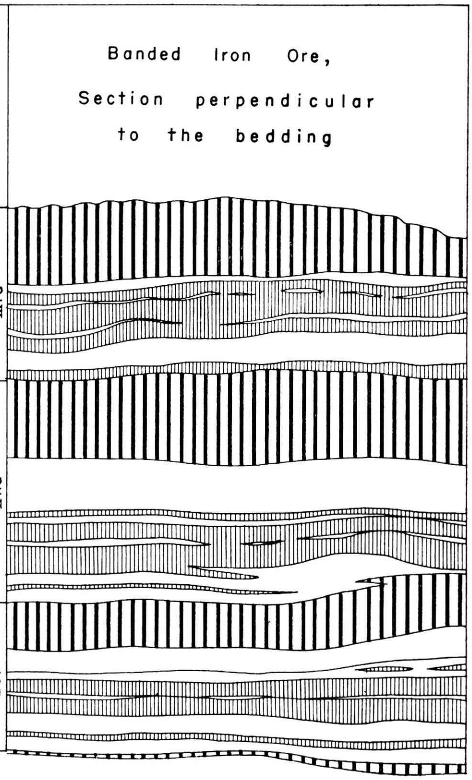

Fig. 1. Cyclic Banding in the Banded Iron Ore from Pai-chia-pu-tze, An-shan.

II. Process of Sedimentation and Development of Banding

A. Earlier Views on the Origin

There seems to be a consensus on sedimentary origin of poor ores while the silicification of tuffs, as recently postulated by Dunn, is quite a unique opinion. One point which deeply concerns me, is the interrelation between two-component and three-component poor ores. In all earlier views, two-component ores are believed to be products of secondary oxidation of three-component ores. This is due to the fact that many students followed the views postulated by Van Hise and

LEITH. These authors believed that the original rock with greenalite and siderite, after oxidation, gave rise to ferruginous chert with hematite, limonite and quartz.

On the deposits in Singhbhum, India, Dunn states that "the study of the chloritic phyllites indicates that they are extremely high in iron, in the form of magnetite as well as chlorite. Frequently as these chlorite phyllites are traced laterally along the strike, both chlorite and magnetite are seen to give place to hematite, eventually merging into a hematite phyllite, hematite schist and even iron ore. Again and again this association of hematite phyllite to chlorite phyllite is demonstrated, forcing the conclusion that the large areas of hematite shales and hematite phyllites are merely another form of the chloritic phyllites completely oxidized."

Svitalsky, on the Krivoy Rog deposit, made following statement; "the ore beds were precipitated from colloidal solutions by electrolytes, and that the primary precipitates of ferric iron were changed into ferrous iron, and by a diagenetic reaction between this ferrous iron and silica and other elements, ferrous silicates and carbonates were formed. Later these primary iron silicate and carbonate sediments were oxidized by hot solutions emanating from intrusive granite magma resulting in the formation of first, a jaspilite and ferruginous chert from a siderite chert, and also ferruginous chert from chloritic hornstone. This hydrothermal action in certain localities, dissolved silica and deposited magnetite in its place. Thus the transformation of iron silicates into jaspilite and ferruginous chert by the oxidation and the formation of rich ores were accomplished simultaneously by the hydrothermal action."

On basis of my recent studies on the ore beds at An-shan I now assume that the interrelation between the two-component ore beds and the three-component ore beds can be accounted for by a sedimentary mechanism under a special environment, and that such an environment was characteristic only in the Precambrian; thus the elucidation of this problem of sedimentation gives a clue to the solution of important problems in the historical geology. In the following sections I will state my ideas about the mechanism of sedimentation of the iron formation and, further, about the environment of sedimentation of the whole Precambrian Group.

B. THE ENVIRONMENT OF DEPOSITION

Iron migrates in acid environments and is precipitated in neutral and alkaline environments. Silica, on the contrary, migrates in alkaline and is precipitated in acid environments. This fact, as the phenomena in the weathering crust, has been quantitatively established by the experiments on the "isoelectric points" by Sante MATTSON.

In my former studies upon the weathering and sedimentation of bauxites and "bando-Ketugan" (aluminous shale), I found that the distribution of soil colloids are in close connection with the acidity of the environment and that the result of MATTSON's experiments upon the isoelectric points are in good harmony with the distribution of soil colloids in natural soil profile. I, then, found out that the systematic distribution of soil colloids in a generallized soil profile of humid soils throughout cold, temperate and tropical zones, could be demonstrated with the "equal silica-alumina molecular ratio lines" inclining towards the south, in the northern hemisphere, to which I proposed a new term "Isosials" (see Fig. 2).

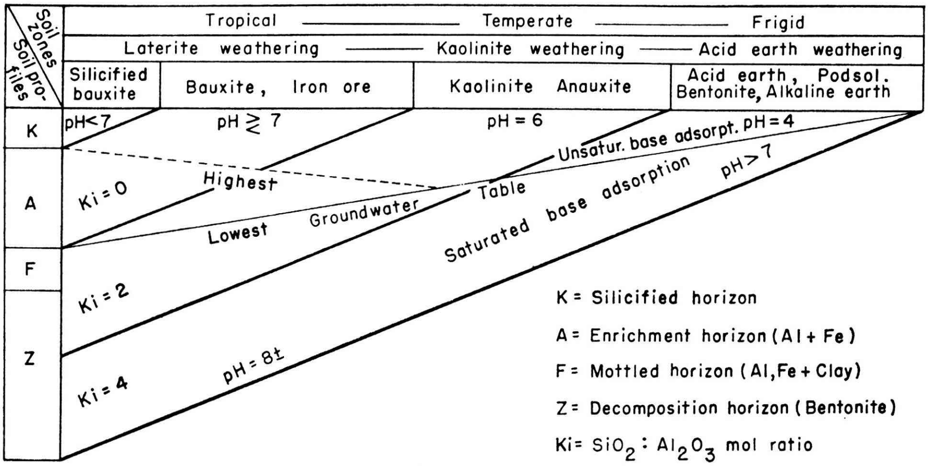

Fig. 2. Diagram Showing "Isosials" or Equal SiO_2: Al_2O_3 Molecular Ratio Lines in Natural Soil Zones and Profiles.

In short, according to the acidity of the environments, the most stable components among the soil colloids remain in situ, while unstable components are dissolved out of the system. Taking into account the above-stated facts, it is known that the iron in the acid environment above the water table and the silica in the alkaline environment below the water table are unstable and migrate until they reach an opposite environment and are redeposited. Especially in the profile above the water table in regions of higher latitudes, the environment is highly acidic and the iron (also part of the alunina) is dissolved out, while in the profile below the water table in tropics, the environment being highly alkaline, the silica is dissolved out.

Taking these facts into consideration in the inference of the Precambrian environmental conditions of weathering, it seems to me that a gleam of light is thrown upon the question of accumulation of unusually large amount of iron and silica. The lack of coarse debris, the homogeneous and normal cycles as in Lake Superior, all point to a mature weathering, as is already pointed out by LEITH. Also it is generally accepted that the Precambrian atmosphere was very rich in CO_2 gas. Under such physiographical conditions, chemical weathering predominates, and especially when the atmosphere contains much CO_2, the surface water in contact with the atmosphere can retain much bicabonates in a solution whose vapor pressure is in equilibrium with the large pressure of the CO_2 in the atmosphere. In other words, rocks are rapidly decomposed and hence, give rise to a condition of a deep going weathering. If so, it is inferred that the soil solution above the water table was acidic with free CO_2 while that below the water table was alkaline with alkali bicarbonates.

Suppose that the annual rainfall was great and divided into periodically dry and wet seasons, or that the same meteorological conditions as the present "monsoon" climate existed; then in dry seasons, the shallow grounds above the water table become neutral or alkaline, while in wet seasons the phreatic zone near the water table become again neutral or acid. Consequently, in wet seasons iron migrates in acidic surface water, while in dry seasons, silicon migrates in alkaline ground water. The majority of iron and silica, though partly consumed in the formation of ferruginous "Ortstein" or silicification of the country rocks, goes into solution and are transported into basins and depressions to get precipitated there as "Fernfaellung."

Suppose, further, that these basins and depressions were wide but shallow, and between the open sea there were only low barriers which separate these basins or lakes from the sea. When, in wet seasons, there is much influx of the surface water, the lake water easily overflows into the sea; while in dry seasons, the influx stops and the lake becomes an inland lake of an arid rigion. The lake water becomes acid in wet seasons, and by convection, the cool, surface water with free oxygen circulates down to the bottom, so all of the whole lake water becomes acid and oxidizing. In dry seasons, on the contrary, the influx of a fresh supply of oxygen-bearing and oxidizing water stops, and owing to the seepage of alkaline underground water, the lake water gets neutralized, and owing to the subsequent evaporation the lake becomes at last an inland lake in the arid region, in which the lake water stays stagnant, oxygen is lost and as the level of the lake water goes down, its reaction becomes alkaline. In the next wet cycle, a fresh influx begins and the level of the lake water rises, the reaction becomes neutral and finally, when it begins to overflow, it becomes acid again.

Similar phenomena can be observed, at present, in rivers and lakes in the semi-arid region in N. W. Manchuria. In the river Sungari, the pH falls in the flood seasons in summer, it rises in low water in winter. Many small lakes around Hailar are all weakly to strongly alkaline and none is acid.

C. Development of Banding

In the lakes where the reaction of water repeats regular cycles of acid-neutral-alkaline-neutral-acid, the condition under which silica and iron are precipitated is inferred as follows:

The iron, either in the form of colloids or true solution, is supplied to the lake in wet seasons. Ferrous iron is oxidized into ferric iron due to an aeration. Then, in arid seasons, when the influx of the surface water stops and the pH of the lake water gradually rises to neutral, ferric hydroxide gets precipitated very rapidly, because its isoelectric point is pH: 7. A little iron still remains in the solution. Due to the seepage of underground water and evaporation, the reaction becomes alkaline, when silica is supplied to the basin as colloidal solution, gradually increasing its concentration as the evaporation goes on. Under an increased alkaline condition, colloidal silica and iron hydroxide combine to form iron silicates (greenalite, chamosite, etc.,), and the rise of the temperature accelerates precipitation of carbonates of iron and other elements. Again, upon the return of a wet season and the influx of fresh surface water, the reaction returns through neutral

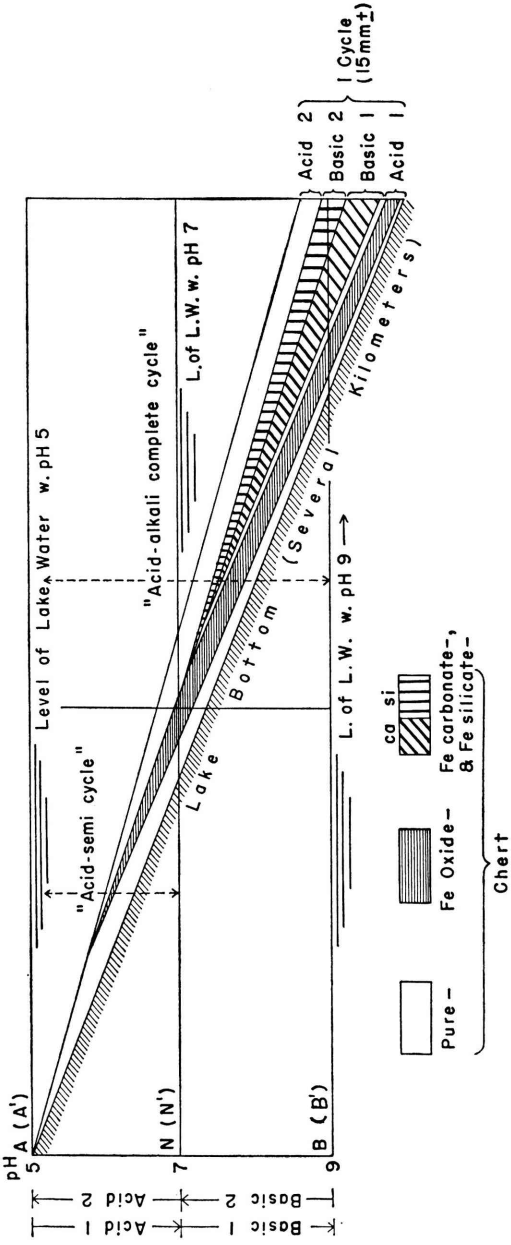

Fig. 3. A Diagrammatic Cross Section Showing the Deposition of Silica, Ferric Oxide, Ferrous Carbonate, Ferrous- and Ferric Silicates in Relation to the Reaction (pH) and Change of Level of Lake Water.

back to acid again. In this stage, silica is totally precipitated, the lake water is acid and contains free oxygen and receives a new supply of iron in solution thus the second cycle gets started and repeated.

The above-stated sequence is diagrammatically shown in the cross section of a lake basin in Fig. 3 and Table 3.

Table 3. The Reaction (pH) of Lake Water and Sediments.

Stage and Reaction	Sediments (Bands)	Area of deposition
A–N (Acid 1)	Ferruginous chert	Entire lake bottom
N–B (Alkaline 1)	Siderite chert	Small area around the center of lake
B′–N′ (Alkaline 2)	Chlorite chert	Small area around the center of lake
N′–A′ (Acid 2)	Pure chert	Entire lake bottom

In the case of a complete cycle, as is seen in the above figure, or a cycle with the succeeding stages of acid-neutral-alkaline-neutral-acid, the sediments shall be, from the bottom upward, a ferruginous chert, siderite and chlorite chert, and pure chert, thus giving rise to a distinct banding. In the deeper portion near the lake center, a three-component poor ore is deposited, while in the shallow, marginal portion, a two-component poor ore.

While, in the case of an incomplete cycle, or a cycle with the succeeding stages only of acid-neutral-acid (or a cycle which may be called an acid semi-cycle), only a two-component poor ore is deposited all over the lake bottom; in the other case of an incomplete cycle of neutral-alkaline-neutral (or a cycle which may be called an alkaline semi-cycle), only three-component poor ore is deposited within a restricted area around the lake center.

The banded structure described in the foregoing chapter, especially the one in the example taken by me from Pai-chia-pu-tzu, An-shan, show a remarkable coincidence with the banding in the acid-alkaline complete cycle in the above figure. And the cycles in the banding of the ore from Yuen-chien-shan taken by Asano, shows, beside acid-alkaline complete cycles, alkaline semi-cycles.

That, each of the two- and three-component poor ores, according to field observations, has locally separate areas of distribution, has been stated in a foregoing chapter. This peculiarity is very easily explained by the scheme of deposition stated above.

The view that the two-component poor ore is secondarily derived from the three-component poor ore by an oxidation seems to have been entertained almost universally. Yet, the fact observed in those ores in which finely banded structures are extremely well preserved like those in An-shan, clearly shows that it is more reasonable to assign this to the primary sedimentational structure and distribution.

The two-component poor ore may, at a glance, seem an entirely different type of ore from the three-component poor ore, yet, upon closer observation, the latter ore is known to be the same as the two-component ore only added with a band of silicates or carbonates of iron in cherts. This is naturally expected from the above-stated condition of sedimentation, that is, an acid semi-cycle is included in an acid-alkaline complete cycle; in fact, the two-component ore, in the lake margin, of the complete cycle, is traced laterally into the lake center, into the constituent bands of the three-component poor ore. Consequently, it is quite impossible that such two-component ore should be derived from a three-component ore by a later oxidation. If oxidation is a necessary procedure, it must have operated exactly at the same time with the deposition of those thin bands, and that, with a regular intermittent recurrence. Such syngenetic oxidation, if present, is only one of the sedimentary conditions under a well aerated, hence oxidizing, lake water. Thus, this coincides with my "acid 1" or "acid 2" stages of the sedimentation.

III. Progressive Metamorphism of "Banded Iron Ores"

A. Metamorphism of Poor Ores

In the preceding section, the stratigraphy of the iron-bearing formation, the banded structure of the iron ores, the mechanism of their sedimentation were considered in the deposits of Lake Superior, Krivoy Rog and An-shan. In these deposits, the "banded iron ores" consist of following mineral components:

Table 4. Poor ores and their mineral components.

Classification	Ores	Component minerals
Two-component poor ore	Ferruginous chert, Jaspilite	Chalcedonic quartz, Red and purple hematite
	Hematite-magnetite-quartz schist	Quartz, Black hematite, Magnetite
Three-component poor ore	Siderite-chlorite-hematite chert, and Siderite chert	Chalcedonic quartz, Siderite, Chamosite, Greenalite
	Thüringnite-magnetite-Gruenerite-cummingtonite-magnetite schist	Quartz, Thüringite, Gruenerite, Cummingtonite, Magnetite

The poor ores in Lake Superior and Krivoy Rog consist largely of compact jaspilite, ferruginous chert or siderite-chlorite chert, while those in An-shan crystalline hematite-magnetite-quartz schist and thuringite-gruenerite (or cummingtonite)-magnetite-quartz schist. In the eastern part of the Lake Superior (Masabi) deposits and in the northern part of the Krivoy Rog deposits are met with crystalline thuringite-cummingtonite-magnetite schist, gruenerite-magnetite schist and further eulysitic ores with pyroxenes and olivines.

In Manchuria, to the east of An-shan, there are many deposits with more highly recrystallized ores than those at An-shan, i.e., such as Miao-erh-kou, Wai-tou-shan and the region to the south of Fu-shun. I have had chances to make field observations of these deposits, but I owe the details of following descriptions to the recent works by ASANO.

In the deposit at Miao-erh-kou, the footwall consists of mica schist and is intercalated with limestones. The iron formation itself and its hanging wall consist of chlorite schist, hornblende schist and injection gneisses and the ores are tremolite-magnetite and hematite-magnetite schists.

At Wai-tou-shan, both in hanging and footwalls are developed actinolite schist, hornblende schist and mica schist, suggesting a mode of emplacements of a large xenolithic mass engulfed in an injection gneiss.

In Kung-chang-ling deposit, on both the hanging wall and footwall of the poor ore bed, a garnet-anthophyllite-fels develope. This rock is believed to have been derived from the chlorite-amphibole schist by a contact metamorphism due to an intrusion of granite.

The latter is very widely developed in the area either in the hanging wall and footwall sides or in an alternation with the poor ore beds. I believe that the garnet-anthophyllite-fels is the metamorphosed equivalent of a three-component poor ore. Therefore, in this deposit, unlike in Miao-erh-kou and Wai-tou-shan, an effect of local superimposition of a regional and a thermal metamorphism is observed.

At Hui-nan and Chin-chuan-hsien, east Manchuria, a green hornblende-magnetite schist is found; at Ma-ho-ssu, Fu-shun-hsien and other small deposits, a pyroxene-olivine-garnet-magnetite schist and coarse grained magnetite-quartz schist are found, all of them being in the form of xenoliths or melanocratic bodies in migmatite gneisses. These correspond to the eulysite in Sweden and show the highest grade of metamorphism.

The above-mentioned deposits are arranged according to degree of metamorphism, and they can be classified into five successive stages as in the following table (Table 5). In this table the formation of rich ore deposits along with the main deposits is also shown. As the metamorphism of the poor ores can be traced in progressive stages, I refer to it as the "ordinary phase," while the formation of the rich ores takes place at any stage irrespective of their grade of metamorphism and I refer to it as the "extraordinary phase."

The fact that the metamorphism of the "banded iron ores" in Manchuria can be traced in progressive stages has already been noticed by ASANO. In this paper, I have completed the list adding the deposits of Lake Superior and Krivoy Rog, both of which I have had opportunity to visit during field observations, to the earlier stages of the series, covering the whole metamorphic history.

In the above list, it is in poor ores with three components that the successive stages of advancing metamorphism are clearly indicated by corresponding mineralogical changes. On the other hand, the poor ores with two components are turned into a hematite-magnetite schist already at the second stages and later at

Table 5. The Progressive Metamorphism of "Banded Iron Ores" and the Formation of Rich Ores.

Stages		I. Siderite-Chlorite Stage →		II. Chlorite-Gruünerite Stage				
Phases		Ordinary Phase	Extraord. Ph. / Hydro-therm Weather-ing	Ordinary Phase			Extraordinary / Hydrothermal	
Ore Deposits		Mesabi Iron Form.	Mesabi Rich Ore	Krivoy-Rog Iron Form.	Singhbhum Iron Form.	An-shan Iron Form.	An-shan Rich Ore	Krivoy-Rog Rich Ore
Ores / Original Sediments		Taconite, Jaspilite	Compact, red hematite	Jaspilite, Fe-chert	Banded Fe-quartzite	Hematite-, Magnetite-q-schist	Magnetite	Martite, Magnetite
Chert with	Fe_2O_3 or $Fe_2O_3 \cdot nH_2O$	Taconite, Jaspilite	Hematite	Jaspilite, Fe-chert	Banded Fe-quartzite	Hematite-q-, Magnetite q-schist	Magnetite	Martite, Magnetite
Chert with	Ankerite (Ca, Fe)CO_3	Siderite		Siderite-cummingtonite-thüringite-schist	Banded chloritic quartzite, Grünerite-schist	Siderite-magnetite-cummingtonite (grünerite) thüringite-schist	Thüringite-magnetite-schist	Cummingtonite-magnetite-schist
Chert with	Greenalite $FeO \cdot SiO_2 \cdot nH_2O$	Greenalite	Hematite					
Chert with	Chamosite $3FeO \cdot Al_2O_3 \cdot 2SiO_2 \cdot 3H_2O$	Chamosite						
Progressive metamorph. of basic Igneous rocks		I. Chlorite facies						
Shale		Slate	Slate	Actinolite-schist, Sericite-schist, Phyllite	Chloritic phyllite, Mica schist w. Ottrel., Staurol., Andalus., Cyanit.	Biotite-, Biotite-sericite-, Chlorite-, Graphite-phyllite, Sericite-, Chlorite-, Actinolite-schist.	Garnet-thüringite-, Tourmaline-sericite-schist	Chlorite-garnet-cummingtonite-schist w. alkali minerals
Sandstone		Quartzite		Sandstone, Quartzite (w. Sericite)		Quartzite, Sericite-q-schist		

		→ III. Tremolite-Actinolite Stage			→ IV. Green Horn-blende stage	→ V. Pyroxene-Olivine Stage		
Phase		Ordinary Phase		Extraord. Ph.	Ordinary Phase.	Ordinary Phase		Extraord. Phase
Weathering				Hydro-therm.				Thermal
Krivoy-Rog Rich Ore	Singh-bhum Rich Ore	Miao-erh-kou Iron Form.	Wai-tou-shan Iron Form.	Miao-erh-kou Rich Ore	Chin-chuan & Hui-nan Iron Form.	Ma-ho-ssu Iron Form.	Ma-ho-ssu & Wang-chiang-tze Iron Form.	Tung-yuan-pu Rich Ore
Limonite	Hematite	Hematite-q- sch. Magnetite-q-schist	Magnetite-q-schist	Magnetite	Magnetite-hornblende-schist	Hedenber-gite-amphibolite-magnetite schist	Hypers-thene-fayalite magnetite-schist	Mg-Ca-Fe-Mn-carbonate-magnetite-schist
Limonite	Hematite	Hematite-q-, Magnetite-q-schist	Magnetite-q-schist	Magnetite		Magnetite-q-schist	Magnetite-q-schist	
Limonite	Hematite	Tremolite-magnetite-, Anthophyllite-magn-, Chlorite-magn-sch.	Actinolite-magnetite-, Anthophyllite-magnetite schist	Magnetite with dolomite	Magnetite-green horn-blende-grünerite sch.	Hedenberg-grüner.-green hornbl.-hemat.-magn.-q-anthophyll.-fels	Hypersth.-hedenberg-fayalite(garnet)-magnetite-fels	Mg-Ca-Fe-Mn carbonates-magn.-fels, Garnet-hypersth.-xanthophyll.-olivine-fels
		II. Amphibolite facies				III. Eclogite facies		
		Mica schist, Amphibolite, Chlorite-sch., Injection gneiss, Phyllite	Amphibolite, Actinolite-schist, Injection gneiss		Mylonite granite, Gneiss	Migmatite gneiss	Migmatite gneiss	
		Quartzite with sericite	Quartzite					

higher stages, they become very stable and undergo little change in components.

In reviewing the whole metamorphic history, I found that the first and second stages may be called a "chlorite facies," the third and fourth an "amphibolite facies" and the fifth an "eclogite facies." These three facies are the classification given by Eskola of Finland, to the progressive metamorphic facies of basic igneous rocks. It is important that the metamorphic history of the banded iron ores, beginning with iron carbonate and iron silicate as their main components, can be closely correlated with that of basic igneous rocks in general.

Along with the advancing metamorphism of the iron ores, the metamorphism of argillaceous and arenaceous members of the series are shown on the list. In reviewing the whole history it is recognized that the first and second stages are mainly dynamic, and passing through the later second and third stages the change in the fourth and fifth stages is more and more characterized with features of thermal metamorphism.

In the main ore bodies at the Mesabi Range, no direct effect of any batholithic intrusives is observed. Regarding the formation of rich ores, there have long since been controversies between a "descending meteoric water" theory of the Wisconsin school and an "ascending hot water theory" of the Minnesota school. However, in the Vermillion Range to the east of Mesabi, highly metamorphosed members such as amphibole-magnetite schist and even eulysitic ores are produced by the contact effect of basic intrusives.

In Krivoy Rog, it is generally accepted that the enrichment was caused by an ascending hot solution, because of frequent occurrence of soda minerals, a batholithic intrusion is inferred in depth.

In An-shan deposit, granitic intrusions are so extensive that the iron formation at Wang-chia-pu-tze and Ying-tao-yuan is in part completely captured in the granite. Also rich ores with thuringite and magnetite, and locally sericite schist from chlorite phyllite are formed by the action of a hydrothermal solution.

At Miao-erh-kou in the hanging wall, and at Wai-tou-shan, in both hanging and footwall, are developed injection-gneisses.

At Chin-chuan, Ma-ho-ssu and also at Wang-chiang-tze, Ching-lung-hsien, Jehol, the iron formations are represented by xenoliths or sometimes merely melanocratic bodies as assimilation relics floating amid the extensive migmatitic gneisses.

The interrelations between the metamorphics and intrusives are thus clearly demonstrated, the higher the metamorphic stages the relation being the more intimate. This fact bears witness to the phenomena which are interpreted with the belief that the "isodynamics are also the isotherms" in a region of an advancing metamorphism. The advancing metamorphism of poor ores with three components is correlated with that of ordinary basic igneous rocks; further, the parallelism between the metamorphism of poor ores of known compositions on the one hand, and that of argillaceous sediments in the series of iron formation on the other hand, can be well established. This is another point worth paying attention to.

B. Genesis of the Rich Ores

In the present status of world technology the economic value of the "banded iron ores" is linked with that of rich ores. The weathering and hydrothermal actions are responsible for the formation of main rich ore bodies, and those deposits in the earlier stages of the advancing metamorphism seems to be more susceptible to those processes of enrichment. It has already been stated above that there are two opponent theories of weathering and hydrothermal processes upon the enrichment of the Lake Superior deposits. I suspect, however, that this enrichment is accounted for by the dissolution of chalcedonic quartz under the lateritic weathering which prevailed over the whole area in the circum-Gulf regions during the Eocene, Wilcox stage. The rich ores in India are surface debris ("Float ores") and powder ores ("Blue dusts") which have been formed under the lateritization process in the Tertiary and Recent.

The process of a hydrothermal action is most pronounced in Krivoy Rog, and is characterized with the association of soda minerals (aegirine, alkali-amphibole, albite, etc.) and chlorite. The formation of soda minerals in a hydrothermal action is also pointed out by T. Kato in the Mosan deposit, N. Chosen.

As an example of rich ores of the thermal metamorphism may be taken the Mn-carbonate-bearing magnetite at Tung-yuan-pu, on the Mukden-Antung Railway line. The co-existence of thermal and dynamic metamorphic minerals in this deposit was noticed by Tsuru. This seems to be of the same type as the skarn ore in the Leptite series in middle Sweden which was described by Magnusson.

C. Metamorphism of the Precambrian Group

Although it is usually the case with the world occurrence of the iron formations that they are comprised in the series showing a medium grade of metamorphism among the whole Precambrian of the regions, the iron formations themselves show the advancing metamorphism from the earliest stage of jasper (chert) and phyllite, through amphibole schist and mica schist, up to eulysite and migmatitic gneisses.

Consequently, from point of view of only metamorphism, the formations containing jasper and phyllite are not different from those of neo-Proterozoic (Sinian) System and even Paleozoic Groups; and eulysite and migmatites are not different from some of the member of so-called Sang-Kan gneiss "nor from those migmatites developed by the injection of Tomita's so-called older Archaean granite" into his Tscha-nan series, Sui-yuan series and Ta-ling series.

According to Tomita, the "Sang-Kan gneiss" together with the Tscha-nan and other series as well as the injection gneisses derived from them, correspond with the lower part of his "Shieh-hu-shan series." The Shih-tsui and the Pai-yun-ssu (Nan-t'ai) series of the Wu-t'ai System correspond with the upper part of the said series. And further, according to him, the lower, highly metamorphosed part was simply assigned to the Archean (Tai-shan complex) and the upper, less metamorphosed part was simply assigned to the Proterozoic, since the time of Willis and Blackwelder.

Now, in such eulysite and migmatite gneisses as those in the southern part of Fu-shun or in Wang-chiang-tze, Jehol banded iron ores with two components or silica and ferric oxides are still retained, pointing to the sedimentaly origin of the metamorphics.

Limestones and highly aluminous minerals such as sillimanite and cyanite, similarly serve as sedimentary criteria. However, there are frequently the cases in which no such criteria can be discernible, and original rocks are not known.

In short, at the highest metamorphosed stage of the "banded iron ores," their lighologic types show quite similar appearances as those assigned to the Archaean. But it is very important that poor ores with two components if included in them, clearly indicates sedimentary criteria.

Tomita, taking up the cycles of igneous intrusion and lithologic characters, tried to establish a criterion to distinguish the Proterozoic from the Archaean. In my opinion, however, it is more important to find a criterion by which the sedimentary and igneous origin of metamorphics can be distinguished with more accuracy. In this sense, "banded iron ores" offer excellent criteria.

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Molybdenum Deposit of the Yang-chia-chang-tzu Mine, Manchuria

Masashi OKUSA

I. Location and Transportation

The Yang-chia-chang-tzu Mine is situated 32 km west of Chin-hsi, a station on the Shan-Feng Railway line which runs from Shang-hai-kuan to Feng-tien via Chin-chou. As the mine is connected to Chin-hsi by a branch railway and a truck road, transportation is very good.

The molybdenum deposit is to the west of the lead-zinc deposit (NISHIZAWA and TATSUMI, 1953).

II. History

It is said that several hundred years ago in the Kao-chu-li period pyrite in this area was mined as a source of sulphur. Afterwards the lead-zinc deposit was worked on a small scale for lead, and in 1933 the deposit was equipped with machinery by a Japanese miner and the lower part of the old lead ore body was worked. In the course of the mining, prospecting was very actively undertaken for unknown deposits in the neighboring area but without success. In 1940 a prospect tunnel was opened on the western side of the Ta-pei-ling saddle and the molybdenum deposit was discovered. At that time the lead deposit was about to be exhausted and continuation of the mining seemed difficult, so mining of this newly discovered molybdenum deposit was started at once.

III. Topography

The upper reaches of the Nu-erh-ho, which flows into Po Hai via Chin-hsi, runs from southwest to northeast, i.e., parallel to the Sinian Trend. The Yang-chia-chang-tzu Mine is situated in the mountainous district between the upper reaches of this stream and the sea. In this mountainous district are developed low undulating hills, 50 to 100 m above sea level, and some monadnocks, 400 to 500 m in height; the former are considered to correspond to the Kuan-tung Paneplain because of the topographic similarity to that of Kuan-tung province.

The mine is located among the monadnocks. Ta-pei-ling, a granite mountain with an elevation of 500 m, lies to the north, and to the south there is a group of several steep sandstone mountains, the Pi-chia-shan Mountains, whose highest peak is 560 m above sea level.

IV. Stratigraphy

The stratigraphic sequence of the mine area is as follows:

A. Cenozoic era
  Quaternary (sand, gravel, and loess)

B. Mesozoic era
  Cretaceous (pyroclastic rocks)
  Triassic (shale, sandstone, and conglomerate; 340 m thick)

C. Paleozoic era
  Permo-Carboniferous (shale, sandstone, and conglomerate, intercalated with coal; 120 m thick)
  Cambro-Ordovician (limestone, dolomitic limestone, shale, and quartzite; 600 m thick)

D. Proterozoic era
  Upper Sinian (cherty limestone and slate; 400 m thick)

E. Igneous rocks
  Granites intrude the strata ranging from the Sinian to the Triassic, and are covered by the Cretaceous pyroclastics.

A. Cenozoic Era

The Quaternary system consists of loess (20 to 30 m thick) deposited at the foot of the mountains, and sand, gravel and clay along the rivers. These sediments are not related to the ore deposit.

B. Mesozoic Era

The Cretaceous system, consisting of andesitic pyroclastic rocks, unconformably overlies Triassic sedimentary rocks and is overlain by loess. It is distributed in the eastern part of the mine area but is not directly related to the ore deposit.

The Triassic system is 340 m thick. Since no fossils were found, the exact age of the strata remains undetermined. Some geologists assigned them to the Permo-Triassic age but, for the sake of convenience, I am assuming that they are Triassic. They unconformably overlie the Permo-Carboniferous system and consist mainly of alternating conglomerates and sandstones. The strata are generally reddish. The base is a compact, white, siliceous sandstone on which lies an alternation of multi-colored (reddish purple, brown, grayish green, yellow, etc.) shales and sandstones. The pebbles in the conglomerates are mainly water-worn pebbles of quartzite and flint; no limestone pebbles are found. Some pebbles are deformed and cracked due to the effect of compression, which may suggest that the conglomerates suffered orogenic movements.

In the upper part there are thick sandstones colored grayish green, yellowish gray, dark gray, etc.

C. Paleozoic Era

The Permo-Carboniferous system is a 120 m thick coal-bearing formation. It disconformably overlies the Ordovician limestone and consists of conglomerate, sandstone, and shale. The basal bed is white conglomerate or sandstone. The sandstones are yellow or white and the shales are multi-colored. The formation is intercalated with 50 cm to 1.5 m thick coal seams, which are mined on a small scale at Hei-yu-kou and Fu-erh-kou. There are three seams of coal, the total thickness attaining 2.5 m in places.

The formation contains plant fossils, such as *Lepidodendron* sp., *Tingia* sp., *Pecopteris* sp., *Stigmaria* sp., *Cordaites* sp., and rarely limestone lenses. The Permo-Carboniferous beds are thinner here than in North China and the other regions of South Manchuria. In the lower part of the basal conglomerate, there is a layer of alumina shale about 1 m thick.

The Cambro-Ordovician system disconformably overlies the Sinian system and consists mainly of limestones and dolomitic limestones with some intercalations of shales. The total thickness is estimated at 600 to 800 m. The strike is generally E-W and the dip is 40°S. At Lien-hua-shan, about 3 km south of the mine, the total thickness may be as much as 800 to 1,000 m and the stratigraphic sequence is as follows:

(1) Black dolomitic limestone; marly in part.
(2) Conglomerate; calcareous matrix with chert pebbles.
(3) Dolomitic limestone, dark gray, partially reddish and shaly.
(4) Flinty limestone; light gray, intercalated with green shale.
(5) Gray laminated limestone.
(6) Alternation of dolomitic limestone and shale, intercalated with micaceous shale.
(7) Laminated dolomitic limestone.
(8) Alternation of dolomitic limestone and sandy shale (each layer is 30–40 cm thick).
(9) Dolomitic limestone, intercalated with several beds of shale.
(10) Oolitic limestone; black and massive.
(11) Gray dolomitic limestone.
(12) Gray limestone; contains *Girvanella manchurica.*
(13) Gray oolitic limestone.
(14) Red and purple shale.
(15) White limestone.
(16) Quartzite.

The white basal quartzite, (16), is highly resistive to weathering and characteristically forms cliffs. It is often brecciated. The quartzite was once considered to be Sinian by some geologists, but later other geologists, during their survey of the lead-zinc deposit, identified this quartzite as the base of the Cambrian system, for the reason that the quartzite disconformably overlies the Sinian limestone and is conformably overlain by the Cambrian limestone. The thickness of the quartzite is 100 to 150 m.

The gray limestone, (12), contains fossils of brachiopods and trilobites in addition to *Girvanella*. The country rocks of the molybedenum and the lead-zinc deposits are generally limestones of this systym. In the 90 m pit, the 120 m pit and in the Ta-pei-ling pit on the mountain sides some of the shales were altered to cordierite-hornfels or biotite-hornfels by the intrusion of the Ta-pei-ling granite.

D. Sinian System

The strata deposited in the Sinian period are exposed near Ta-pei-ling and Lung-wang-miao. They consist mainly of siliceous limestones, often intercalated with chert, and locally slaty limestone and shale. Total thickness is about 400 m.

E. Igneous Rocks

Granitic rocks occur as loccoliths in the area north of Yang-chia-chang-tzu. They affected sedimentary rocks with contact-metamorphism. In the west of Ta-pei-ling pass, the width of the contact-metamorphosed zone reaches several hundred meters, and molybdenite-bearing garnet-skarn is found there.

The granite in the vicinity of Ta-pei-ling is coarse- to medium-grained and pinkish. Under a microscope the rock is found to consist of phenocrystic quartz, orthoclase and biotite, occasionally with a small amount of hematite.

The marginal part of the granite laccoliths is monzonitic, more or less greenish, consisting of orthoclase and green biotite, but no quartz.

Many dikes extend from the laccolith; they are generally quartz porphyry or monzonite porphyry.

V. Ore Deposits

The ore deposits of the Yang-chia-chang-tzu mine have been formed by mineralization in the contact zone of the granite and limestone. The deposits are of four types according to the grade of mineralization: (a) Molybdenite deposit; (b) Magnetite deposit; (c) Copper deposit; and (d) Lead-zinc deposit. Type (d) is further subdivided into (d–i) the Yang-chia-chang-tzu type (low temperature replacement); (d–ii) the Shang-pien type (high temperature vein); and (d–iii) the Sung-shu-wu type (low temperature vein). In this report only the molybdenite deposit will be discussed.

The molybdenite deposit occurs in a body of skarn formed by the strong contact-metamorphism which is known as the Ssu-chien type metamorphism. The skarn is in the folded part of the Cambro-Ordovician limestone along the western

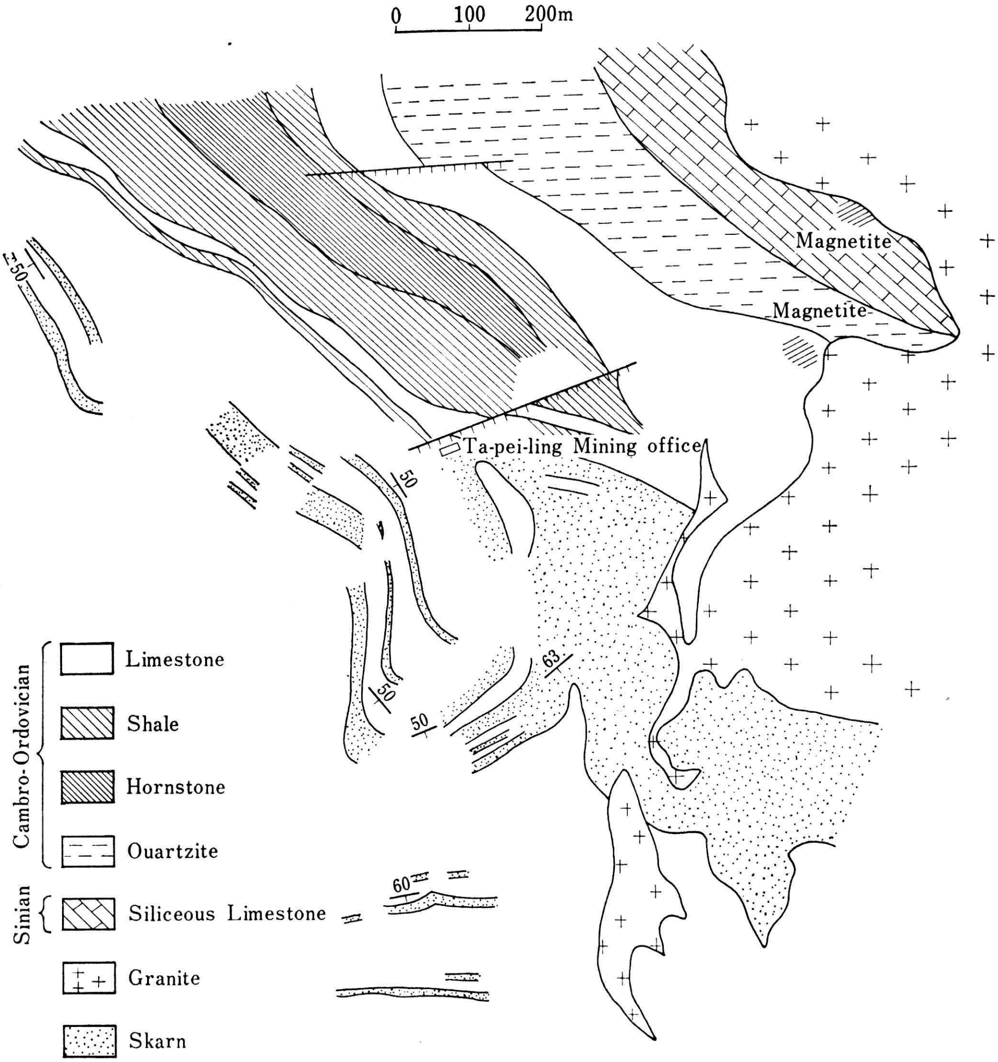

Fig. 1. Geological map of the Yang-chia-chang-tzu molybdenum deposit.

contact of the granite which extends like a tongue in the area between Ta-pei-ling and Ssu-chien.

The skarn is dark brown, brown, light brown, green or yellowish brown, and is crossed by quartz and calcite veins parallel or oblique to the bedding plane. The brown part consists almost entirely of aggregates of garnet crystals some of which are as large as a finger tip. Diopside is also abundant, filling the interspaces of garnet. In addition, there are mica, hornblende, augite, vesuvianite, epidote and calcite. Molybdenite occurs as veins, impregnations and lumps in this skarn.

The ore body, which was encountered in No. 8 Ta-pei-ling shaft, is parallel to the bedding plane of the limestone. It strikes NNW-SSE and dips 55°W. In the southern part, this body makes a large turn as shown in Fig. 2. Its total extension is more than 300 m, including four parallel ore shoots. Width of the ore shoots increases downward, or eastward, locally exceeding 30 m. The second to fourth ore shoots are 2 to 5 m wide, partially swelling. The molybdenite grains are generally 0.3 mm in size, occurring as impregnations often parallel to the bedding plane of the country rock. In some cases, small flakes or fine grains of molybdenite fill the fissures which obliquely intersect the bedding plane.

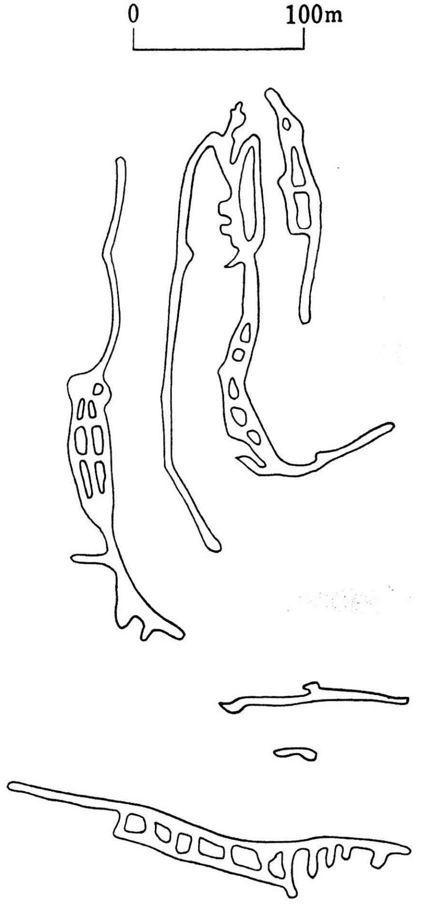

Fig. 2. Sketch of tunnel in Ta-pei-ling ore body.

According to the results of analysis, the average MoS_2 content reaches 1% to 5% in the high-grade portion and about 0.55% in the 5 to 10 m wide low-grade portion. After the completion of the sorting plant, mining was carried out setting the standard grade of crude ore at 0.65% MoS_2.

As the mineral assemblage of the ore is simple, the sorting was not considered to be difficult, but the results of the sorting were not good because of lack of investigation and of much mechanical trouble owing to the forced production increase during the war. Although the deposit remained undiscovered for a long time, the mine was required to produce considerable amounts of refined ore. Under these conditions, prospecting and equipment necessary for sorting were not always sufficient.

The mining has not been flawless, but mining conditions are very good and as it has not been long since mining was started a large part of the deposit is not exploited yet. The net reserves are at least 2,000,000 tons and the probable reserves amount to more than 5,000,000 tons. This molybdenum mine, therefore, is considered to be second in size to the Climax Molybdenum Mine in the United States, in reserves and ore quality. Considering that the Climax Mine started with relatively small probable reserves, 5,000 tons, and afterwards became the largest molybdenum mine in the world, the mining of this deposit should be carried on at a moderate rate—not more than 3,000 to 5,000 tons per month of ores with the MoS_2 content higher than 1%. The mine could then surely have a great expectancy.

After the war, I proposed a plan based on this rate of operation to Nationalist China, but the government set the mining rate at 2,000 tons per day, a figure far larger than mine, so the plan was not realized. The molybdenum deposit is one of the best deposits in the world, and should be mined as soon as possible.

Output of ore since the beginning of mining is as follows:

Year/month	Sorted ore (tons)	Grade of crude ore (MoS_2%)
1940/1–1940/12	9,080	0.69%
1941/1–1942/3	65,961	0.55
1942/4–1943/3	137,611	0.53
1943/4–1944/3	166,429	0.47
1944/4–1944/6	54,045	0.50
Total	533,126 tons	

VI. Mineral Assemblage

Rokuro SHIMA (1944), in his graduation thesis listed the following mineral assemblages:

(1) Magnetite and molybdenite

At Han-chia-kou, molybdenite fills the interspaces of magnetite. Magnetite is therefore considered to have crystallized before molybdenite.

(2) Molybdenite and pyrite

At Ta-pei-ling, pyrite fills the interspaces of molybdenite. Molybdenite is therefore considered to have crystallized before pyrite.

(3) Molybdenite and lead-zinc ore

Galena and zincblende are also found in the skarn of Ssu-chien, Ta-pei-ling, but no ore shows molybdenite-galena or molybdenite-zincblende paragenesis. But from several facts molybdenite is believed to have crystallized before galena and zincblende.

The mineral assemblages and their paragenetic relations are shown in the following table compiled by SHIMA.

Paragenesis of Minerals

									Skarn													
		Granite			Monzonite		Q-porphyry		Ta-pei-ling					Central part				Ssu-chien		East wing		Han-chia-kou
Ore	?	○		○													○					
	Magnetite																				○	○
	Molybdenite									○	○		○				○					○
Calcite									○	○		○	○					○		○		
Tremolite																○						
Epidote											○										○	
Vesuvianite										○	○											
Augite															○							
Diopside										○	○	○		○				○	○	○		
Garnet									○	○	○	○	○	○	○		○	○	○	○		
Green hornblende																				○		
Mica	(Mica)									○												
	Muscovite			○																		
	Green biotite				○	○	○															
	Brown biotite	○	○	○	○	○																
Feldspar	Plagioclase									○					○							
	Orthoclase	○	○	○	○	○	○	○	○													
Quartz		○	○	○			○	○	○					○			○					

VII. Summary

The Yang-chia-chang-tzu Mine is connected with Chin-hsi station on the Shan-Feng Railway line by a branch line 32 km long. It started as a lead mine, but just when the lead deposit was almost exhausted the molybdenite deposit was discovered and was at once worked as an important resource for Japanese military operations during World War II.

The molybdenite deposit is a contact deposit resulting from a granite intrusion into the Sinian to Permian strata. The molybdenite deposit in limestone was formed during the period from the later stage of the pneumatolysis to the earlier stage of the hydrothermal process. Molybdenite is partially paragenetic with pyrite of the succeeding stage, but escaped impregnation by galena and zincblende of the later stage.

Possible ore reserves exceed several million tons. When 3,000 to 5,000 tons of sorted ore are to be dealt with monthly, the grade of crude ore should be MoS_2= 1.0%, and if the monthly output is increased to 30,000 tons the ore grade must be lowered to MoS_2=0.6%.

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The An-tu Antimony Mine

Hiroshi OZAKI

I. Location and Access

Ta-tien-tzu of An-tu is located at 70 km west-southwest of Ming-yueh-kou station on the Chang-chun—Tu-men Railway line. The antimony ore deposits occur at about 9.5 km directly west-northwest of Ta-tien-tzu. Taking the road through Hsi-pei-chai, the distance from Ta-tien-tzu to the deposits is about 15 km; the road is very poor and hardly passable for trucks.

II. Geology and Ore Deposits

There are two ore deposits centering around Ta-tien-tzu, one is called the Hsi-pei-chia deposit and the other Wan-pao-kai-tzu deposit. The latter deposit was once prospected but was later abandoned, so the present report deals only with the Hsi-pei-chia deposit.

The ore deposit at Hsi-pei-chia was previously reported by UCHINO and ASANO (1939). I will describe the deposit on the basis of my own observations made in August, 1945, and referring to UCHINO and ASANO's reports as well.

The Hsi-pei-chia area is composed of leucocratic biotite granite, the Upper Paleozoic Tou-man formation captured or intruded by the granite, hornfels, and the Jurassic formation.

The granite might have intruded in the late Paleozoic or early Mesozoic period. It is pinkish or pale reddish brown, and fine- to medium-grained. Although biotite occurs as a mafic mineral, the rock is generally leucocratic. Essential minerals are labradorite, microcline, orthoclase and quartz, accompanied by muscovite as well as biotite. Apatite and magnetite are present as accessory minerals.

The hornfels, probably belonging to the Tou-man formation, occurs as xenoliths in the granite north of the ore deposit. Xenoliths of limestone are found around the deposit.

The Jurassic formation consists of basal conglomerate, sandstone and shale. The formation is well exposed at Nan-ta-tien-tzu where the occurrence of *Podozamites* sp. is noticed. The formation strikes N 80° W and dips 12° S. The sandstone is generally grayish white, locally intercalated with reddish purple sandy shale. The basal conglomerate is exposed near the deposit. It is composed of pebbles of the above-mentioned granite, and the interspaces of the pebbles are partially filled with stibnite.

Prospecting of the ore deposit is still insufficient, but outcrops of the deposit and boulders of ore are found in places. In most cases, ore occurs in the leucocratic granite. Crystals of stibnite are found in the silicified portion of the country rock. In some cases, however, stibnite fills the interspaces of pebbles of the Jurassic conglomerate, as observed in the Kinen (Memorial) mine lot. Stibnite is found mostly as small prismatic crystals, 1 mm to several centimeters long, scattered throughout the silicified zone. On rare occasions, prismatic crystals as long as 20 cm aggregate into a bundle. A small amount of pyrite is often associated with stibnite. The gangue mineral is mostly quartz. Thus, the mineral assemblage of the ore is very simple. According to the result of prospecting the deposit of the Kinen mine lot is most promising.

A. Ore Deposit

Mode of occurrence of the ore deposit is hardly observed on the ground, since the exposures are poor. On the surface the deposit looks like a silicified part of the leucocratic granite. However, underground observation reveals that the deposit fills the interspaces of the pebbles of the conglomerate which unconformably rests on the granite, and extends with a trend of roughly N 30° E. Prospecting was carried out by digging nine pits (represented as shafts on the map), of which the following five encountered the ore:

Pit No. 1:—A shaft was driven in the direction of N 30° E. A very small amount of stibnite was noticed in the granite near the entrance.

Pit No. 2:—When a shaft was driven for 10 m in the direction of S 42° E, three ore veins were found within a width of 3 m. The veins strike N 30° E, dip 80° NW or vertical, and join those in Pit No. 3 in the south.

Pit No. 3:—The ore veins were pursued by driving a shaft. At the bottom of the shaft, a drift was driven along the ore veins whose trend changed to N–S. By a westward cross-cut the drift is connected with the level of Pit. No. 5.

Pit No. 5:—After a shaft was driven for 10 m, an inclined drift was driven. Because of the winding of the drift it is difficult to assume the mode of occurrence of the ore deposit, but a mineralized zone, about 4 m thick, contains several ore veins striking N 30° E and dipping vertically. From the bottom of the drift, a level was driven to join No. 3 in the north and No. 6 in the south.

Pit No. 6:—A cross-cut driven in the direction of S 75° E met with an ore body at a spot 10 m from the entrance. From this spot a drift was driven to pursue the ore body. Another cross-cut, 15 m long, was also driven from the same spot. The observation in this cross-cut revealed that the ore body lies in the conglomerate consisting of granitic pebbles. The conglomerate contains fragments of carbonized wood. Judging from the geologic setting of the neighborhood the conglomerate is supposed to be Mesozoic (Jurassic?) in age. Prismatic crystals of stibnite, 1 mm to several centimeters long, are filling the interspaces of pebbles in a radial pattern or forming irregular aggregates. The mode of occurrence of the stibnite crystals may represent the structure of the conglomerate. The country rock is bleached white and the thickness of the sericitized zone is more than 5 m, but the ore-bearing part is about 2 m thick. The ore body branches into veins in the direction of N 30° E. A fractured zone stretching in this direction is mineralized.

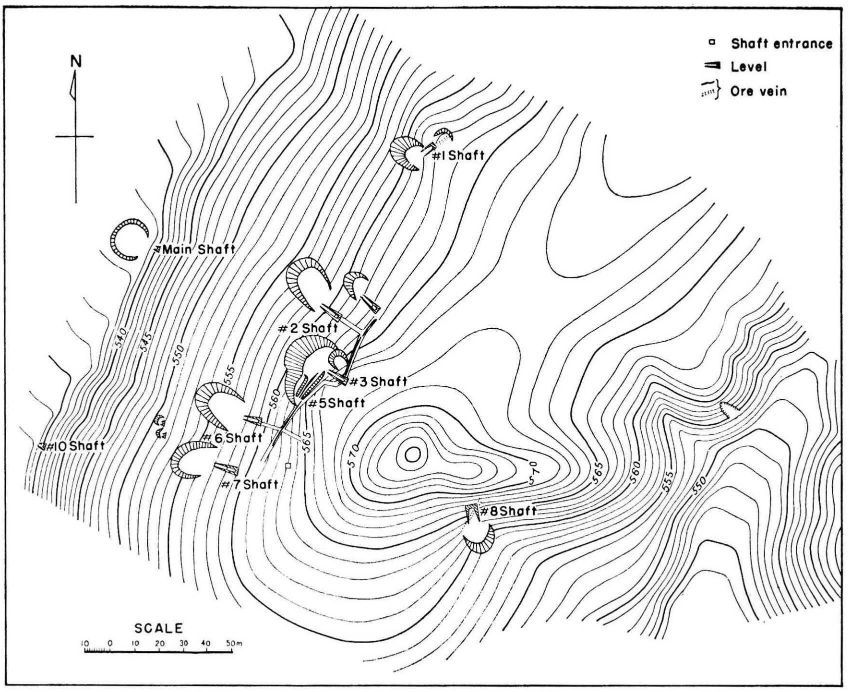

Fig. 1. Sketch map of An-tu mine (antimony).

B. Grade and Reserves of Ore

The above-mentioned prospecting pits are all very shallow, 4 to 8 m from the ground surface, but it was confirmed that the ore deposit has an extension of 60 m between Pit No. 2 and Pit No. 6, and its northern extension is impregnated with stibnite. Taking Pit No. 1 into account, the extension of the ore deposits would amount to at least 100 m. Ore veins are 2 m thick on the average and the stibnite content is 1.0 to 1.2% judging from the record at the time of my investigation in 1945. Due to the topographical conditions it is difficult to drive a new cross-cut at a depth more than 20 m. Therefore, exploration of the deeper part would not be accomplished in a short period of time.

Assuming that the ore deposit continues down to the depth of 30 m, I estimated the probable reserves of ore as follows:

$$100 \text{ m} \times 30 \text{ m} \times 2 \text{ m} \times 2.6 = 15{,}000 \text{ tons}$$ (2.6 is specific gravity of ore)

If the ore was mined at a rate of 1,000 tons per month, the reserves would be exhausted within about 15 months. Under the existing circumstances it is advisable that the mining is operated by a private enterprise with its own refinery, aiming at the monthly output about 500 tons.

III. Mining Situation

At the time of the investigation, the An-tu mine was operated by a private company, the Continental Mining Company. Working at the mine site were one Japanese engineer, several Korean employees and 20 to 30 Manchurian laborers. Crude ore was treated by means of gravity concentration, and was transported by truck to the refinery across a stream near Ming-yueh-kou station. At the refinery the ore was refined into metal antimony by means of a simple pot-shaped smelting furnace equipped with crucibles. One Japanese and several Koreans were working there. The company had experienced hard times since the Manchurian Incident, and in April 1945 they finally stood a fair chance of success in the mining business. They drafted a plan for a monthly production of 5 tons of metal antimony.

The Kinen mine lot was the main source of supply, however, prospecting of the ore deposit had just begun, and unless the downward extension of the deposit was confirmed it would be difficult to attain the goal, since 1,000 tons of crude ore would be required in order to produce 5 tons of metal antimony.

IV. Conclusion

The ore deposit of the An-tu antimony mine is a network of quartz in silicified zones along the fissures of the leucocratic granite and the overlying conglomerate. Outcrops and boulders of ore are found in places around the mine site.

The ore minerals are stibnite, occurring as prismatic crystals of 1 mm to several cm long, and a small amount of pyrite. Crude ore is easily crushed and is suitable for gravity concentration. The largest deposit lies in the Kinen mine lot, which is 100 m long, 2 m wide and with a stibnite content about 1%. Several outcrops and boulders of ore are found nearby.

It is considered that the development of this mine will cast some light on the development of similar deposits in Manchuria, including the ore deposits at Ching-tsui-tsu of I-tung Hsien and Hua-shu-lin-tzu of Hua-tien Hsien.

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Vanadiferous Iron Ore Deposits in Manchuria

Makoto Muraoka

I. Introduction

The vanadiferous iron ore deposits of magmatic differentiation are mainly distributed in the northern part of Cheng-te, and ores are classified into three types: ilmenite-magnetite, rutile-magnetite and apatite-ilmenite-magnetite ores.

Total reserves of all the deposits is estimated to be 4 million tons, and 3.8 million tons of which is concentrated in the environs of Ta-miao about 35 km north from Cheng-te.

Table 1. List of Vanadiferous Iron Ore Deposits in Manchuria.

No.	Province	Name of Mine	Location	Chemical Composition			Reserves (Million tons)
				Fe	V	TiO_2	
1	Je-ho	Chi-chia-tzu	35km NNW from Cheng-te railway station.	40–57	0.05–0.30	12–15	2.0
2	〃	Erh-tao-ho-tzu	35km NNW 〃	40–57	0.05–0.30	12–15	
3	〃	Tieh-ma-tu-kou	45km NW 〃	45–50	0.1—0.3	10–12	0.18
4	〃	Ta-ta-shan	3km NW from Tieh-ma-tu-kuo	–	–	–	small
5	〃	Hei-shan	30km NNW from Cheng-te Railway station.	40–57	0.2—0.4	10–15	1.6
6	Chin-chou	Kitamura	60km N from Chao-yang railway station.	–	–	–	0.2

II. Country Rocks

The deposits in lenticular and/or massive forms occur in gabbro which intruded into the so-called "Huang-ku-tun formation" being composed of gneiss and crystalline schist. The gabbro can be classified into two kinds, melanocratic and leucocratic, and the latter is intruded by the melanocratic gabbro and hornblendite which sometimes changes to chlorite schist or hornblende schist.

The leucocratic gabbro sometimes shows gneissose structure and is exposed in a large area. It usually consists of a small amount of pyroxenes and hornblende with smaller amount of magnetite, ilmenite, chlorite, apatite, rutile and pyrite as accessary minerals. Although the iron ore deposits usually occur in the melanocratic gabbro and hornblende schist or chlorite schist, both of them are derived from the former. In the Ta-miao district, they are always in coarse-grained hornblendite containing many spots of aggregate of chlorite and diopside.

Rock-forming minerals of the melanocratic gabbro are same as those of the leucocratic gabbro and only difference between them is a quantity of mafic minerals in each rock. The melanocratic gabbro is, moreover, often impregnated with small grains of magnetite.

III. Deposits

From the viewpoint of a combination of ore minerals, the ore deposits could be classified into three types:

(1) Ilmenite-bearing magnetite deposit;
(2) Rutile-bearing magnetite deposit;
(3) Apatite-bearing ilmenite magnetite deposit.

The Chi-cha-tzu deposits in the northern part of the Ta-miao mine, the Kitamura mine, and the Hei-shan mine belong to (1), the Erh-tao-ho-tzu deposit in the southern part of the Ta-miao mine belongs to (2) and the Tieh-ma-tu-kou mine belongs to (3). Ores produced from the (1)-type deposits contain small quantities of rutile, and in spite of type difference, ores usually contain 0.05–0.40% vanadium.

The boundary between ore bodies and country rocks is comparatively distinct when ore bodies occur in the leucocratic gabbro. However, ore bodies change gradually to country rocks when the country rocks are rich in mafic minerals.

A. Chi-chia-tzu Deposits in Ta-miao Mine

There are thirty-four lenticular or vein-shaped ore bodies in the melanocratic and leucocratic gabbro, and sixteen of them are longer than 20 m in length. The maximum width of the largest ore body here is 42 m (18 m average) and can be traced 180 m along its strike. Moreover, the middle part of its outcrop shoots out more than 15 m vertically from the slope of the mountain.

Scale of ore deposits in the leucocratic gabbro is generally larger and quality of their ores are superior than those of ore deposits in the melanocratic gabbro.

B. The Erh-tao-ho-tzu Deposit in the Ta-miao Mine

There are six ore bodies running east to west, on the northern bank of the Erh-tao-ho-tzu-hsi-kou river. All ore bodies are in the melanocratic gabbro and three of them are longer than 100 m in length. They have a tendency to decrease their width at about 20 m beneath the surface. The Ta-miao mine had been mined to make vanadium steel and titanium white from the magnetic concentrated ore during World War II.

C. The Tieh-ma-tu-kou Mine

The mine is located on a spur, east of Tien-ma-tu-kou, 45 km northwest from Cheng-te city, and eight ore bodies are observed in the horblendite. The ores are rich in apatite and contain 45–50% Fe, 0.1–0.3% V, and 10–12% TiO_2, and reserves are calculated to be 180 thousand tons.

The Manchurian Match Company's plan to open this mine to produce phosphorus to avoid the inconvenience of using sulphur for matches in the latter stage of World War II could not be realized because of long distance transportation to their factory.

D. The Hei-shan Mine

This mine is located about 8 km east from the Ta-miao mine, and more than twenty ore bodies are found in the leucocratic gabbro or chlorite schist that occurs in the former, over an area 2.0 km long, 1.5 km wide. The ore bodies reach the maximum length of about 100 m and width of about 20 m, but are poor in underground extension like those of the Ta-miao mine. Reserves are estimated to be 1.6 million tons of ore; 40–57% Fe, 0.2–0.4% V, and 10–15% TiO_2.

E. The Kitamura Mine

Sometime in 1945, the vanadiferous magnetite deposit was discovered in gabbroic mass, 60 km north of the Chao-yang railway station on the Chin-ku line, and was named the Kitamura mine after the family name of the mining license applicant. There are numerous iron ore outcrops scattered over an area of 4×4 sq k, but none of them represents a part of large-scale ore body. The result of magnetic prospecting also indicated that there would be no ample hope for discovering large-scale ore bodies.

IV. Ores

A. Ilmenite-magnetits Ore

This is a steel-greyish, coarse-grained, massive magnetite ore usually found at the Chi-chia-tzu and the Hei-shan mines. Microscopic observations show the typical "Widmannstatten Figur" of minute ilmenite layers after etching the ore with conc. HCl for one or two minutes. There are also very small quantity of euhedral ilmenite which can be observed along the interstices of magnetite crystals. As accessary minerals, there are small amounts of hematite, hornblende, plagioclase, quartz, kaolinite, chlorite, apatite and rutile in the ore.

Chemical compositions other than the essential elements shown on Table 1, of the ores from Ta-miao and Hei-shan mines are as follows:

Ta-miao ore: 2.22% SiO_2 5.71% Al_2O_3 0.046% P 0.091% S 0.182 % Mn.

Hei-shan ore: 5.48% SiO_2 0.017% P 0.091% S 0.184% Mn 0.49% Cr_2O_3

A concentration of 65% Fe was produced by magnetic separation, in which vanadium was also concentrated. However, the iron content of tailings could not be lowered less than 28%.

B. Rutile-magnetite Ore

This is brownish black massive ore produced from the Erh-tao-ho-tzu deposit. Rutile occurs as interstitial matter along cleavages of magnetite or as minute granular grains in magnetite crystals. It is also found as fine euhedral crystals in chlorite.

Ore, of course, mainly consists of magnetite, of which rhombohedral cleavages are filled up by aggregates of chlorite crystals.

C. Apatite-ilmenite-magnetite Ore

This is a fine-grained blackish ore with a large amount of apatite and a few spinel and titanite. Chlorite occurs along cleavages or partings of magnetite crystals.

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The Geology of the Pei-piao Coal Field, South Manchuria

Shōichi NISHIDA

I. Location and Access

The Pei-piao coal field, one of the most important coal fields in Je-ho (Jehol) Province, is located about 10 km northeast of the town of Ch'ao-yang. Pei-piao is the terminus of the Pei-piao line that branches at Chin-ling-ssu from the Chin—Ku line (Chin-hsien—Ku-pei-kou) which is a branch line of the Feng—Shan (Feng-tien—Shan-hai-kuan) railway.

The railway distance between Pei-piao and Chin-hsien is an easy 120 km. The coal field includes Chien-shan-tzu to the northeast and Hsing-lung-kou to the southwest, and trends northeast to southwest. Its area is 24 km by 3 km. The town of Pei-piao lies approximately in the center of the coal field. The coal field was worked in three blocks—Chien-shan-tzu, Kuan-shan and Tai-chi-ying-tzu (Tai-chi on the geologic map), until the end of World War II. The coal-bearing area consists of low hilly land. Its southeast side is surrounded by steep mountains composed of Ordovician quartzite and dolomitic limestone. There are also small mountain blocks on the northwest composed of the Upper Triassic volcanic rocks and associated detrital rocks. These mountains form a basin which trends from northeast to southwest.

II. General Statement on Stratigraphical Sequence

The stratigraphical succession of the coal field can be subdivided as follows:

Hei-cheng-tzu series	H_2	*Lycoptera*-bearing formation
	H_1	Andesite and agglomerate formation
		~~Clinounconformity~~~
Yang-shan series	Y_5	Pale greenish-gray sandstone formation
	Y_4	T'u-ch'eng-tzu conglomerate formation
	Y_3	Reddish-brown sandy shale formation
	Y_2	Pyroclastic rock formation
	Y_1	Basal conglomerate
		~~Paraunconformity~~~
Pei-piao series	Pu	Upper coal-bearing formation
	Pm	Main coal-bearing formation
	Pl	Pei-piao volcanic formation
		~~Unconformity~~~
Ordovician system		Limestone and quartzite formation

A. Limestone and Quartzite Formation

This formation consists of an alternation of quartzite and limestone, and forms the basement of the coal field. At the southeastern border of the coal field, it is in

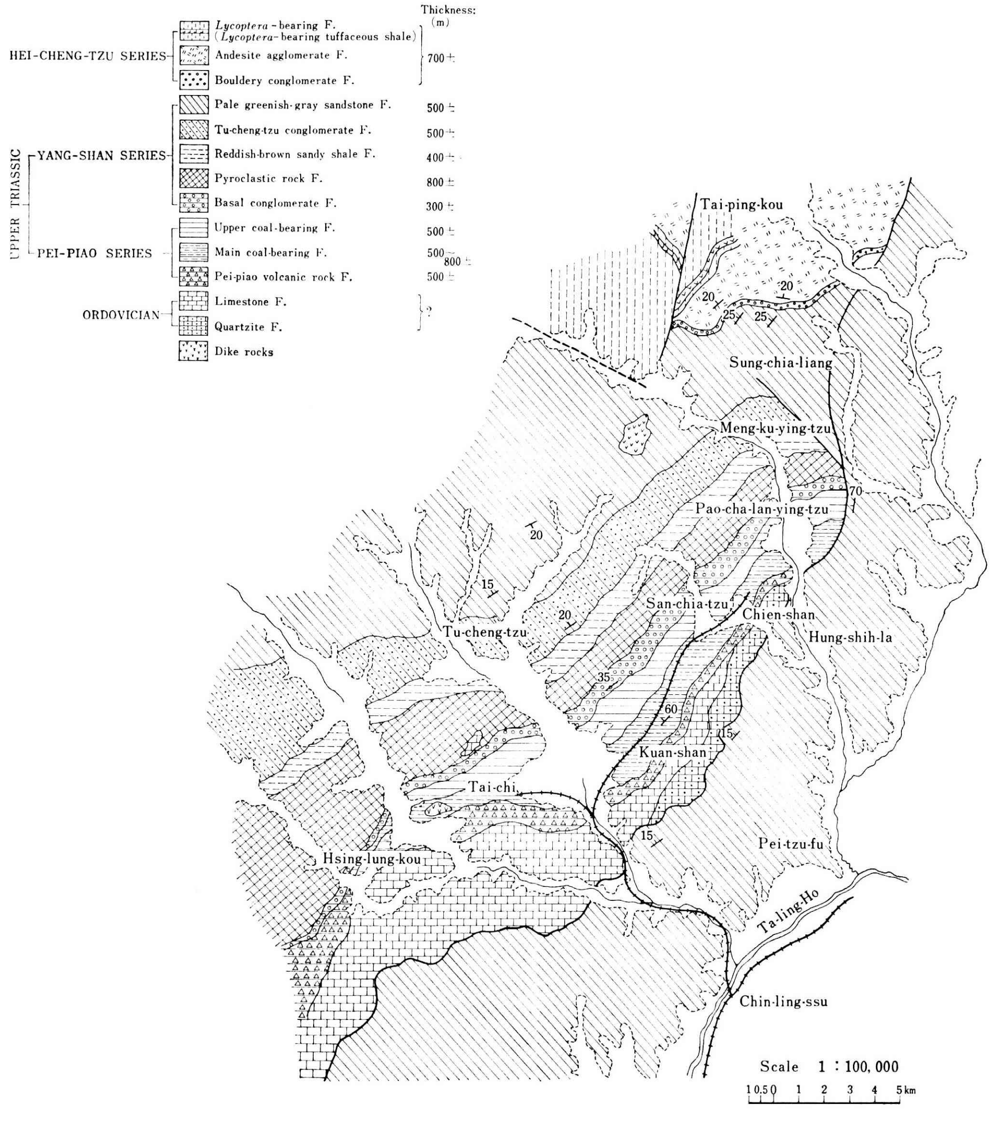

Fig. 1. Geological map of the Pei-piao coal field.

contact with the pale-green sandstone as the result at an overthrust fault. This fault forms the uppermost horizon of the Yang-shan series.

The central part of the overthrust fault dips gently, less than 15°, but it becomes considerably steeper toward the north and south. Quartzite is extremely rare. Only one exposure southeast of Chien-shan-tzu is known. It is generally grayish white and brownish gray. Limestone is generally dolomitic, with 20 percent MgO; some of it has become *Cryptozoon* limestone. *Maclurites bigsbyi* and *Armenoceras* sp., which indicate the Ordovician age were discovered in the formation. The formation was once thought to be Sinian, but the fossils proved it to be Ordovician.

B. Pei-piao Series

As stated above, it consists of three formations. Although it has been found in various localities along the Chin—Ku line, other than in the Pei-piao coal field, the name Pei-piao coal field lends itself to the type locality because it forms a most important chronological and stratigraphical unit in the study of coal-field structure of Manchuria.

(1) *Pei-piao Volcanic Formation (Pl)*. (Tan, H. C. G., 1926, Lower volcanic formation; Matsuzawa, I. 1939, Pei-piao volcanic formation). This formation stretches along the foot of the mountains composed of the Ordovician formations in a narrow area trending from northeast to southwest. Good exposures were observed in various places such as Chien-shan-tzu, Pei-piao and Sung-chia-cheng-tzu. The thickness is 450 m near Chien-shan-tzu and about 500 m near Pei-piao. No direct evidence is available regarding its relation to the Ordovician formation, but judging from the boring tests and the underground workings, it may be assumed that the formation directly underlies the principal coal measure, and unconformably overlies the Ordovician formation. The principal coal measures generally contain key plant fossils. Therefore, the age of the volcanic formation can also be determined with certain accuracy, in accordance with its relation to the stratigraphical sequence. From the available data it has been assumed to be the oldest Mesozoic volcanic rock in Manchuria.

(2) *Main Coal-bearing Formation (Pm)*. (Tan, H. C. G., 1926, Lower coal measure; Matsuzawa, I. 1939, Pei-piao coal measure). It conformably overlies the Pei-piao volcanic formation, and contains all the workable coal seams of the coal field. It consists of an alternation of shale, sandstone, conglomerate, and 9 coal seams. Shale is gray, gray black, or greenish gray, and is sandy or marly. It often contains plant fossils, and is rich in carbonaceous matter.

Sandstone is mainly medium- or coarse-grained, and bluish gray or grayish white. The weathered surface is light grayish yellow or dark yellow. Part of it grades into fine conglomerate.

Conglomerate alternates with the sandstone. The pebbles are well ground and their diameter varies from 1 to 3 inches. It is composed of pebbles of quartzite, granite, slate, and vein quartz, of which quartzite predominates. The pebbles have been cemented by dense siliceous sandstone. The most remarkable one is the basal conglomerate of the coal measure, which is fairly indurated and has a thickness ranging from 50 to 60 m near Chien-shan-tzu. It irregularly intercalates grayish-white, medium-grained, siliceous sandstone about 3 m thick. It directly overlies the Pei-piao volcanic formation, and a gradual transition takes place between it and the underlying agglomeratic conglomerate of the Pei-piao volcanic formation, so the relationship is assumed to be conformable. Plant fossils have been found mainly in the shaly parts of the coal measure, especially in the hanging wall of seam no. 4.

Fossils that were found in the coal measure are as follows: *Neocalamites carrerei* Zeiller. *N. hoerensis* Schimper, *Coniopteris hymenophylloides* Brongniart, *Clathropteris meniscoides* Brongniart, *Hausmannia* sp., *Cladophlebis haibrnensis* L. and H., *C. denticulata* Brongniart, *C. nebbensis* (Brongniart), *C. williamsoni* Brongniart, *Baiera gracilis* Bunbury, *Ginkgoites digitata* var, *huttoni* Seward, *G. sibirica* Heer, *Phoenicopsis* cfr. *manchurensis* Yabe and Oishi, *Czekanowskia vigida* Heer, *C. setacea* Heer, *Elatocladus* cfr. *tenerrima* Feistmantel, *Podozamites lanceolatus* L. and H. This coal measure has a thickness ranging from about 800 m around Pei-piao to about 500 m around Chien-shan-tzu.

(3) *Upper Coal-bearing Formation (Pu)*. (TAN, H. C. G., 1926, Upper coal measure; MATSUZAWA, I. 1939, Jehol coal measure). It overlies the principal coal measure, and consists of an alternation of sandstone and shale, with a conglomerate at the bottom.

There is a gradual transition between the conglomerate and the top layer of sandstone of the main coal-bearing formation which suggests continuous sedimentation. Furthermore, thin conglomerate is rarely found in the upper part. Thus, the relationship between the upper and main coal-bearing formations may be considered as a transitional conformity. The shale can be subdivided into light-gray and black shales. The former is generally muddy, but often becomes sandy.

The sandstone is medium- and coarse-grained, grayish, and has a banded structure. It is compact, and has an onion structure, as the sandy shale does, and intercalates massive coarse sandstone. The shale and sandstone are generally stratified in thin layers, repeating regular alternations.

The black shale is remarkably foliated, and is well developed around Chien-shan-tzu. It alternates with the other shale and sandstone. However, it gradually thins out and eventually disappears near Pei-piao. The conglomerate is best developed in the vicinity of Chien-shan-tzu. It consists mainly of medium-sized and fairly well-ground quartzite and granite pebbles. The conglomerate serves as a partition between the upper and main coal-bearing formations. Several impure coal seams about 20 cm thick intercalate the sandy shale. Therefore, the formation is named the upper coal-bearing formation. It was first called the upper coal-bearing formation by TAN, and later it was named the Jehol coal measure by MATSUZAWA. However, as the latter is a general name covering all of Jehol, it is now losing its stratigraphical meaning. Therefore, I have followed TAN's nomenclature. Plant fossils such as *Neocalamites hoerensis* Schimper, *Phoenicopsis* sp., and *Pityo-*

phyllum sp. have been discovered near the sandy shale that contains coal seams and in the black shale. In addition, *Corbicula* sp., and well-preserved insect fossils and fish scales have also been discovered. Total thickness of the coal measure is about 500 m.

C. YANG-SHAN SERIES

As previously stated, this series consists of four formations. It lies directly over the Pei-piao series, and is covered unconformably by the Upper Jurassic Hei-cheng-tzu series. A most significant feature of the series is the discovery of the footprint of *Jeholsauripus*. It was first discovered at Yang-shan, about 73 km south of Ch'ao-yang. I designated the series after the name of the locality.

(1) *Basal conglomerate* (Y_1). The basal conglomerate lies directly over the Pei-piao series, and occupies the basement of the Yang-shan series. The pebbles of the conglomerate are generally well-rounded or half-rounded boulders of granite, gneiss, and quartzite, usually the size of a man's head, but sometimes more than one meter in size. These boulders are compactly cemented by coarse sandstone, but not as compactly as the Pei-piao series. The conglomerate often contains thin beds or lenses of coarse sandstone, and the alternations of conglomerate and sandstone are repeated to the upper level, but generally are not sufficiently sorted. In like manner, volcanic detritus becomes a mixture near the top, and it grades into a pyroclastic bed.

The thickness of the formation varies greatly in different localities. Near Chien-shan-tzu it attains a thickness of as much as 300 m and to the south it is about 200 m. It nearly disappears around Tai-chi-ying-tzu. This conglomerate formation is associated with the pyroclastics to the top, and was named the Upper volcanic formation by TAN, MATSUZAWA included it in his Ma-chuan-tzu volcanic formation (Jehol volcanic formation). The relationship between the conglomerate and the underlying Pei-piao series is a parallel unconformity. There is no information on the discovery of fossils in both the conglomerate and the overlying pyroclastic formation. However, I found the following fossils in the siliceous shale that is intercalated in the upper part of the conglomerate, at a place west of Chien-shan-tzu. They are the plant fossils *Neccalamites hoerensis* Schimper, *Cladophlebis haibrnensis* L. and H., *Cladophlebis williamsoni* Brongniart, *Cladophlebis denticulata* Brongniart, *Coniopteris hymenophylloides* Brongniart, *Taeniopteris spatulata, Ginkyoides* sp., *Czekanowskia* sp., and *Pterophyllum* sp., and shell and insect fossils.

In addition, a zone rich in silicified wood, *Xenoxylon latiporosum* (Cramer) Gothan has been found in the tuff, which is very useful as a key bed. Thus, it is noteworthy that they have a considerable number of common facies, both in flora and fauna, with the Pei-piao series.

(2) *Pyroclastic rock formation* (Y_2). (TAN, H. C. G., 1926, Upper volcanic rock formation; MATSUZAWA, I. 1939, Jehol volcanic rock formation, Ma-chuan-tzu volcanic rock formation).

The lower limit of the formation is above the conglomerate where effusive volcanic rocks became rapidly prevalent, and its upper limit is marked by the beginning of the deposition of the reddish-brown sandy shale. Accordingly, the limits of both the upper and lower parts are transitional and are considerably ambiguous. In addition, the formation often intercalates agglomeratic and tuff, and both the upper and lower limits usually contain agglomeratic conglomerate. The volcanic rocks display quite regular transitional properties; in ascending order they are, basalt—andesite—dacite or more acidic liparite (ASANO, G). The effusion are initiated by peridote, basalt, quartz basalt and hyalocrystalline basalt, followed by augite andesite and two-pyroxene andesite which were erupted in such a manner that they became alternated with pyroclastic rocks. Then, dacite containing augite and hornblende was erupted, and finally liparite was produced. The thickness of the formation is about 800 m.

(3) *Reddish-brown Sandy Shale Formation* (Y_3). This formation consists mainly of reddish-brown sandy shale, with alternations of agglomerate, agglomeratic-conglomerate, and sandstone. It is a transition zone between the pyroclastic rock formation and the T'u-cheng-tzu conglomerate formation, which will be described later.

The formation is valuable as a key bed because of its peculiar color. It is generally tuffaceous with frequent intercalations of bedded or lenticular calcareous masses. The agglomeratic property of the upper part of the conglomerate contained in the formation decreases gradually, and the conglomerate becomes the T'u-cheng-tzu conglomerate. At the same time, the reddish-brown sandy shale that alternates with the agglomeratic conglomerate gradually decreases in thickness and tapers away. A noteworthy point is that the overlying agglomeratic conglomerate contains a small amount of egg-sized granite pebbles. The total thickness of the formation is not certain, but it is inferred to be about 400 m.

(4) *T'u-ch'eng-tzu Conglomerate Formation* (Y_4). The conglomerate formation extends throughout the northwest area of the Pei-piao coal field, and also in the southeast area from Chin-ling-ssu to both sides of the Chin—Ku line (Chin-hsien —Ku-pei-kou). The best exposures can be observed near T'u-cheng-tzu and Chin-ling-ssu. I use in this paper the name T'u-ch'eng-tzu conglomerate which is conventionally used by the engineers of the Pei-piao coal mine. The aspect of the lower limit has already been discussed in the preceding section. The upper limit has been placed on a horizon where the size of the constituent pebbles gradually becomes smaller, and the strata become abundant in pebbly sandstone and sandstone. This means merely that there is a transitional boundary between horizons with different petrographical properties. These pebbles are generally half-rounded and the majority are egg size, but larger boulders can also be found. They consist mainly of granite, quartzite, volcanic rocks, and rarely limestone.

The cementing material is fairly compact indurated medium-grained sandstone, and the rock as a whole is massive. The conglomerate formation is frequently fine-grained, and often intercalates grayish-white or reddish-white medium-grained sandstone. The thickness may vary, as the upper and lower limits have settled artificially, but it has been roughly estimated at 500 m.

(5) *Pale Greenish-gray sandstone Formation* (Y_5). This formation, probably Upper Triassic, consists mainly of the sandstone that graded from the foregoing T'u-ch'eng-tzu formation, and is unconformably overlain by the Hei-cheng-tzu series. It extends mainly to the eastern part of the Pei-piao coal field, and in the vicinity of Nan-ling, along the Chin—Ku line. In the eastern area of the Pei-piao coal field, the formation has been overlain by the Ordovician formation as the result of an overthrust fault. The horizon near the lower limit contains a grayish-white medium-grained sandstone with a mixture of conglomerate or pebbly sandstone. The upper half is occupied mainly by pale-greenish or reddish-gray medium- or fine-grained sandstone, with rare intercalations of tuffaceous sandstone. The sandstone is generally compact, and has a peculiar appearance due to its thick aspect.

A characteristic of the sandstone is its remarkable cross-bedding. It can be seen both microscopically and megascopically that the rock consists of well-worn oölitic sand grains, and it can be assumed that the rock was formed under semi-desert conditions. Another special characteristic of the formation is the discovery of fossil footprints of *Jeholsauripus satoi* Yabe, Inai & Shikama, *Jeholosauripus gigas* Endo, Nishida & Shikama (M.S.).

a. Stratigraphical Relationship between the Pei-piao and the Yang-shan Series

There is an abrupt change in rock facies between the basal conglomerate of the Yang-shan series and the underlying Pei-piao series, and a fairly abrupt erosion surface was also found there. The relationship may be inferred as a paraunconformity.

The upper coal-bearing bed is covered by the basal conglomerate of the Yang-shan series at Chien-shan-tzu, Pei-piao, and Tai-chi-ying-tzu. However, in the southern part of the coal field, or around Hsing-lung-kou, the conglomerate formation directly overlies the main coal-bearing formation and the Pei-piao volcanic rock formation. Accordingly, a clino-unconformity might exist between the two series, but it could be more reasonably interpreted as a paraunconformity inasmuch as the rock facies of the Pei-piao series change remarkably to the northeast and southwest.

D. Hei-cheng-tzu Series

This series extends around Hsia-sun-chia-liang, about 4 km north of Meng-ku-ying-tzu-ts'un of the Pei-piao coal field.

A large bouldery conglomerate 30 m thick forms the basement and covers the underlying pale-green sandstone formation. The succession of strata, in ascending order, is large bouldery conglomerate, andesitic agglomerate formation, and *Lycoptera*-bearing formation, formed principally of volcanic detritus. In the upper part of the formation there are two beds of grayish-white, fissile, tuffaceous shale about 25 m thick, with many fossils including *Lycoptera davidi* Sauvage, *Estheria mid-dendorffii* R. Jones, and insects. The total thickness probably is not less than 700 m. From the paleontological standpoint the formation may be correlated with the Lower Fu-hsin series, or the I-hsien volcanic rock formation of the Fu-hsin coal field.

a. Stratigraphical Relationship between the Yang-shan and the Hei-cheng-tzu Series

As previously stated, the Hei-cheng-tzu series covers the pale-green sandstone formation, or the uppermost part of the Yang-shan series. The relationship can most clearly be observed at Hsia-sun-chia-wan-tzu, where there are remarkable differences in both strike and dip. A clear clinounconformity has been observed in the mode of distribution of the two series. Crustal movement probably took place after the deposition of the Yang-shan series and before the deposition of Hei-cheng-tzu series. The author regarded the movement as the second step of the Yen-shan movement, and as far the Pei-piao coal field is concerned, the movement was a certain block movement.

III. Coal Seams and Properties of the Coal

All the coal seams that have been worked in the Pei-piao coal field are contained in the Main coal-bearing formation. There are 3–14 coal seams in the Upper coalbearing formation.

The number of coal seams differs with each block, and each coal seam differs in thickness and extent. Such a phenomenon could also be inferred from the sedimentation facies of the Pei-piao series, as stated previously. Accordingly, it is extremely difficult to correlate the coal seams throughout the coal field, and to make general statements on the number, thickness, mutual relationships, and extent of the coal seams. However, certain coal seams such as San-tsao (no. 3 seam) and Ssu-tsao (no. 4 seam) can be traced throughout the coal field. Variations in the general strike as measured successively from the northeast to the southwest are as follows: the Chien-shan-tzu block strikes N50°–70°E, the Pei-piao block N60°–75°E, the Tai-chi-ying-tzu block E–W, or N70°–75°W, and the Hsing-lung-kou block N40°–45°E. The dip is generally N40°–50°NW, but often less than a 35° angle. Midway between Chien-shan-tzu and Pei-piao the dip angle is steeper than 70°. There are 7 workable coal seams in the Chien-shan-tzu block, the northeastern part of the coal field, and there are 3 workable seams in the Pei-piao (Kuan-shan) block in the central part of the coal field. There are three or four principal ones which vary in thickness from 1.2 m to 3.5 m, and often attain a thickness of 5 m.

A description of the coal seams of the Pei-piao block, which is the representative and principal part of the coal field, follows. The Kuan-shan shaft cuts through 16 coal seams, 8 of which have been workable. They are as follows, in descending order: no. 2 seam (thin and unworkable), no. 3 seam (4.75 m thick, with partings;

the principal seam), no. 4 seam (1.98 m thick, no partings; the principal seam), no. 5-A seam (1.27 m thick, no partings), no. 5-B seam (1.30 m thick, no partings), no. 6 seam (1.00 m thick, no partings), no. 7 seam (1.27 m thick, no partings), and no. 8 seam (1.06 m thick, with partings). Of the 8 workable seams named above, seams 3 and 4 are the principal ones in the area. The most important coal seams throughout the entire coal field are only two or three. The quality of coal seam differs according to locality, and may even differ in one and the same seam. The coal seams of the central block near Pei-piao (Kuan-shan) generally contain high-grade bituminous coal and produce much lustrous lump coal, and that of the northeast block, or the Chien-shan-tzu block shows a defect that a large part of the coal is slack coal. The latter is due to the effect of strong crustal disturbances, and block is not very suitable for mining. The seams of the southwest block or around Tai-chi-ying-tzu, however, have not been disturbed, but the number of workable seams decreases. Analyses of the coal seams of the Kuan-shan shaft, Pei-piao block, are as follows:

	Moisture content (%)	Volatile matter (%)	Fixed carbon (%)	Ash (%)	Sulfur (%)	Heat value (cal)	Coking property
A	1.45	35.44	55.75	7.16	0.73	6,975	Coking
B	2.05	38.45	46.59	12.91	0.55	6,837	Coking
C	1.45	46.53	45.43	6.59	0.26	7,788	Coking
D	2.12	36.42	46.71	14.42	0.52	6,918	Coking

Note: Analyses by the Central Laboratory, South Manchuria Railway Co. (1929).

A rough estimate of the known coal reserves of the main coal-bearing area of the coal field that extends from the northeastern part of Chien-shan-tzu to the south-western part of Tai-chi-ying-tzu is 40 million tons. Coal production in 1943 was roughly 1,000 tons per day at Chien-shan-tzu, 3,000 tons per day at Kuan-shan, and 1,000 tons per day at Tai-chi-ying-tzu.

IV. The Chronological Correlation between the Pei-piao and the Yang-shan Series

I would like to discuss the geologic age of the Pei-piao and the Yang-shan series as the problem is important and interesting, but this would require a lengthy dissertation. Therefore, only an outline will be given here for reference. The first point to be considered is the flora found in the Pei-piao series.

About 17 species of plants have been found, of which two or three are important for the determination of geologic age. Judging from its aspect, the Pei-piao flora could be the traditional Rhaeto-Liassic flora. However, a new chronological conclusion has been attained in the Far East. The age of the strata, which was considered to be Rhaeto-Liassic base on its floral aspect, should be revised to the older Upper Triassic because of its faunal and stratigraphical aspects. Examples are the Nariha flora of Japan, Hongey flora of French Indochina, and the Mongugai flora of Siberia.

The Pei-piao series has also fallen into the same category because of the discovery of *Jeholosauripus* from the Yang-shan series, and the subsequent revision to the Upper Triassic. The Yang-shan series, as well as the Pei-piao series, contains a number of plant fossils and some important common species are found in both. However, evidence of the living conditions of the flora from the former indicates a more arid climate than the latter.

Jeholosauripus, the fossil footprint that characterizes the Yang-shan series, closely resembles the Grallator of Grallatoridae from the Connecticut Valley U.S.A. Based on this fact the Yang-shan series can be correlated with the Newark series. Accordingly, it is possibly Triassic.

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Hao-kang Coal Field, Sankiang Province Manchuria

Shigeo SAKAGUCHI

I. Locality, Transportation and Topography

The Hao-kang coal field is located in Hao-li Hsien, Sankiang Province, with Hsing-shan village as the center, and extends for some 120 km NNE–SSW from Lo-pei near the boundary between the Soviet Union and Manchuria on the north to the Sung-hua Chiang, or the Sungari River, passing through the plains west of the town of Hao-li-kang on the south.

The description here is limited to an area 30 km long and 4.5 km wide where the coal seams are actually recognized due to military operations in the northern part of the coal field during my investigation in 1940, and because a heavy mantle of surface sediments in the southern section was so thick that it could not be geologically determined at all.

The maximum width of the coal-bearing beds is known to be some 4.5 km in the vicinity of Hsing-shan village. The Hsing-shan head office of the Hao-kang coal mine is located at long. 130°18′E and lat. 47°20′N.

A small railway is operated for transporting coal and other materials some 56 km between the Lien-chian-kou railway station of the Chia-mu-ssu—Sui-hua railway line and Hsing-shan, the main coal mine.

Lien-shan-chieng station is located on the northern bank of the Sungari River, just opposite the city of Chia-mu-ssu. The station is not only a land transportation center but is also useful in summer as a navigation harbor on the Sungari River, especially for the city of Harbin in the upper reaches, although all transportation facilities are closed the other half of the year except for some travel by sledge.

The west side of the coal field is bounded by several fairly high hills which extend from NE to SW, while the east side of the coal field is surrounded by a vast area of swamps along the Amur and Sungari rivers except for a few small hills as islets.

There are several streamlets in the coal field, such as the Wu-tun Ho, Shih-tou Ho, Hao-li Ho, and the A-ling-ta Ho all originating generally from hills to the northwest and running SE or S to empty into the Sungari River. These streamlets

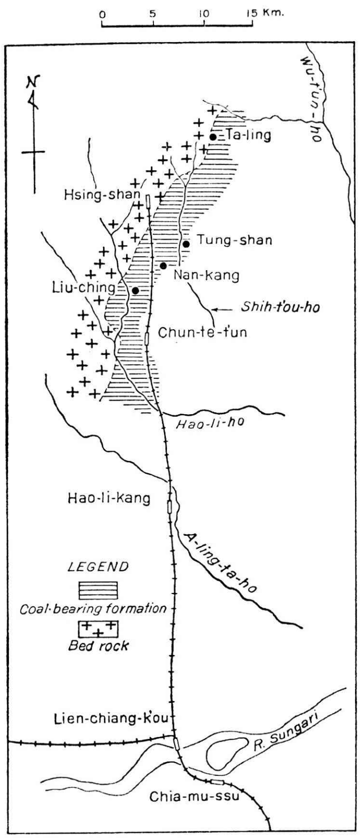

Fig. 1. Map showing position of the Hao-kang coal field.

usually meander remarkably in the alluvial sediments of the district. Almost all alluvial plains along these streamlets are often completely covered by water during floods in the summer, and sometimes form enornous swamplands.

II. Geology

Owing to the thick cover of surface sediments in one part of the coal field, the general geology of the district is not clear yet though some natural exposures of the series above the coal-bearing strata exist.

The principal formations of the coal-bearing strata can be seen only in open-pits, or along clearings for roads and railroads, or by prospecting boring; there were several investigations on this subject before my studies in 1939 and 1940.

The geology of the coal field is divided as follows, in descending order:

A. Alluvial sediments
B. Nan-kang conglomerate formation
C. Hsun-te pyroclastic formation

D. Hao-kang series
E. Granite and gneiss
F. Limestone

A. Alluvial Sediments

The alluvial sediments are distributed mainly in the flood plains along each streamlet mentioned above. They are mostly arkose sand and gravel derived from granite. Some thin clay beds are sometimes interbedded in these sediments. The surface of the sediments is usually covered with black earth (chernozem). The thickness of the alluvial sediments increases more to the south of the coal field than to the north, *viz.*, it is estimated at 10 m near Hsing-shan village, 80 m in the swampland west of Hsun-te-tun, and over 100 m south of the town of Hao-li-kang.

A fossil mammal, *Elephas mammonteus*, was found in a sand bed 7 m beneath the ground surface along the eastern wall of an open-pit of No. 2 coal seam.

B. Nan-kang Conglomerate Formation

The Nan-kang conglomerate formation covers the upper and middle coal-bearing strata of the Hao-kang series. It forms hills somewhat higher than the neighboring ground. A quarry at Nan-kang, south of Hsing-shan, is the type locality of the conglomerate, where it is excavated for ballast. The general thickness of the formation is about 100 m here.

The formation strikes generally N–S and dips about 5°E. It consists principally of conglomerate interbedded with lenticular sandstone.

The pebbles constituting the conglomerate are variable in size, usually smaller than a human skull. They are mainly liparite, sandstone, granite, porphyrite and quartz, of which the first predominates occupying more than 50% of the constituents. All of the pebbles are remarkably rounded due to erosion and corrosion.

The direct relation between the conglomerate formation and the underlying Hsun-te pyroclastic formation is not clear. However, it can be assumed that the conglomerate formation may lie with a clinounconformity on the pyroclastic formation, because of the difference in dip of the two series; the former dips only 5° to the east, while the latter dips 20° in the same direction, although the strike of both series is similar at the same locality.

C. Hsun-te Pyroclastic Formation

This formation directly covers the Hao-kang series and tells us the period of volcanic activities in the Hao-kang region. All sediments of the Hsun-te pyroclastic formation are nothing but the results of activities of volcanoes in this region; a fact which is proved by the abundant volcanic ejecta in most of the formation.

The formation can be divided into two members, sandstone in the upper part and andesite in the lower part.

The sandstone member, over 500 m thick, crops out in the northeast of Hsun-te-tun. It consists chiefly of coarse-grained yellowish brown sandstone, accompanied by conglomerate and sandy conglomerate, and is intercalated with a thin coal seam several centimeters thick. The upper limit of this member remains unknown on account of the heavy mantle of sediments.

The andesite member is distributed at a small hill south of Ta-ling and in the northeast of Hsun-te-tun. It consists of gray or grayish black andesite, andesitic agglomerate, tuff, tuffaceous conglomerate, black shale, grayish white sandstone, grayish yellow conglomeratic sandstone and shale; the tuffaceous conglomerate generally contains fist-size gravel of quartz and granite, sometimes with boulders of granite. White liparite tuff occurs in the upper portion of the member. The black shale yields fossil plants, such as *Brachyphyllum* sp., and bivalves. The gray andesite usually contains black hornblende as phenocrysts in the hard and compact groundmass.

The direct relation between the Hao-Kang series and the Hsun-te pyroclastic formation could not be observed. There may exist an unconformity between the two but the structural discrepancy is negligible.

The geologic age of this formation may be Upper Jurassic or Lower Cretaceous, because the age of the underlying Hao-kang series is at least Upper Jurassic as indicated by some index fossils and is evidently correlated with formations of northeastern and central Manchuria.

D. Hao-kang Series

The name Hao-kang series is used for the Jurassic formations of northern Manchuria. The Hao-kang coal field is the type locality of this series. It is thought to be a series of formations which have accumulated continuously without any interruption.

The series can be divided into three coal-bearing formations, the upper, the middle, and the lower. Sandstone commonly predominates, but the lower and the upper formations are locally intercalated with conglomerate.

Productive coal seams occur mostly in the middle formation; only one coal seam is workable in the lower formation though there are several thin coal seams; no minable seams were found in the upper formation at the time of the investigation.

The abundance of fossil plants corresponds to the productivity of coal seams, that is, the abundance of fossils coincides with the richness of coal seams, as in the middle formation, and the scarcity of fossils indicates fewer and less workable coal seams, as in the upper and lower formations.

The upper formation is separated from the middle formation by the top of No. 1 coal seem of the middle formation, which, in turn, is separated from the lower formation by the white sandstone which lies between No. 5 and No. 6 coal seams. The upper formation is generally yellowish gray to yellowish brown, while the middle formation is predominantly grayish white. The sandstones near the coal seams are remarkably white.

Upper coal-bearing formation:—Only a part of this formation was investigated by means of boring, owing mainly to poor exposures and to the lack of any productive coal seams in it. The formation is composed mostly of coarse-grained sandstone and conglomeratic sandstone, with a total thickness about 500 m. A small exposure of the upper part of this formation along the Shih-tou Ho exhibits some impressions of fossil plants in the yellowish gray conglomeratic sandstone. The boring cores revealed that the middle and lower parts of this formation are composed of grayish yellow sandstone, conglomerate, conglomeratic sandstone and shale, with a thin lenticular coal seam.

Middle coal-bearing formation:—There are ten coal seams in the Hao-kang coal field, and five of them, No. 1 to No. 5, occur in the middle coal-bearing formation. No. 2 through No. 5 are thick and workable. The formation consists chiefly of yellowish gray or grayish white sandstone, interbedded with white arkose sandstone or white tuff. Plant fossils are abundant in the horizons above and below the productive coal seams.

No. 1 coal seam:—Its properties are only partially known as a result of some prospecting borings, and coal production has not yet begun at this coal seam.

No. 2 coal seam:—The succession of beds observed in the open pit is as follows in descending order: Dark grayish shale; yellow coarse-grained sandstone; alternation of yellow sandstone and gray sandstone; a thin coal seam; gray shale; a thin coal seam; yellow sandstone; No. 2 coal seam.

The following plant fossils are found in the gray shale:

Coniopteris hymenophylloides (BRONGN)
Onychiopsis elongata (GEYLER)
Sphenopteris suessi (KRASSER)
Sph. sp.

Of these, *Onychiopsis* and *Sphenopteris* are especially abundant. *Podozamites lanceolatus* (L. et H.) is found to aggregate at about 10 m above this horizon.

No. 3 coal seam:—The following plant fossils are found in sandstone and shale above No. 3 coal seam and in a parting of the coal seam as observed in the open pit:

Cladophlebis denticulata var. *tuberculata* THOMAS
Cl. lobifolia (PHILLIPS)
Sphenopteris suessi (KRASSER)
Taniopteris sp.
Baiera gracilis BUNBURY et BEAN (MS)
Eladocladus manchurica (YOKOYAMA)
Pityophyllum lindstroemi NATH.
Podozamites sp.
Carpolithus sp.

No. 4 coal seam:—No fossil has been reported from this coal seam yet. The thickness of the coal seam is over 7 m with a parting of sandy shale, about 0.2 m thick, in the middle. The hanging wall is yellow sandstone, but the footwall is not known.

No. 5 coal seam:—White arkose sandstone forms the hanging wall and the footwall of the coal seam. The following plant fossils are found in the hanging wall:

Equisetites sp.
Cladophlebis denticulata (BRONGN.)
Cl. lobifolia (PHILLIPS)
Cl. nebbensis
Coniopteris cfr. *hymenophylloides*
Co. sp.
Sphenopteris suessi (KRASSER)
Sph. sp.
Nilssonia sinensis YABE et OISHI
Nil.? sp.
Ginkgoites sibirica (HEER)
G. digitata (BRONGN.)
Baiera manchurica YABE et OISHI
Czekanowskia rigida HEER
Phoenicopsis sp.
Stenorachis sp.
Elatocladus manchurica (YOKOYAMA)
El. submanchurica YABE et OISHI
El. sp.
Elatides sp.
Pityophyllum longifolium (NATH.)
Pityostrobus Endo-riujii OISHI
Podozamites lanceolatus (L. et H.)

Lower coal-bearing formation:—The formation is composed mainly of yellow to grayish brown arkose sandstone and gray conglomerate, the latter contains pebbles of quartz porphyry or liparite, 2 to 10 cm in diameter. Conglomerate predominates in the north of Hsing-shan, while sandstone is the leading rock in the south, and no basal conglomerate is found in the vicinity of Hsing-shan. The exact boundary between the formation and the basement (probably granite) is hardly determined on account of the thick surface soil, so that prospecting by means of drilling is necessary. Even by trenching, it is difficult to discriminate the weathered zone of the granite from the weathered basal sandstone of the lower coal-bearing formation. It is probable that the relation between this formation and the basement is locally unconformable and locally in fault-contact.

No. 6 coal seam:—This is the thickest coal seam in the Hao-kang coal field. It is over 20 m thick near Hsing-shan and 13.5 m in the Liu-ching district to the south. The following plant fossils are found in the pit at Tou-tao-kou:

Equisetites sp.
Cladophlebis denticulata (BRONGN.)
Otozamites sp.
Czekanowskia rigida HEER
Pityophyllum longifolium (NATH.)

Podozamites lanceolatus (L. et H.)
Pinites sp.

There are four more coal seams, Nos. 7, 8, 9 and 10, beneath No. 6, but in the Hao-kang coal field they are too thin to be worked. The coal seams are intercalated with yellow arkose sandstone and conglomerate. *Equisetites* sp., *Cladophlebis* cf. *lobifolia* (PHILLIPS), *Phoenicopsis* sp. and other plant fossils have been collected at the prospecting site of No. 8 coal seam at Tou-tao-kou.

The geologic age of the Hao-kang series should be Upper Jurassic, corresponding to the coal-bearing beds of the Mi-shan coal field in northeastern Manchuria and those of the Fu-hsin coal field in southwestern Manchuria, on the basis of the *Onichiopsis-Sphenopteris* flora which is common among the three coal fields.

E. GRANITE AND GNEISS

Granite and gneiss are distributed in the western hills of the Hao-kang coal field. Their boundary with the coal-bearing beds is easily defined in the north because of the characteristic topography, but in the southern area the boundary is inferred only by boring, since the granite and gneiss are distributed even beneath the swamps along the Hao-li Ho, as observed at Hsun-te-tun.

The gneiss is coarse-grained granite-gneiss and crops out at the Shih-hui-yao quarry. It sometimes contains impure limestone as xenoliths which have been contact-metamorphosed into marble. The gneiss is also accompanied by quartz diorite. All these rocks with granite make up the basement of the coal-bearing formations in the Hao-kang district.

F. LIMESTONE

Limestone crops out at a point 1.5 km NNW of the Hao-kang coal mine office in an extremely small area, occurring mostly as small masses enclosed in the granite and the gneiss by which it was metamorphosed into saccharoidal white crystalline limestone (marble). Under the microscope the limestone is found to consist chiefly of white crystals of calcite, less than 1 cm in diameter.

III. Geologic Structure

The general strike of the Hao-kang series and the Hsun-te pyroclastic formation is N20°E, dipping some 20° to the southeast, showing a monoclinal structure. The overlying Nan-kang conglomerate formation dips easterly at an angle of some 5°, much gentler in dip than is the underlying series. The relation between these two seems to be clino-unconformable.

There are two groups of faults in the Hao-kang coal field; one is the strike-fault and the other is the dip-fault. The former is rather rare, but is exemplified by the Shih-tou-ho fault that runs roughly N–S along the Shih-tou Ho and cuts the coal-bearing beds. On account of this fault, the principal coal seams make their appearance repeatedly near Tung-shan in the east.

By the group of dip-faults the Hao-kang coal field can be divided into the following five sections:

Ta-ling Section:—It comprises the area north of the Ta-ling fault which extends NW from Liu-tao-kou in the upper reaches of the Shih-tou Ho. The northern limit of this area remains unknown.

Hsing-shan Section:—This is an area trending E–W some 8 km between the Nan-kang fault, which runs E–W through the railroad cut at Nan-kang, and the Ta-ling fault. This section comprises four coal mines; Ta-ling, Hsing-shan, Tung-shan, and Nan-kang.

Liu-ching Section:—This is an area between the Nan-kang fault and the so-called No. 6 fault which runs E–W in the vicinity of No. 6 signal station on the railroad. The E–W length of this area is at least 5.5 km. The Liu-ching coal mine is located in this section.

Hsun-te Section:—The area of this section is 6.5 km E–W and lies between No. 6 fault and the Hao-li-ho fault of E–W trend passing through Hsun-te station. Existence of coal-bearing beds has been confirmed by boring, but exploitation is not started as yet, on account of the thick surface soil.

Hao-li Section:—The section comprises an unsurveyed area south of the Hao-li-ho fault. However, existence of at least one coal seam, some 5 m thick, has been confirmed in the river bed of the Hao-li Ho, west of Hsun-te-tun.

IV. Coal Seams, Reserves and Properties

The mode of occurrence of coal in the Hao-kang coal field is described below, mainly on the basis of investigations by Uchino and Bessho (1935) of the Geological Institute, South Manchuria Railway Company. The materials are those from the Hsing-shan, Tung-shan and Ta-ling areas, excluding those of the area south of Nan-kang where detailed prospecting has been done later.

The thickness of each coal seam at the Hsing-shan and Tung-shan coal mines is as follows:

Coal seam	Thickness (m)
East No. 1	13.3
East No. 2	7.9
East No. 3	5.4
No. 2	5.8
Coal seam below No. 2	3.2
No. 3	7.7
No. 4	4.1
No. 5	5.6
No. 6	13.5
No. 7	3.7
No. 8	3.6
No. 9	2.6

Coal seams No. 2 to No. 6 are being worked at the Hsing-shan coal mine. No. 7 to No. 10 are not productive. Seams East Nos. 1, 2 and 3 are those at the Tung-shan coal mine, and probably correspond to Nos. 2, 3 and 4 coal seams of the Hsing-shan coal mine due to the Shih-tou-ho fault, that is, No. 2 of Hsing-shan corresponds to East No. 1, and No. 3 corresponds to East No. 2, and so on.

The mode of occurrence of the coal seams of the Nan-kang coal mine is quite similar to that of the Tung-shan coal mine. At the Liu-ching coal mine No. 6 coal seam is as thick as 13.5 m and other seams cannot be thinner than those in the Hsing-shan area. If my memory serves me right, the apparent thickness of some coal seams determined by test boring in the Hsun-te area was 11 m for No. 5 coal seam, 4 m for No. 4 and 8 m for No. 3. In the Hao-li area only one coal seam, about 5 m thick, is known.

In 1935 Uchino and Bessho estimated the reserves of coal in the Hsing-shan, Tung-shan and Ta-ling areas at 644 million tons. The reserves were calculated again in 1944 by the Committee of Investigation of Coal Reserves in Manchuria. In the calculation the Hsun-te and Liu-ching areas were included, and the total amount, including ascertained, inferred and expected reserves, was estimated at 1,700 million tons.

Representative coals of the Hao-kang coal field were analyzed by the Central Laboratory of the South Manchuria Railway Company, with the result as follows:

Coal seam	Moisture (%)	Ash (%)	Volatile matter (%)	Fixed carbon (%)	Sulphur (%)	Coking power	Calorie
South No. 2	2.13	10.84	33.76	53.36	0.44	Coking	7,120
North No. 2	1.94	3.25	39.28	52.53	0.23	〃	7,600
No. 3	2.24	8.03	34.72	55.01	0.21	〃	7,370
No. 4	1.58	34.26	25.72	38.44	0.23	〃	5,090
No. 5 (lower)	1.62	7.70	38.98	51.70	0.24	〃	7,510
No. 6 (upper)	1.42	7.77	34.49	56.23	1.02	〃	7,530

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Magnesite Deposits in the Districts of Ta-shih-chiao and Hai-cheng, Manchuria

Keiji UETANI

I. Introduction

Existence of magnesite deposits in Manchuria became known in 1913 when YOSHIZAWA, a chemist at the Central Laboratory of the South Manchuria Railway Company collected magnesite ore at Chuan-shan-tzu in Kai-ping county, Mukden Province. Subsequently, the Geological Institute of the South Manchuria Railway Company, the Geological Survey of Manchoukuo and the Manchuria Mining Development Company carried out geological survey and discovered numerous deposits of magnesite in such places as the Ta-shih-chiao and Hai-cheng districts (Niu-hsin-shan to Hei-shan) of Mukden Province, Ma-chou of Shang-nien in Fu-shun county, Wa-fang-tien in Hsiu-yen county, An-tung Province, Hei-lao-wu-shih and Hsiao-fang-shen in An-tung county, An-tung Province, in addition to the above-mentioned Chuan-shan-tzu. The deposits, especially in Ta-shih-chiao and Hai-cheng, were found to surpass, in both quality and quantity, the magnesite deposits in Germany, Austria and Italy which were believed to rank as top in the world. Thus, magnesite became one of Manchuria's largest products, along with soybeans and coal.

II. Location and Transportation

Distribution of the magnesite deposits in the Ta-shih-chiao—Hai-cheng districts extends over three counties, Kai-ping, Hai-cheng and Liao-yang, of Mukden Province. The Niu-hsin-shan deposit located about 7.5 km southwest of Ta-shih-chiao station marks the western end of the distribution area. Starting from Niu-hsin-shan the magnesite deposits extend N70°E for about 70 km with a maximum width 4 km. Known for magnesite deposit are; Pai-hu-shan, Hung-chi-shan, Kao-li-cheng-shan, Hou-pai-chai-tzu, Kuan-ma-shan, Sheng-shui-ssu, Hsiao-sheng-shui-ssu, Hsiao-kao-chuan-tun, Hsiao-kao-chuan-tun, Ping-erh-fang, Ching-shan-pai, Shui-chuan, Ching-shan-ssu, Chia-chia-pu-tzu, Hsia-fang-shen, Chin-chia-pu-tzu, Yang-chia-tien, Li-shu-kou, Hung-tu-ling-tzu, Fan-le-ma-yu, Hsi-

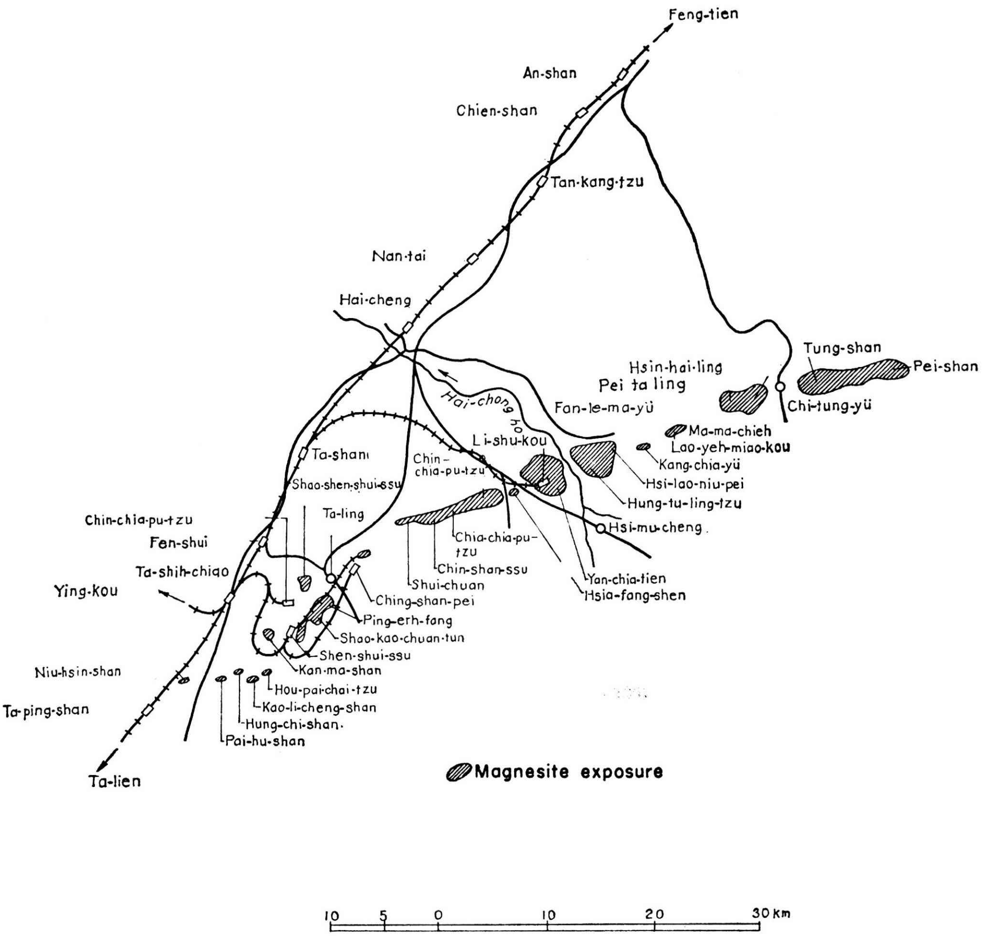

Fig. 1. Magnesite deposits area in Ta-shih-chiao, Hai-cheng district.

lao-niu-pei, Kang-chia-yu, Lao-yeh-miao-kou, Ma-ma-chieh, Pei-ta-ling, Hsin-kai-ling, Tung-shan and Hei-shan.

The Lien-ching Railway runs along the western margin of these deposits in a NE–SW direction, with such stations as Ta-ping-shan, Ta-shih-chiao, Fen-shui, Ta-shan, Hai-cheng, Nan-tai, Tang-kang-tzu, Chien-shan and An-shan. For transportation of ore, there are the branch railways, belonging to the South Manchuria Railway Company, between Ta-shih-chiao station and the Ta-shih-chiao plant for a distance of 1.5 km, and from the Ta-shih-chiao station to the Sheng-shui-ssu plant and to the Ching-shan-pai mine for 20 km; the electrified branch railway of the South Manchuria Mining Company between the Sheng-shui-ssu plant and the Hsiao-sheng-shui-ssu mine for 2 km; the branch railway of the Manchuria Talc Industry Company between Ta-shan station and the Yang-chia-tien mine for 28 km; the cablecar between the Sheng-shui-ssu plant and the

Ching-shan-pai mine for 8 km. From the highway between Hai-cheng station and Hsi-mu-cheng a truck road branches off to the Chin-tzu-pu-tzu mine. A truck road runs also from Fen-shui station to Hai-cheng station via Ta-ling, from Hai-cheng station to Fen-le-ma-yu, and from An-shan station to Chi-tung-yu.

Thus, the transportation between the sites of ore deposits and the Lien-ching Railway is convenient, and the ore is carried from those stations to the Ta-lien and Ying-kou ports.

III. Topography and General Geology

A. Topography

The area reported on is located on the western slope of the Liao-tung backbone range which trends in the Sinian direction, and has old or mature-stage topography.

The ridge of the range, starting from Niu-hsin-shan in the west and stretching roughly in a N70°E direction, is composed largely of dolomite and magnesite. The western part of the range is hilly land, but the range becomes higher and steeper toward the east. In the eastern part the southern slope is gentler than the northern slope. The land along the Lien-ching Railway has been dissected for the most part, leaving behind monadnocks in places.

Few of the drainage systems are notable. The Hai-cheng River, the Pa-li-ho and its tributaries (all being branch streams of the Liao-ho) flow through the central part of the area, and the western part is drained by the Ching-ho. They flow either parallel to or at right angles with the strike of the strata.

B. Geology

Geology of the area is represented by the Liaoho system, named by Saito (1937, 1938, 1943), comprising metamorphic rocks and sedimentary rocks of Archean age. The Liaoho system is divided into three parts, the upper (Kaiping series), the middle (Tashihchiao series) and the lower.

The upper and lower parts are composed chiefly of phyllite, locally accompanied by injection gneiss, mica schist and talc schist. The middle part is mostly dolomite containing *Collenia*-like fossils(?), and is intercalated with phyllite, sericite-chlorite schist and talc schist, striking N 60–90°E and dipping 30–50°S. These rocks are unconformably covered by quartzite of the Proterozoic Sinian system which is locally exposed on the ground surface. The Quaternary sediments, consisting of loess, sand and gravel, are distributed along the rivers and at the foot of the mountains.

Representative igneous rocks are granites. Small exposures of lamprophyre dikes are found in places. Most of the granites are gray, grayish white or pink granite gneiss which locally becomes dioritic. Where the granites intrude the Liaoho system, injection gneiss has been formed. Judging from the fact that the granites are unconformably overlain by the quartzite of the Sinian system, as well as on the basis of their lithologic character, the greater part of the granites can be correlated with the Late Archeozoic Kungchangling granite (SAITO, 1938; HADA, 1925, 1931; TSURU,—) that is widely developed in South Manchuria. The lamprophyre dikes are usually about 1 m in width, dark green (or grayish brown when weathered), fine-grained and compact. They intrude the rocks of the Liaoho system, but the age of intrusion remains unknown.

IV. Magnesite Deposits

A. Mode of Occurrence

Magnesite deposits occur in the dolomite of the Tashihchiao series, which extends from Niu-hsin-shan to Hei-shan in a N70°E direction for about 70 km with a maximum width 4 km. The dolomite stretches farther east, so that the occurrence of magnesite is possible in the eastern area also. (There is reliable information that magnesite deposits exist in the vicinity of Chi-chia-pu-tzu station on the An-feng Railway line).

Magnesite deposits are usually interbedded within dolomite, and the bedding plane is roughly parallel with that of dolomite. In some places, however, the deposits have an irregular massive form without showing any distinct bedding, as observed in the Hsiao-sheng-shui-ssu deposit and in part of other deposits. The boundary of the ore deposits is generally uneven except for the cases where the deposits are in fault contact with the country rock, namely, dolomite. Both ends of the bedded ore bodies terminate abruptly in an irregular plane, seldom thinning out. Ore bodies occasionally contain dolomite pebbles. In some parts of the footwall of the Ching-shan-pai and Sheng-shui-ssu deposits, brecciated magnesitic dolomite is found in the contact with the country rock.

The ore deposits are intruded everywhere by lamprophyre dikes and quartz veins. Talc veins are abundant along the boundary between the deposits and dolomite.

It is worthy of mention that ore deposits occurring at the apex of an anticlinal structure of dolomite are generally large and excellent in quality whereas those at the bottom of a synclinal structure are poorly developed and inferior in quality. This characteristic mode of occurrence, as exemplified by the deposits at Hsiao-sheng-shui-ssu, Ping-erh-fang and other places, requires further study.

B. Ore Grade

Magnesite of the report area is crystalline and has a white, grayish white, gray or pink tint. On a fresh surface magnesite has a strong glassy lustre by which it can be distinguished from dolomite. When weathered, dolomite assumes a gray or grayish white, massive and relatively smooth appearance while magnesite is usually gray to grayish yellow or grayish brown, and coarse sandy. Distinction with the naked eye between dolomite and so-called dolomitic magnesite (containing free dolomite so that the MgO content is too small to be economically mined) is difficult.

In comparison with magnesite ores of foreign countries the magnesite ore of this area contains less impurities, especially the CaO, Fe_2O_3 and Al_2O_3 contents are very small, although some parts abound in SiO_2 which may have been derived from talc. When lime and silica are less than 1% each, the ore is ranked as first class.

The magnesite ore of the report area is variable in character, and can be classified into the following three types:

(1) Sheng-shui-ssu type
(2) Hsiao-sheng-shui-ssu type
(3) Ching-shan-pai type

(1) Sheng-shui-ssu type

This is the most predominant type in the area. Ore occurring as bedded deposits at Sheng-shui-ssu and to its west belongs to this type. It is coarse-grained, white or grayish white, sometimes pink, and partially banded with gray and grayish black layers. A stylolitic structure is locally observed.

The major components (%) are as follows:

Ignition loss	SiO_2	$Fe_2O_3+Al_2O_3$	CaO	MgO
50.0	2.5	1.0	1.0	45.5

Because of the large content of SiO_2 the ore is unfit for dead burning.

(2) Hsiao-sheng-shui-ssu type

Microcrystalline, snow-white ore belongs to this type. Its fresh surface is hardly distinguishable from microcrystalline marble, but its strong lustre helps discriminate it from the latter. In most cases the ore of this type is irregular and massive in form.

The major components (%) are as follows:

Ignition loss	SiO_2	$Fe_2O_3+Al_2O_3$	CaO	MgO
51.0	1.0	1.0	0.5	46.5

It is best for clinkering because of the least amount of impurities such as CaO and SiO_2. This type is represented by the ore from E section of the Hsiao-sheng-shui-ssu mine. Part of the ore from Fan-le-ma-yu, Pei-ta-ling and Hsin-kai-ling belongs to this type. Similar ore is found at Wa-fang-tien of Hsiu-yen county, An-tung Province.

(3) Ching-shan-pai type

This is an intermediate type between (1) and (2). When fresh, the ore is white or pale pink, becoming grayish brown when weathered. It is medium- to coarse-grained and occurs where bedded ore and massive ore coexist.

The major components (%) are as follows:

Ignition loss	SiO_2	$Fe_2O_3+Al_2O_3$	CaO	MgO
51.0	1.0	1.5	0.5	46.0

In quality it is somewhat inferior to type (2), but a large content of Fe_2O_3 and the coarseness make sintering easy, so that the ore is good for dead burning.

This type is represented by the ore from the main body of the Ching-shan-pai deposit. Part of the ore from the Hsiao-kao-chuang-tun, Ping-erh-fang and Chin-chia-pu-tzu deposits also belongs to this type.

C. Ore Reserves

Estimated reserves of magnesite ore in the Ta-shih-chiao—Hai-cheng districts are as follows:

Name of deposit	Uses	Reserves (t)
Niu-hsin-tai	Calcined, partly dead burnt	2,000
Pai-hu-shan	Calcined	20,000
Hung-chi-shan	Calcined	500
Kao-li-cheng-shan	Calcined	200
Hou-pai-chai-tzu	Calcined	20
Kuan-ma-shan	Calcined	50,000
Sheng-shui-ssu	Calcined	50,000
Hsiao-sheng-shui-ssu	Dead burnt	50,000
Hsiao-kao-chuang-tun, Ping-erh-fang	Calcined, partly dead burnt	500,000
Ching-shan-pai	Dead burnt	50,000
Shui-chuan, Ching-shan-ssu, Chia-chia-pu-tzu, Chin-chia-pu-tzu	Calcined, partly dead burnt	2,000,000
Hsia-fang-shen	Calcined	3,000
Yang-chia-tien, Li-shu-kou	Calcined, partly dead burnt	1,000,000
Hung-tu-ling-tzu, Fan-le-ma-yu, Hsi-lao-niu-pai	Dead burnt and calcined	4,000,000
Kang-chia-yu	Calcined	20
Lao-yeh-miao, Ma-ma-chieh	Calcined	50
Pei-ta-ling, Hsin-kai-ling	Calcined and dead burnt	1,000,000
Tung-shan, Hei-shan	Calcined	1,500,000

D. Origin of the Deposits

Regarding the origin of the magnesite deposits in the Ta-shih-chiao—Hai-cheng districts, there are two different views. One maintains a primary precipitation origin and the other a sedondary replacement origin. In the genetical study of the magnesite deposits the following facts may be referred to:

(a) Magnesite is crystalline.

(b) Most of magnesite deposits occur in a bedded form or as irregular masses within dolomite.

(c) Their boundary with dolomite is always somewhat uneven.

(d) On some occasions, brecciated dolomite is found within the ore deposits, or in the footwall of the ore deposits as seen at Ching-shan-pai and Sheng-shui-ssu.

(e) Around the ore deposits are found large bodies of intrusive rocks which are supposed to be the Kungchangling granite.

(f) Pseudomorphs of clinochlore, probably derived from monoclinic augite, and pseudomorphs of limonite after pyrite are contained in the ore deposits.

(g) Talc deposits which are apparently of hydrothermal origin are often associated with magnesite deposits.

All these points suggest that dolomite is the country rock of the magnesite deposits in the districts of Ta-shia-chiao and Hai-cheng, and that the deposits are of hydrothermal replacement origin connected with the Kungchangling granite. Nevertheless, the formation mechanism of the deposits awaits further study.

Regarding the origin of the Hei-lao-wu-shih magnesite deposit in An-tung Province, Asano (1940) proposed the following interesting interpretation: Impure dolomite undergoes thermal and regional metamorphism——olivine-diopside rock or olivine-diopside dolomite is formed——hydrothermal action takes place under somewhat uneven pressure——talc rock, serpentine-talc rock, chlorite rock, tremolite rock and edenite rock are formed, giving rise to formation of magnesite deposits. However, this interpretation does not apply to the magnesite deposits of the Ta-shih-chioa—Hai-cheng districts because presence of any rocks corresponding to tremolite rock and edenite rock remains unknown there.

Although Kato (1943) and Saito (1938A) attached importance to the existence of lamprophyre dikes, the dikes are apparently unrelated to the origin of magnesite deposits so far as the observations at the Hsiao-sheng-shui-ssu and other deposits are concerned.

E. Mining

For the purpose of exploiting the magnesite deposits in the Ta-shih-chiao—Hai-cheng districts, the South Manchuria Mining Company was established in 1918 as an affiliated company to the South Manchuria Railway Company.

The company acquired the greater part of the mining concession and started mining of ore by the stepped (10–20 m) open-cut method. The Niu-hsin-shan deposit in the westernmost area was mined by the Showa Steel Works, and part of the Yang-chia-tien deposit in the central area was worked by the Kang-te Mining Company. In several other places the ore was exploited by small private companies. The principal mining places are as follows:

Name of deposit	Mode of occurrence	Ore grade (%)	Equipment	Average daily yield (t) in 1944
Niu-hsin-tai	Bedded	$CaO=1$ $SiO_2=2$		150
Kuan-ma-shan	Bedded	$CaO=1$ $SiO_2=2.5$	Hand-digging	300
Sheng-shui-ssu	Bedded	$CaO=1$ $SiO_2=2.5$	Compressor (100 HP) 1 Jackhammer 6	300
Ping-erh-fang (including Hsiao-kao-chuang-tun)	Bedded, partly massive	$CaO=1$ $SiO_2=2$	Hand-digging	500
Haiso-sheng-shui-ssu	Massive	$CaO=0.5$ $SiO_2=1$	Compressor (200 HP) 1 Compressor (100 HP) 4 Jackhammer 30 Drill-sharpner 1	800
Ching-shan-pai	Bedded, partly massive	$CaO=0.5$ $SiO_2=1$	Compressor (100 HP) 4 Jackhammer 20	300
Chin-chia-pu-tzu	Bedded, partly massive	$CaO=1$ $SiO_2=2$	Hand-digging	100
Yang-chia-tien	Bedded, partly massive	$CaO=1$ $SiO_2=2$		150

The annual production of the South Manchuria Mining Company since 1926 is listed below:

1926	13,400 (t)	1936	135,000 (t)
1927	20,300	1937	131,000
1928	26,600	1938	223,000
1929	33,900	1939	385,000
1930	31,300	1940	450,000
1931	25,200	1941	500,000
1932	43,400	1942	550,000
1933	48,000	1943	600,000
1934	58,000	1944	700,000
1935	90,000	1945	—

In 1944, in compliance with the demand of the Japanese Kuan-tung Army for increased magnesite production for wartime supplies, the South Manchuria Railway Company laid a branch railway between the Sheng-shui-ssu plant and the Ching-shan-pai mine. However, the war terminated before the operation aiming at the output of 1,000 kt per year was put into practice.

F. Uses

Magnesite is used for the following purposes.

(a) Dead burnt magnesia (heated at 1,500 to 1,600°C)
(magnesia, clinker, magnesia-brick) → (refractory material for open furnace and electric kiln in steel manufacture)

(b) Carbon dioxide (produced in calcination of ore)
(dry ice, liquified CO_2, refreshing drinks, other industries)

(c) Calcined magnesia (heated at 700 to 800°C)
magnesium chloride → metal magnesium
magnesium carbonate → (rubber compound, medicine, adulterant in tooth powder and cosmetics, paints, printing ink, polisher, filler)
magnesium sulphite → wood pulp manufacture
magnesium sulphate → medicine, rayon coagulant
magnesium nitrate → (solvent of regenerated silk, porcelain and glass manufacture, fertilizer manufacture)
Lignoid* → building and flooring
Matris* → building and flooring
Elasco* → building and walling
Rockstacco* → building and walling
(* commercial name)

G. Equipment and Capacity

(1) Magnesia

Shaft Kiln:—Magnesite ore and anthracite (Hongei coal from French Indo-China and Yang-chuan coal from North China) are packed alternately in a shaft kiln and heated at 1,500 to 1,600°C with the help of an air blower, thus producing magnesia, or magnesia-clinker. Approximately 20 to 30 tons of ore is used for one kiln. The process requires about 48 hours. Daily output of clinker is about 5 tons. The number of shaft kilns in the Ta-shih-chiao district is as follows:

Company	Location	Number of kilns
South Manchuria Min. Co.	Ta-shih-chiao Sheng-shui-ssu Fen-shui	29 72 4
Kang-te Mining Co.	Ta-shih-chiao Yang-chia-tien	6 5
Tien-on Kung-ssu (Co.)	Ta-shih-chiao	5
Fu-yuan Kung-ssu	Ta-shih-chiao	6
Hsing-yuan Kung-ssu	Ta-shih-chiao	3

Tunnel Kiln:—The South Manchuria Mining Company installed a tunnel kiln at Sheng-shui-ssu, but before yielding any notable results the company met the end of the war. Magnesia clacined in a rotary kiln is pulverized and air-dressed to get rid of impurities. Then it is compressed into square blocks, and placed in a tunnel kiln to be heated at 1,500–1,600°C. Magnesia-clinker is thus produced. The company had a low-temperature dry-distillation plant and a gas generator, producing Coalite (commercial name) and coal gas to be used as fuel for the tunnel kiln. The manufacturing process, comprising preliminary heating, incandescence and cooling, requires about 24 hours. Daily output is about 300 tons.

A tunnel kiln is superior to a shaft kiln in the respects that ore-dressing can be accomplished, addition of impurities from fuel can be prevented and successive heating can be performed.

(2) Calcined Magnesia

Reverberatory Kiln and Shaft Kiln:—Using coal as fuel, magnesite is heated at 700–800°C. About 6 hours are needed to obtain calcined magnesia. Daily output is about 10 tons by a reverberatory kiln and about 12 tons by a shaft kiln. The number of kilns for calcination in the Ta-shih-chiao district is as follows:

Company	Reverberatory kiln		Shaft kiln	
	Location	Number	Location	Number
S. Manchuria Min. Co.	Ta-shih-chiao Sheng-shui-ssu Kuan-ma-shan Kao-chuang-tun	13 9 26 20	Fen-shui	4
Kang-te Mining Co.			Yang-chia-tien	10
Shirakawa-gumi			Ta-shih-chiao	6
Hsing-yuan Kung-ssu			Ta-shih-chiao	2

Rotary Kiln:—The Sheng-shui-ssu plant of the South Manchuria Mining Company has two rotary kilns (the smaller one is seldom operated). Lumps or powder of ore are heated in a rotary kiln at 700–800°C to get calcined magnesia. Fuel for the larger kiln is coal gas produced by the appurtenant coal-distillation plant and gas generator. Calcination requires about 3 hours. Daily output of the larger kiln is about 600 tons and that of the smaller kiln is about 10 tons. A rotary kiln has the following advantages: Powder ore, which in the past was discarded as waste, can be calcined, consecutive operation can be performed, and it can be operated with a tunnel kiln which helps eliminate impurities.

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Dolomite Deposits in the Districts of Ta-shih-chiao and Hai-cheng, Manchuria

Keiji UETANI

I. Introduction

Carbonate rocks, whose age is usually Paleozoic or older, are abundant in southern Manchuria, and are defined as dolomite. The MgO content of these rocks has a tendency to increase with age.

The largest dolomite bed in Manchuria belongs to the Archean Liaoho system. It extends between Ta-shih-chiao railway station on the Lien-ching line (Ta-lien to Hsin-ching) and Tsao-ho-kou railway station on the An-feng line (Mukden to An-tung) for a distance of about 150 km with a considerable width, trending N70°E.

The present paper deals only with the western half of this dolomite bed, because little is known about the eastern half although it seems quite similar to the western half in general geology and mode of occurrence.

The western half of the dolomite stretches from Niu-hsin-shan to Hei-shan, for some 70 km, roughly parallel to the magnesite deposits which are described by the author in a separate paper.

II. Location and Transportation

The dolomite is exposed widely in three counties, Kai-ping, Hai-cheng and Liao-yang, of Mukden Province. It extends from Niu-hsin-shan, 7.5 km southwest of Ta-shih-chiao station, to Hei-shan for about 70 km with a width 4 km, passing through Sheng-shui-ssu, Ta-ling, Ching-shan-pai, Chin-chia-pu-tzu, Yang-chia-tien, Hsi-lao-niu-pai, Ma-ma-chieh and Chi-tung-yu.

The area of dolomite deposits is bounded on the west by the Lien-ching Railway on which nine stations are located, namely, Ta-ping-shan, Ta-shih-chiao, Fen-shui, Ta-shan, Hai-cheng, Nan-tai, Tang-kang-tzu, Chien-shan and An-shan, from south to north. A branch railway starts from Ta-shih-chiao and reaches Ching-shan-pai, passing through Chen-chia-pu-tzu, Sheng-shui-ssu and Ping-erh-fang stations. Besides this, a light railway of the South Manchuria Mining Co. runs between Sheng-shui-ssu and Hsiao-sheng-shui-ssu for some 2 km, and another

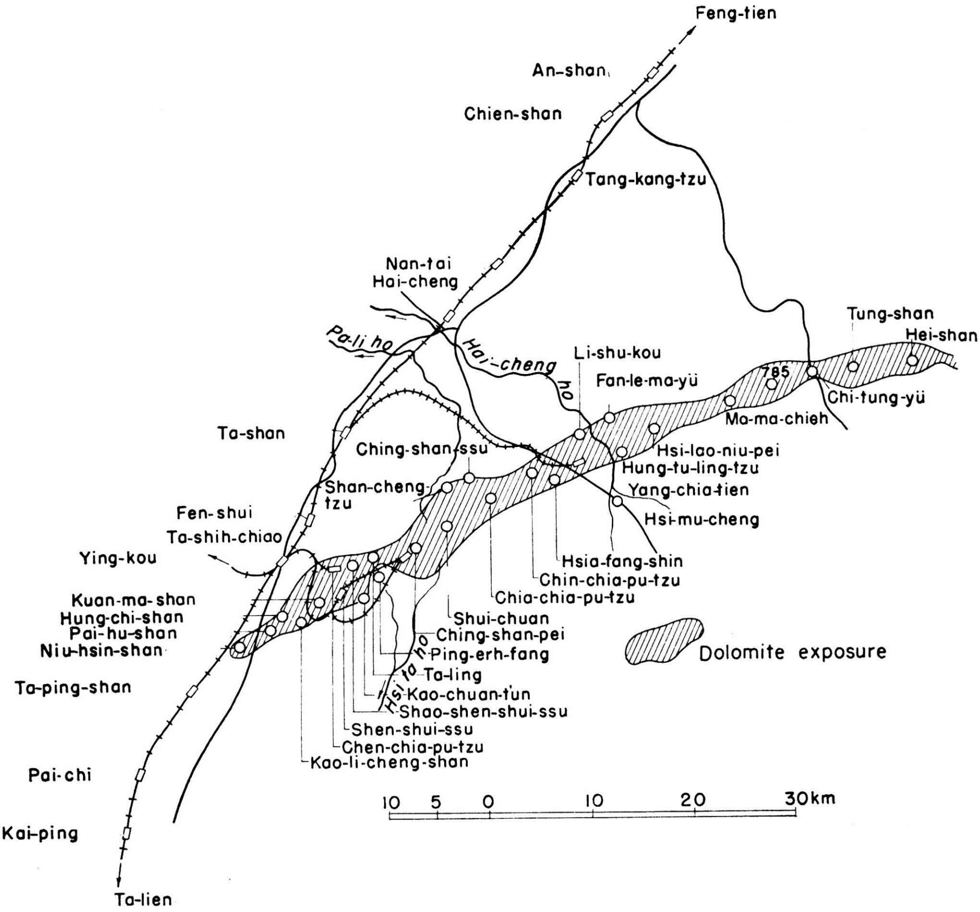

Fig. 1. Dolomite deposits area at Ta-shi-chiao, Hai-cheng district.

light railway, 28 km long, of the Manchuria Talc Industry Co. runs between Ta-shan and Yang-chia-tien. For about 8 km between Sheng-shui-ssu and Ching-shan-pai a cablecar is operated to carry ore. Hai-cheng and Hsi-mu-cheng are connected by the national highway which branches into a truck road leading to Chin-chia-pu-tzu. A truck road runs also between Fen-shui and Ta-lien, and between An-shan and Chi-tung-yu. Thus, transportation to various dolomite mines is relatively convenient.

III. Geology and Dolomite Deposits

A. Geology

The geology of the area reported on consists of metamorphic rocks and sedimentary rocks belonging to the Archean Liaoho system named by Saito in 1943. They are roughly divided into three parts as follows:

Upper part (Kaiping series)
Middle part (Tashihchiao series)
Lower part

The upper and lower parts are composed mainly of phyllite which is locally accompanied by injection gneiss, mica schist and talc schist. The middle part is a thick formation of dolomite often containing *Collenia*. The formation strikes N60–90°E and dips 30–50°S.

The Liaoho system is unconformably overlain by quartzite which belongs to the Proterozoic Sinian system and is exposed in places. Quarternary sediments consisting of loess, sand and gravel are distributed along the rivers and the foot of the mountains.

Granites are predominant among igneous rocks. Small exposures of lamprophyre dikes and quartz veins are found locally. The granites are gray, grayish white or pink, mostly gneissose with remarkable crystals of microcline, and occasionally dioritic. Most of the granites are considered to belong to the so-called Kung-chang-ling granite, which is broadly developed in South Manchuria. It is assigned to Late Archeozoic in age, because, where the granites intrude into the Liaoho system injection gneiss has been formed and the granites are unconformably covered by the Sinian quartzite, and also because of lithologic similarity.

The lamprophyre dikes are generally 1 m or so in width, dark green (grayish brown when weathered), fine-grained and compact. They intrude the Liaoho system in places but the age of intrusion is not known.

B. Dolomite Deposits

(1) Mode of occurrence

The Tashihchiao series constituting the middle Liaoho system is composed almost entirely of dolomite. Though it is locally disturbed the dolomite formation strikes N75°E, dips 40°S, extending about 70 km with an average thickness about 600 m. The basal part of the formation is intercalated with thin beds of phyllite and sericite-chlorite schist, and the middle part contains thin talc schist and magnesite. Vortical fossils(?) apparently *Collenia* (30 cm in maximum diameter) are observed in some parts of the formation.

(2) Ore grade and reserves

The dolomite is white or grayish white and fine-grained. Its glassy lustre is weaker than that of magnesite.

Analytical data of the dolomite of the report area are few. Generally speaking, however, bedded dolomite is rather uniform in composition, having MgO 18–20% and $Fe_2O_3+Al_2O_3$ around 1%. Contents of lime and silica vary from place to place. Where the silica content exceeds 3% the grade of dolomite is low. In non-bedded dolomite adjoining magnesite deposits MgO increases with decreasing SiO_2, and some parts have a reddish brown or reddish purple tint due to the presence of a small amount of iron oxide but the ore grade is high.

The ore reserves are estimated at 24.4 billion tons, calculated by assuming that the extension of the deposits is 70,000 m, thickness 600 m, depth from the surface 200 m and specific gravity 2.9. Thus, the reserves are almost unlimited. However, if the high-grade parts are mined selectively, the workable reserves would become much smaller.

(3) Mining

Dolomite is a good refractory material, but the dolomite of the report area has been mined very little, because more valuable magnesite deposits occur in the neighborhood. Only the reddish purple dolomite associated with the Sheng-shui-ssu magnesite deposits was mined by the South Manchuria Mining Co. for a short period. In other places the dolomite was used by the nearby dwellers as building material. Starting in 1943, when the branch railway was laid between Ta-shih-chiao and Sheng-shui-ssu, the dolomite deposits in the northeastern hill of the village of Chen-chia-pu-tzu (about 5 km east-southeast of Ta-shih-chiao station) were worked by the Manchuria Iron Manufacturing Co. and produced about 150 tons per month. The dolomite of Chen-chia-pu-tzu comprises two types, one is grayish white fine-grained dolomite to be used as a flux in steel furnace, and the other is reddish brown or reddish purple coarse-grained dolomite to be used as a refractory material for steel furnace.

IV. Conclusion

The dolomite deposits of the Ta-shih-chiao and Hai-cheng districts, occurring in the Tashihchiao series, middle part of the Liaoho system, are primary sediments of the Archean Era. The deposits, striking N70°E and extending 70 km with a thickness about 600 m, are large in sacale and conveniently located.

The ore grade is low for the most part. Future development of the dolomite mining is questionable, because deposits of magnesite, which is a much better refractory material than dolomite, are found in the neighborhood and are easily mined.

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NORTH CHINA, SOUTH CHINA AND TAIWAN

Survey Report on the Bain-Bokto Iron Ore Deposit in Wulanchapu Mêng, Inner Mongolia

Ryuichi SONOBÉ

I. Preface

In July, 1940, I surveyed the Bain-Bokto ore deposits for seven days while T. KAGAMI took charge of the topographic survey.

The deposit in Bain-bokto is excellent, in respect to both ore reserve and quality. It occurs, however, in a remote region that is still unexploited. I intend to introduce in this paper the results of my survey for future developments.

II. Location and Access

Bain-Bokto[1] is situated on the western extremity of Haerh-ha Yuchi (Taerh-hanpeilêchi) in Wulanchapu Mêng, and is adjacent to Maominganchi, in the west. The iron ore deposits occur some 48 km from the WNW of Pailingmiao,[2] where the government office of Wulanchapu Mêng is located.

A road extends westward for 34 km from Pailingmiao to Chungkung Mêng. Then, to its north for 14 km, there is an undulating grassy plain having no road and continuing far beyond the horizon. However, it is possible to establish a good road without artificial rolling or hardening of the road surface by running horses and vehicles daily. Along the way, there are river beds and swamps in several places. However, the Chungkung Mêng road is usually rather busy, so the road surface is generally hard enough for trucks, except during rainy season (see section on climate). It takes one hour and half to run from Pailingmiao.

There are four roads connecting Pailingmiao to important villages, i.e., Huhuhéto Line, Paotou Line, Chungkung Line and Hsisunite Line; each of Huhuhéto and Paotou lines are connected with the railway.

Pailingmiao is located about 156 km northwest of Huhuhéto (Suiyuan), along

1) Both Bain and Bokto mean fertile and holy place or sacred ground, respectively, in the Mongolian Language.

2) Pailingmiao is called Bato Hargan-Sumê in Mongolian. Bato means strong or stable, Hargan means gate of a castle, and Sumê means a manusoleum.

the Peking-Paoťou Railway Line and also, about 150 km north-northeast of Paoťou. The area along Pailingmiao to Wuchúan, some 111 km in distance, is occupied generally by grassy land, but swamps are rare. Trucks and other vehicles can therefore easily pass any time, except rainy season. However, the road between Wuchuan and Huhuhéto, 45 km distance, has a steep mountain path, crossing the Yinshan Mountain Range, and the road conditions are not favourable. Furthermore, the road between Pailingmiao and Paoťou is generally better than the road described above.

Trucks, camels and donkeys are used for traffic, and it takes four to five hours, to run by truck between Pailingmiao and Huhuhéto and also, between Pailingmiao and Paoťou.

III. History of Investigation and Problems Concerning Concession

In the 13th Year of Republic of China, Tingtaohêng of the National Geological Survey of China first investigated the area. As there is no fixed right of domain in Mongolia, as the rule, the land has been available freely for any inhabitant of the region. Recently, however, taxes have been imposed in some places.

The famous Bain-Obo is located on the summit of Bain-Bokto. As Obo is the mecca for Mongolians, it is strictly prohibited to plant or dig up the ground in the area, and therefore no application for mining, has been recorded up to date.

IV. Topography and Geology

There are rolling hills, generally 20–30 m high, near the ore deposits, and the dome shaped hill of Bain-Bokto-Agola,[3)] some 100 m high, exist above these low hilly tracts.

Rocks occurring in the area, being composed of crystalline schist, siliceous limestone, and loess, and fluorite can be seen, even in the older rock series. Beside these, a contaminated diorite is exposed at the site, some 1 km to the south or the southeast of this area. The details of each rock series will be stated in the following.

(1) CRYSTALLINE SCHIST: These may be divided into alkali hornblende-quartz schist and graphite-sericite schist.

(a) Alkali hornblende-quartz schist is exposed in the northern extremity of this region, and is in direct contact with siliceous limestone, but the stratigraphic relation between these two is unknown, because they were bordered directly with a fault. The rock shows dark gray colour, often schistose, and consists mainly of quartz, plagioclase and alkali-hornblende. The alkali-hornblende mineral shows light purplish blue in colour, having small columnar crystal form, abundant in the rock and resemblance in appearance to cyanite minerals.

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3) Agola means a height.

(b) Graphite-sericite schist is overlaid by boulders or blocks of iron ores, south of the main ore body, and is peeped out in small area at the bottom of the dales or ridges. It is composed chiefly of small grained quartz, sericite and graphite, and often associated with biotite, showing schistose structure. The schistosity varies from N80°W to N80°E in strike, dipping more than 65° to the south. The structural relation between this rock and the siliceous limestone is obscure. The rock is traversed often by quartz or feldspar veins of 3 cm (max. 4.5 cm) in width, and accompanied frequently with fluorite, forming fluorite schist, in places where the content of fluorite minerals relatively abundant.

(2) Siliceous limestone, is exposed to a relatively wide limit at the north of the main ore body, but is covered with boulders or blocks of iron ores near the main ore body. The rock is light blue or dark bluish gray coloured, and massive. The bedding is undefined, in general, but so far as my observations could determine, the strike runs N25–30°E, dipping 40–55° southward, in the northern area. However, the bedding running eastwesterly with 40–45° dip to the south, in the southern area. Then, a fault may be supposed by reason of the discontinuity between these two areas. In addition, the limestone occurring near this supposed fault in the northwest of ore body I, being altered and alkali-hornblende, aegirine-

Table 1.

Number of Samples	Occurrences	CaFe	SiO_2	FeO	P	S	CaO	Ig. Loss	Sp. Gr.
4	Impregnated in compact iron ore, mixed hematite and magnetite	12.39	0.28	51.56	0.029	tr.	—	—	4.71
19	//	14.13	0.74	45.88	0.040	0.003	—	—	3.66
38	Impregnated in magnetite	15.73	0.08	36.24	0.034	0.001	—	—	4.37
9	Impregnated in hematite	43.23	0.26	30.84	0.034	0.001	—	—	4.70
35	Impregnated in low grade iron ores, replaced limestone	59.86	—	14.80	—	—	1.03	1.35	—
37	Impregnated in low grade iron ore, remaining rather large amount of limestone due to incomplete replacement	2.05* (?)	—	26.10	—	—	26.10	32.55	—

Note: * As the content of fluorite may be observed as 10–15% in naked eyes, this value will be doubtful.

augite, epidote and fluorite, are contained sometimes rather large amount in the rock.

(3) Loess, is a loamy grayish brown soil, and covers all of the preceding rocks.

Fluorite

Having a purple colour it occurs as disseminated or vein form in crystalline schist, limestone and iron ores, and is especially rich in the main ore body and their environs. The value of analysis of fluorite contained in iron ores, are as follows: (Analysed by the Central Laboratory of the South Manchuria Railway Co. Ltd.)

Except for the above-described occurrences, fluorite mineral could be detected obviously with the naked eyes at seventeen places. Fluorite veins in the fluorite schist and limestone are superior in tenor, and contain about 50% CaF_2.

Regrettably, due to lack of time I could not carry out field survey sufficiently, and could only prepare the extent of occurrences and an assay map of the fluorite-bearing ores, but also average contents of CaF_2% in iron ore deposits. However, it is probable that the ore is suitable for use in blast furnaces and open-hearth furnaces or converters. In my mind, the mine is the first example of an iron ore containing fluorite. After the survey, F. Homma stated that rare minerals could be found in these fluorite-bearing rocks.

V. Ore Deposits

The iron ore minerals are chiefly hematite with subordinate magnetite. The deposits formed by replacement, and small ore bodies around the main ore body, with incomplete replacement residual rock particles, may constitute a small or major part of the ore.

Two or three zones, containing quite a lot of aegirine, are found nearby.

Most of the ore bodies occur in limestone. However, a few of them, occur in graphite-sericite mica schists.

The ore can be detected, distinctly upon the exposure of hematite and magnetite enriched parts as shown on the geologic map (Fig. 1) and these ore minerals are mixed up intensely in places, forming compact ore mass.

Hematite is mainly dark gray in colour, with metallic luster and massive. It is accompanied by small amounts of scaly-type micaceous iron ore.

Magnetite is remarkably iron-black in colour, granular or massive, and magnetic.

The main ore bodies, such as I and II, being close contact with each other, are exposed in lenticular shapes in the southern part of the summit. Ore body I, is 900 m long from east to west, and averages 200 m, with maximum 300 m, in breadth. While ore body II, is 700 m long from east to west, and averages 100 m with maximum 150 m, in breadth. The dip of these ore bodies, tends to incline from 45°–60° forward the south.

There are seven small ore bodies in limestone and three in graphite-sericite

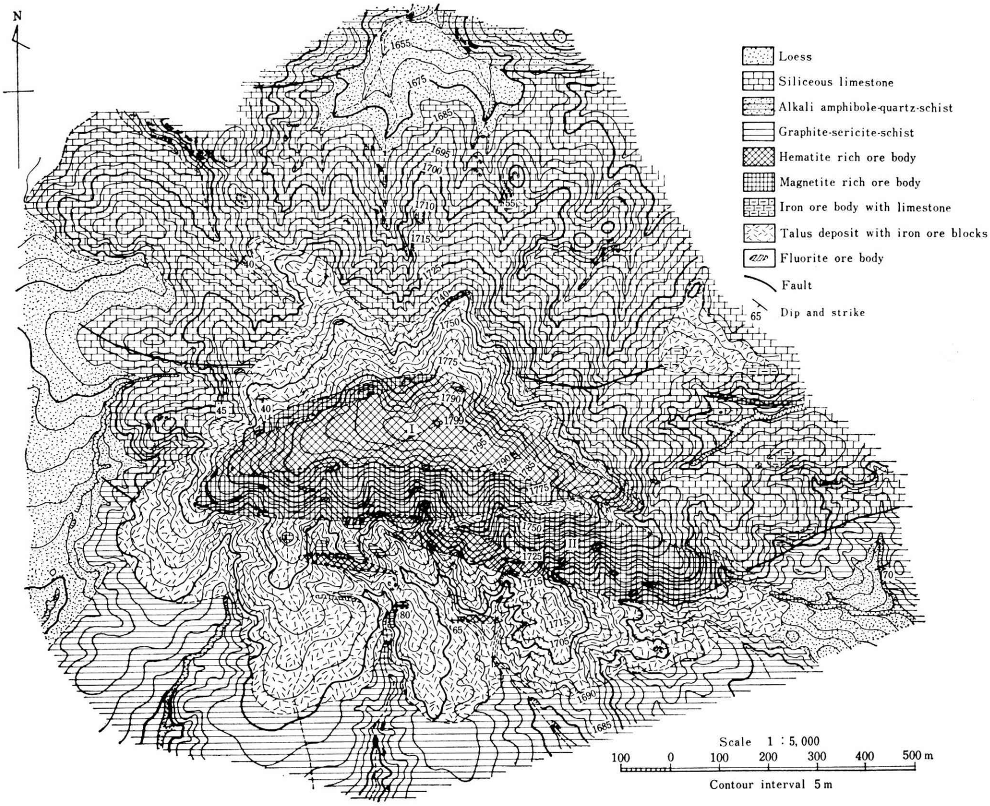

Fig. 1. Geological map of Bainbokto (Pai-yun-pokuto) iron ore deposit.

schist, so that the total sum of the small ore bodies is ten. The largest one among them, is 200 m long, and is some 20 m, in breadth; while the smallest one, is less than 10 m long, and is only 1 m, in breadth. Moreover, most of the small ore bodies are about 10 m long and 2–3 m in breadth.

These small ore bodies, which occur mostly near the main ore body, have either less or a lack of surface-soil capping and are well exposed. Therefore, open-pit mining is possible.

Boulders and Blocks

Boulders and blocks of iron ore are generally scattered irregularly around the northern and the southern parts of the main ore body. They are accumulated as angular-shaped ore masses, especially in the southwestern margin of ore body **I**, and can be mined by the open-pit method. Each ore size varies from the size of a fingertip to the size of a cow's head, but are mostly larger than a man's fist. The thickness of their accumulations is estimated to be more than 1 m.

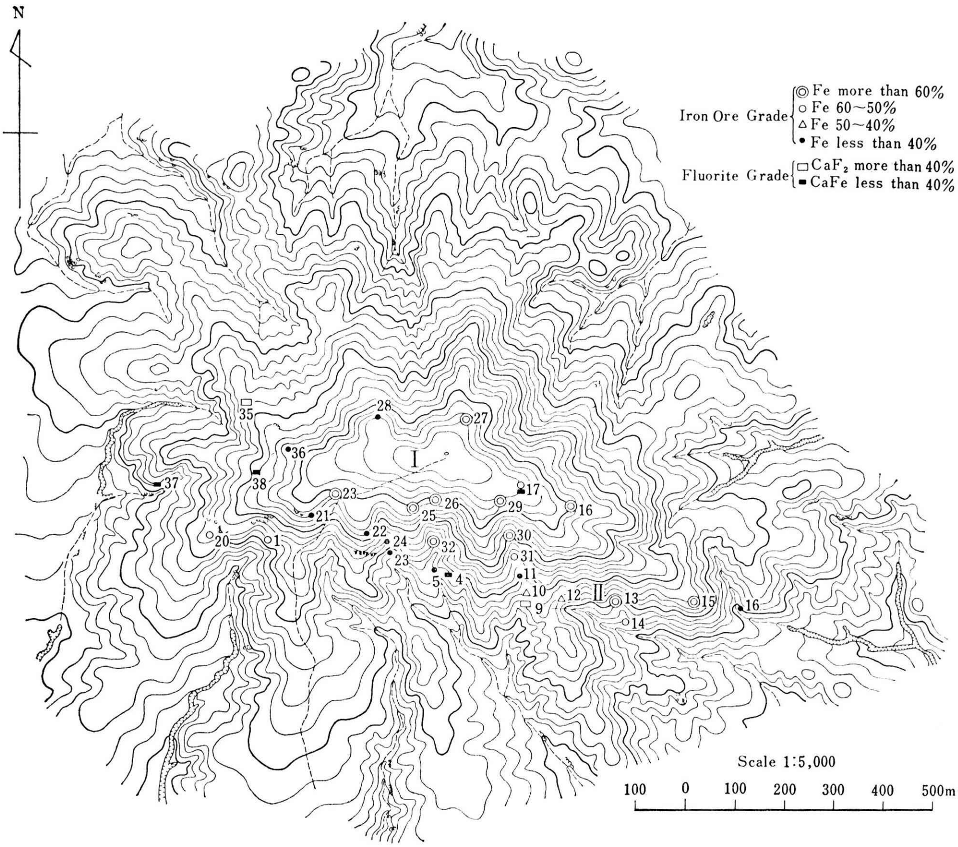

Fig. 2. Sampling localities of Bain-bokto (Paiyunpokuto) iron ore deposit.

VI. Quality and Ore Reserve

A. Quality

Chemical analysis of specimens was performed exclusively by the Central Laboratory of the South Manchuria Railway Co. Ltd.

Eighteen specimens were collected at random from the main ore body I, and the average contents revealed was 48.59% Fe, 9.98% SiO_2, 0.21% P, and 0.07% S, specific gravity was 4.43. These values do not indicate the highest quality, because of impure rock occurrences as described in the remarks concerning fig. 2: namely, seven specimens (39%) include moderately large amounts of siliceous limestone, fluorite or aegirine, and of low grade ores, varying from 20–40% Fe; their distribution is confined to specific areas. If these impure parts are excluded, the average value for other eleven speciments of relatively rich ore become 61.67%

Table 2. Chemical Composition of Ores Four the Main Ore Body I.

No.	Fe	SiO_2	P	S	Va	Cr	Ti	Cu	Mn	Ca F_2	Sp. Gr.	Remarks
1	52.67	0.18	0.059	0.089	—*	0.01	tr	—*	0.13	—	4.70	
17	51.56	0.28	0.029	tr	—	—	—	—	—	12.39	4.71	Contains fluorite
18	66.13	0.72	0.081	0.125	—*	—*	tr	—*	0.13	—	4.75	
20	53.63	0.34	0.212	0.147	—*	—*	0.244	—*	0.08	—	4.72	
21	26.87	47.30	0.383	0.058	—*	—*	Re	—*	0.06	—	3.36	Siliceous limestone of about 10% contained.
22	27.88	28.78	0.502	0.113	—*	—*	1.002	—*	0.04	—	3.68	
23	34.35	27.58	0.281	0.091	—*	—*	0.284	0.003	0.02	—	3.90	
24	20.29	30.50	0.335	0.061	—*	—*	tr	—*	0.22	—	3.42	Contains rather large number of aegirine augite bouders
25	64.10	0.76	0.367	0.069	—*	—*	tr	—*	0.13	—	4.87	
26	67.31	0.52	0.076	0.049	—*	—*	tr	—*	0.04	—	4.93	
27	66.24	0.38	0.046	0.053	—*	—*	tr	—*	tr	—	5.15	
28	39.90	9.08	0.488	0.088	—*	—*	tr	—*	0.01	—	4.13	
29	63.46	2.24	0.135	0.164	—*	—*	tr	—*	0.60	—	4.84	
30	64.74	2.36	0.155	0.027	—*	—*	tr	—*	0.02	—	4.82	
32	63.69	0.14	0.051	0.037	—*	—*	tr	—*	0.01	—	4.87	
33	64.91	0.82	0.063	0.096	—*	—*	tr	—*	0.05	—	4.88	
36	29.70	27.64	0.691	0.066	—*	tr	tr	—*	0.04	—	3.78	Siliceous limestone remained
38	36.24	0.08	0.034	0.001	—	—	—	—	—	15.73	4.37	Contains fluorite

Note: * Not determined.

Table 3. Chemical Composition of Main Ore Body II.

Specimen No.	Fe	SiO_2	P	S	Va	Cr	Ti	Cu	Mn	$Ca F_2$	Sp. Gr.	Remarks
4	45.88	0.74	0.040	0.003	—	—	—	—	—	14.13	3.66	Fluorite contains
5	26.39	17.60	0.036	0.059	×	×	×	×	1.52	—	3.56	Limestone remained
9	30.84	0.26	0.034	0.001	—	—	—	—	—	43.23	4.70	Rather large amount of fluorite contained.
10	44.02	4.04	0.048	0.067	×	×	×	×	tr	—	4.43	
11	51.60	17.20	0.022	0.051	×	×	×	×	0.11	—	4.03	
12	40.17	7.34	0.104	0.045	×	×	×	×	0.04	—	4.36	
13	66.40	1.08	0.016	0.053	×	×	×	×	0.04	—	4.90	
14	55.56	4.66	0.031	0.037	×	×	tr	×	0.28	—	4.40	
15	55.02	2.48	0.384	0.096	×	Small.	tr	0.005	0.02	—	4.67	
16	37.23	0.48	0.455	0.032	×	×	Small.	×	0.54	—	4.32	Limestone remain
31	50.86	1.42	0.201	0.069	×	×	0.758	×	0.13	—	4.54	

Fe, 0.79% SiO_2, 0.11% P, and 0.07% S, specific gravity is 4.84. Thus, these values are roughly close to those of ore body I and generally, show higher quality.

The chemical compositions of eleven specimens collected in a similar way from the main ore body II, are given in Table 3.

The table gives an average composition of 45.82% Fe, 5.2% SiO_2, 0.12% P, and 0.06% S, and 4.59 for specific gravity. These values do not indicate quality higher than that of ore body I. Impurities, such as limestone or fluorite are also found. Then, if these impurities (six specimens, 54% of which have less than 45% Fe) are excluded, the average of five specimens of moderately rich ores become 55.89% Fe, 0.54% SiO_2, 0.13% P, and 0.061% S and 4.41 for specific gravity. It is difficult to determine the quality of the ore body as a whole, from these data, because specimens collected and analysed were only from a few places. However, it seems that the quality of ore body II is relatively inferior to that of ore body I.

In respect to the above-described two main ore bodies, ore less than 40% Fe occupy the localities from specimen No. 28–38 and from No. 21–24, in ore body I and from No. 5–12 in ore body II. Namely, low-grade ore occurs chiefly in the margin of ore body. The area occupied by low grade ore is about 10% of the total area of main ore bodies I and II.

Moreover, most of small ore bodies, scattered around the main ore bodies are in general, low grade, because they contain rather large amounts limestone remains or other impurities; however, in places more than 50% Fe can be found.

B. Ore Reserve

Ore from the main ore bodies I and II is available for working after the quality is assessed whenever the time for development can be decided, assuming that problems of the haulage have also been settled.

Ore body I, is 900 m, in length; 200 m in breadth; the relative height of the ore exposure is, about 65 m from the level of the nearby ground. Its specific gravity averages 33.

Ore body II, is 700 m, in length; 100 m in breadth; the relative height of the outcrops is about 90 m. The specific gravity averages 4.6.

These two ore bodies are contiguous with each other as to massive bodies, intercalated only by a thin bed of limestone. They will be mined as one ore body because they seem to be connected deep below the surface, after the occurrence of replacement. The area occupied by these two is calculated by planimeter to be 0.356 km^2. Taking 120 m as the relative height from the lowest level of ore body II to the highest level of the iron ore outcrops of ore body I, for the workable depth; assuming that the specific gravity of the iron ore as 4.5; and also, supposing that the ore body is cone shaped, then, the total reserve including $3{,}920 \times 10^3$ mt of the limestone, is $64{,}130 \times 10^3$ mt. Hence, the value becomes 60,213,550 mt, i.e., approximately $60{,}000 \times 10^3$ mt.

The computation formula is based on that of a cone formula which is represented as follows:

Iron ore reserve

(Basal area) (Height) (Sp. Gr.) (Amount of limestone to be excluded)

$$\frac{356{,}000\times 120\times 4.5}{3}-(550\times 25\times 95\times 3)=60{,}214{,}550 \text{ mt.}$$

VII. Some Notes in Reference to Exploitation

A. CLIMATE

Cold and severe winter days continue for seven months, from October to April. The rest of the seasons, i.e., spring, summer and autumn are confined only five months, ranging from May to September, in Pailingmiao and its neighbourhood. The rainy season comes in July. However, which based on the amount of the rainfall, for July, 1940 as an example, was 176.3 mm; rainfall is not unusually heavy. It is said that the temperature never exceeds $-14°C$ on the average, even in the coldest season which ranges from January to March. However, as the deposit area occupies an isolated high land area, without any obstacles, it may be considered much colder than in Pailingmiao. Nevertheless, open-pit mining is done, even in the colder North Manchurian district; hence, it is possible to operate throughout the year.

B. INHABITANTS AND LABOUR SITUATION

Generally speaking, there is no Chinese settlement found in Inner Mongolia. A few Chinese are employed temporarily by the government offices and private organizations, or are engaged as merchants and engineers, in the vicinity of Pailingmiao. However, Chinese dwell only either in Maomingan-ch́i, a part of Ssutzŭ village, or Wuchuan Hsien. Hence, Inner Mongolians who are generally nomads, are difficult to employ as workers in the vicinity of Pailingmiao. Then, workers must be employed at Paoťou or Huhuhéto. It may be therefore impossible in addition to employ Mongolians as mine workers, without special measures for aptitude training.

C. OTHERS

As already stated, Mongolians are generally nomads, and there are no cultivated lands within the unmixed Mongolian zone. Consequently, it is necessary to maintain food supplies in the beginning; both cultivation and forestration should be dealt with parallel to the construction of houses, when the time comes for exploitation.

VIII. Conclusion

In conclusion, the Bain-Bokto iron deposit is excellent, both in quality and in ore reserve, and can be mined easily, but the following will be obstacles to exploitation:

a. Construction of roads for haulage

b. Securing of labour

c. Securing of food

It seems to be nearly impossible to exploit the ore deposit at present. However, if the mine would be exploited, an iron foundry and other accessory works should be constructed in the vicinity, in consideration of the Tach́ingshan Coal as a coking coal.

Lung-yen Iron Ore Deposits and Stratigraphy of the Sinian System, North China

Seiichi SHOJI and Tatsuo YAMASAKI

I. Introduction

We had an opportunity to investigate in detail the Ta-tung region, a part of the Lung-yen iron ore field,[1] in North China for 6 months beginning in August, 1941. One of us (YAMASAKI) returned to Japan with detailed data and important specimens before completion of the survey. This paper covers these data, so inevitably the scope is rather narrow. SHOJI continued survey, and investigated the San-cha-kou region in Hsin-yao concession, and compared all the concessions and regions, but much of this data could not be taken back to Japan. This paper includes only a limited amount of this data.

The distribution, discovery, investigation, exploitation, geology, ore deposit, and ores were already described by TEGENGREN (1921, 1923) many years ago, and by M. WATANABE (1939) and KADOKURA (1939) recently, and many papers have been published on each region, so this paper will not be concerned with these aspects. We will discuss only the order of strata and the correlation of the Sinian system, involving ore beds, and will state the results of recently completed analysis and microscopy of ores.

We gratefully acknowledge the help of Dr. F. HOMMA and other senior geologists who directed us when they were in China, Professors K. KINOSHITA, T. TOMITA and M. NODA, who looked over this paper also kindly directed us, Mr. S. MATSU-KUMA, and Mr. M. YAMAGUCHI who made microscopic examination of the ores, Mr. T. HARA, who analysed the ores for us, and Mr. Y. OKAMOTO, determined the minerals. We were especially guided by Dr. TOMITA while we were in Peking, and were given detailed instructions for correlation by Professor NODA.

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1) According to TEGENGREN (1921, 1923), J. G. ANDERSSON called this iron ore deposit the Hsuan-lung iron ores, but the name Lung-yen iron ores was taken from the name of the company after the ores began to be exploited. When the North China Development Co. started investigation, the names of concessions, such as Yen-tung-shan, Pang-chia-pu, and Hsin-yao, were used and every concession was divided into regions. The particulars are shown in Fig. 2. As for the name of places, see TEGENGREN, M. WATANABE (1939), and KADOKURA (1939) in the References.

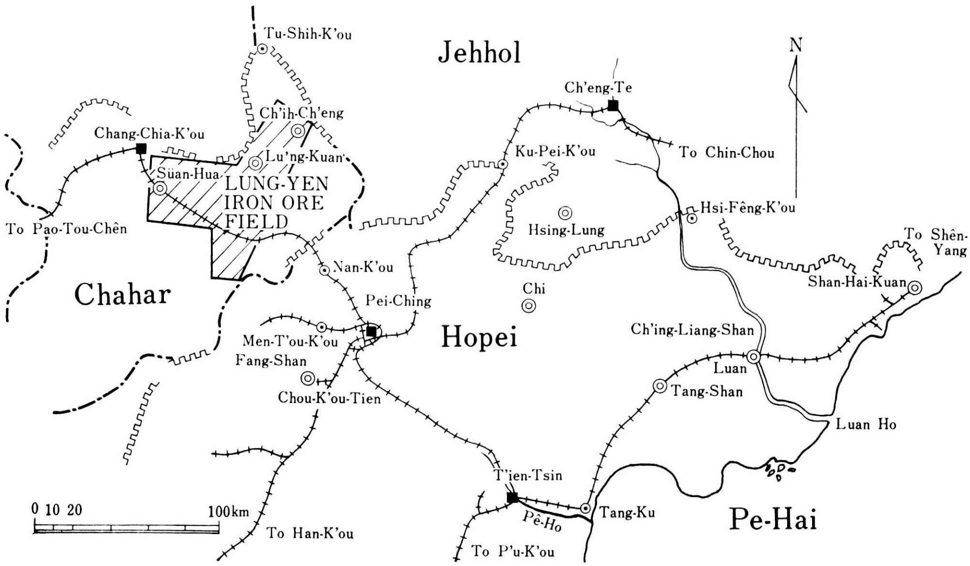

Fig. 1. Sketch map of Chahar, Hopei and Jehhol.

II. Outline of Geology

The area treated in this paper is continuous to the Yen-tung-shan region, which was operated actively, extending across a wide valley. It extends for about 15 km from Tung-pao-sha in Hsuan-hua-hsien in the west to Tung-ke-yu in the east, and for 4 km from north to south. As to access; from Hsuan-hua go 5 km to Erh-tai-tzu, turn north then go up along the river bed for 4 km.

In this district, the Sinian system is developed regularly upon the base of Sang-kan gneiss system of Archaearn with unconformity. These two are overlaid by loess, having large scale gulleys, and also by alluvium on mountain foot and low lands.

Gneiss system is denuded extensively resulting in a mature topography, and is distributed widely in the northern portion of this district. The gneiss and Sinian systems, when viewed from their sides, are bordered with steep cliffs, and extend from east to west for over 10 km along the ridge line parallel to the strike. The southern slope of this ridge coincides with the dip of strata, that is about 15 degrees. In other words, the same bedding plane is extensively exposed to present a different topography quite different from that of the northern slope, showing a typical cuesta topography.

There are two or three valleys, deeply incised from south to north with steep slopes on both sides, on its southern slope. The exposure of the iron ore member of the Sinian system is traced from both banks to the northern slope of cuesta ridge, and extends for 15 km from east to west.

The structure of the Sinian system is very simple, dipping at 15 degrees to the

Table 1. Correlation Table of Sinian System in Lung-yen Iron Ore Field.

Locality and Author		West Part of Ta-tung Reg., Yen-tung-shan Concession (SHOJI and YAMAZAKI, 1951)	Yen-tung-shan Region (NAITO, 1938)	Pang-chia-pu Region (MATSUDA and ASAHI, 1939)	Hsin-yao Region (OTANI and ASAHI, 1939)
Younger Rocks			Jurassic or Cretaceous Conglomerate and Sandstone	Jurassic or Cretaceous Volcanic Rocks	
Sinian System	Pang-chia-pu Series	Siliceous Sandstone Member 30 m±	Shui-mo Member 1,000 m	Upper Siliceous limestone Member 450 m±	Upper Siliceous limestone Member 300 m±
				Siliceous Sandstone Member 125–150 m	Siliceous Sandstone Member 140 m
		Lower Siliceous Limestone Member 95–110 m	Upper Limestone Bed 30 m Siliceous Clay Shale and Limestone, Alternating Bed 26 m Lower Limestone Bed 50 m	Lower Siliceous Limestone Member 130–200 m	Lower Siliceous Limestone Member 160 m
	Yen-tung-shan Series	Green Phyllite Member 10–13 m	Green Clay Slate Member 30 m±	Phyllite Member 20–90 m	Phyllite Member 40 m
		Iron-Bearing Member 20–25 m	Siliceous Claly Slate and Sandstone Member 20 m±	Iron-Bearing Member 3.9–8.9 m	Iron-Bearing Member 7 m
		Quartzite Member 65 m±	Quartzite and Siliceous Clay Slate Member 52 m±	Quartzite Member 80–110 m	Quartzite Member 110 m
		Clay Slate Member 60 m±	Clay Slate Member 150 m	Clay Slate Member 80–90 m	Clay Slate Member 80 m
San-kan Gneiss System					

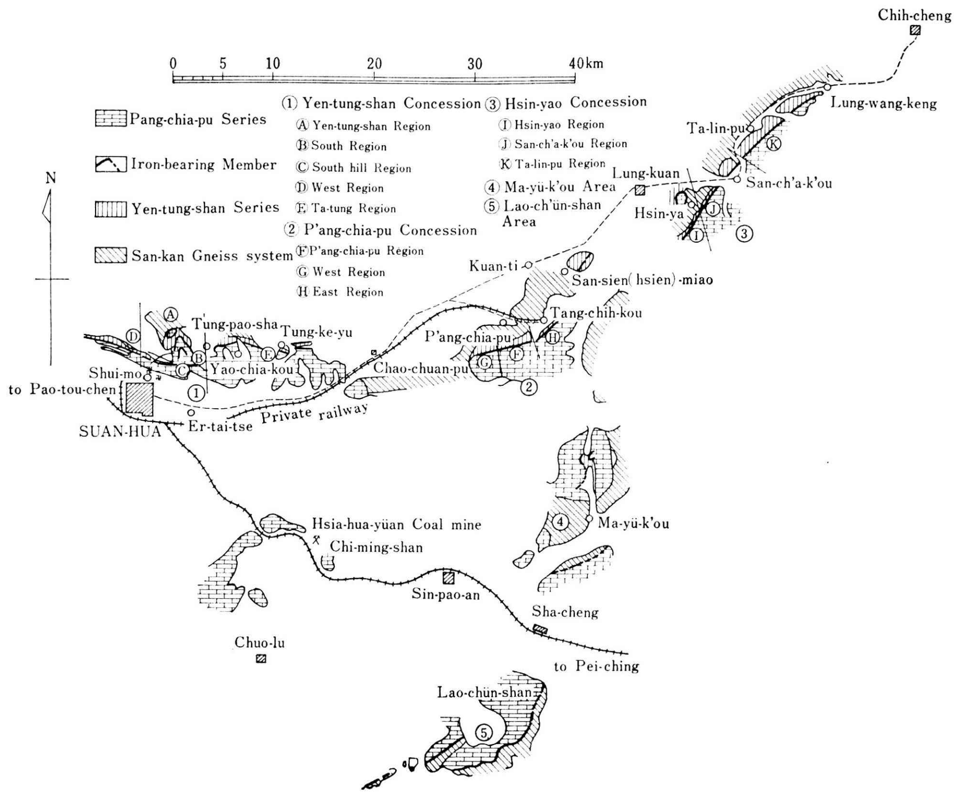

Fig. 2. Distribution of iron-bearing member in Lung-yen iron ore field.

south and practically without any folds. There are only two or three minor faults including a hinge fault with a throw of 10 m.

III. Sinian System

The results of correlation between strata of other concessions of Lung-yen iron ore deposits and those of this region are as follows: Since this region occupies only one part of the iron ore field where the iron ores of this horizon, are exposed, it may not be proper to propose the names of series as shown on Table 1, from the study of this region only. However, the name of Yen-tung-shan and Pang-chia-pu series will be used provisionally for the convenience of explanation.

The Pang-chia-pu series is to be correlated to so-called Nan-kou limestone in the Nan-kou valley, and the continuous exposure of the same horizon is not seen on account of fault, but the complex forms a mountain range. And the Yen-tung-shan series can be correlated to the clastic rock in the lower part of Nan-kou valley and the Ho-shan sandstone in Shan-si Province.

The Sinian system in the area surveyed by us and referred to in this paper, is about 1,900 m or more in thickness, but there is a 280 m geologic columnar section now available (see Fig. 3) only up to the lower part of the Pang-chia-pu series, as shown on Table 1. Even the actual thickness of Upper siliceous limestone only is over 1,500 m, as shown in Table 4, although there is no columnar section. The relation with the Sang-kan gneiss is unconformable, and the truncation of the schistosity of gneiss can be clearly seen from distance. There is no basal conglomerate but a rather arkose siliceous sandstone is seen at the direct contact with the unconformity plane. The unconformity plane has the strike of N80°E and the dip of 35°S, while the schistosity of gneiss is N30–40°E in strike and 35°S in dip, and the Sinian system shows the strike of E–W and the dip of 15°S. This unconformity plane and the Sinian system rest upon the erosion surface of gneiss in an overlapping form,[2] although this feature is seen only locally. This system is sometimes in contact with gneiss by fault in Yen-tung-shan and Hsin-yao, but there is no such occurrence in this region.

A. Yen-tung-shan Series

This series is a complex of clastic rocks, 160 m thick in this region and 200 m thick in Yen-tung-shan and other places, as shown on Table 1. Marked cross-bedding, sun crack or ripple mark, present the lithic character of shallow water facies. It can be divided into four parts distinctly. Namely, the lower part is phyllitic and siliceous clay slate, and upon it, there occurs thick white quartzite, forming cliffs, and then iron bearing member, and green phyllite in the uppermost part.[3]

The rock facies and the order of strata are equal to three other regions,[4] so correlation is achieved easily. The Yen-tung-shan region[5] is especially so short in distance that characteristics are common between the two, even in particulars.

1. *Clay Slate Member*

This is the thickest, namely 150 m, in the Yen-tung-shan region, 80–90 m in other regions, and thinnest, or 60 m or so, in this region. The rock facies is the same as to those in other regions. It is mainly composed of grayish green clay slate, which is phyllitic and exfoliates imbricately. It is divided into upper and lower parts.

The lower part contains compact and hard siliceous sandstone lenticularly or alternately, and the siliceous sandstone in the basal part, being in direct contact

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2) Possibly cross-bedding.

3) It corresponds nearly to "member" on page 17 of *the Report of Society for Research of Nomemclature of Strata*, and it is doubtful whether it should be called bed simply.

4) Three mine lots, Pang-chia-pu, Hsin-yao and Yen-tung-shan (western half of Yen-tung-shan mine lot).

5) Yen-tung-shan mine lot includes the Yen-tung-shan region, the southern contiguous region of Yen-tung-shan, the south mountain of Yen-tung-shan and the western contiguous region of Yen-tung-shan.

with gneiss, is rather arkose, and is with marked cross-bedding and includes small spots of iron hydrooxide. These sandstones get fine in granularity upward.

The upper part is composed of clay slate and reddish brown siliceous slate in alternation, but clay slate predominates in the lower part, while siliceous slates often contain ripple marks and sun cracks.

2. *Quartzite Member*

This forms remarkable cliffs upon the clay slate member and below the iron-bearing member, so it becomes a good index bed. It gets thick gradually from Yen-tung-shan to the east, as seen in Table 1. It is 65 m or so and often forms white cliffs, 30 m in height.

The quartzite is white, compact and hard, and partly sandy. It is composed of quartzites, 30, 70 and 17 m thick in lower, middle and upper parts, respectively, and two layers of dark purple siliceous slate, from 5 to 6 m thick, are inserted between them. The lower quartzite is abundantly spotted with iron hydro-oxide, 0.1–3 cm in diameter.

This bed has ripple marks and sun cracks all over the bed, especially in siliceous slate.

3. *Iron-bearing Member*

This member is from 20 to 25 m in thickness, and consists of siliceous slate, siliceous sandstone, quartzite, and iron ore beds, as shown in Fig. 3. The rock facies varies in both horizontal and vertical directions remarkably. In short, this is due to the gradual transition among siliceous sandstone, quartzite and ore bed. Therefore the iron ore bed itself is not definite in upper and lower limits, as well as in length and number of layers, but forms irregular lenses, concentrating in two beds, lying in the middle of the iron-bearing member, as seen in Fig. 4.

About 5 m in the uppermost of iron-bearing member is composed of remarkably characteristic siliceous sandstone, and forms cliffs with quartzite members, as already stated, so the location of the ore bed can be pointed out even from a distance. The iron-bearing member is rich in cross beds, ripple marks and sun cracks which will be discussed later, and sun cracks and rain drops, filled with iron, were discovered in Yen-tung-shan by T. TOMITA. These evidences and the remarkable variation of rock facies in horizontal and vertical directions suggest an environment of shallow water which often became land. Figure 4 shows a typical sections obtained from about 60 trenches made in this member.

This member is divided into four parts from rock facies. The lower part is mainly composed of bluish gray siliceous slate, often phyllitic, and about 7 m thick. The basal bed, 1 to 2 m thick, is a ferruginous, siliceous sandstone, often interbedded with siliceous slate. At its contact with the underlying quartzite is found a layer, about 1 cm thick and resistant to weathering, which consists of thin lamina of kidney shaped hematite ore of 1 to 2 mm in thickness. In the upper part, sandy iron ore is found which either contains ferruginous sandstone or forms a sandstone rich in oolitic hematite.

The middle part is composed of, in order from below, iron ore bed about 1 m

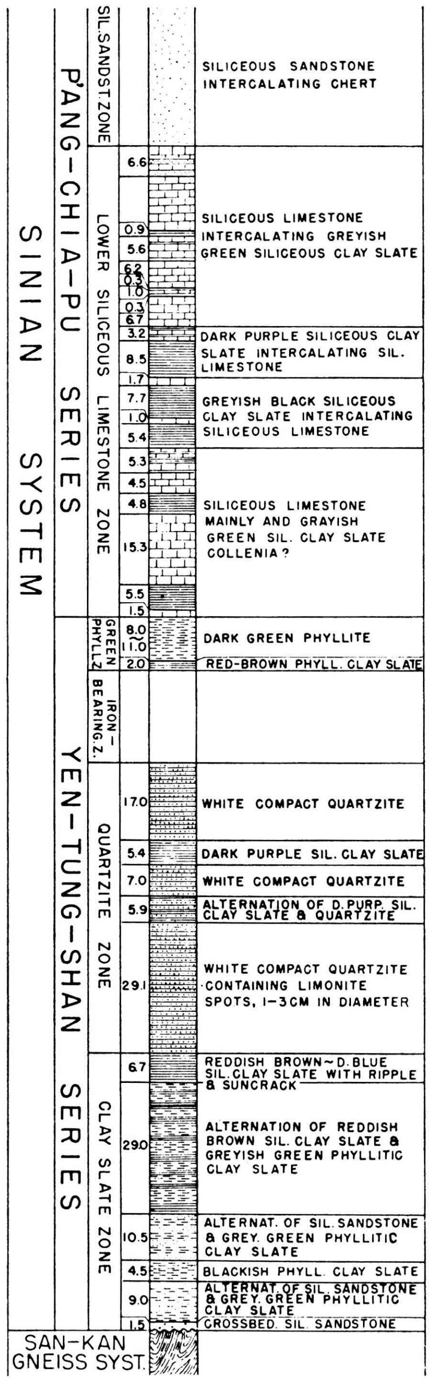

Fig. 3. Columnar section of the Sinian system in the Lung-yen iron ore field.

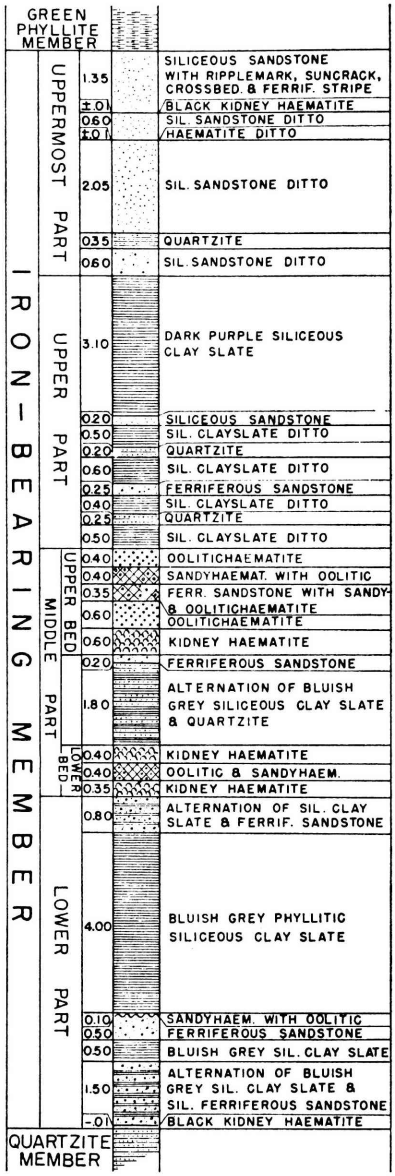

Fig. 4. Columnar section of the iron-bearing member.

thick, alternation of quartzite and siliceous slate about 2 m thick, and iron ore bed about 2 m thick, and occupies the important part of iron-bearing member which is about 5 m in its aggregate thickness. Concerning iron ore beds only, there is no one so thick as that of Pang-chia-pu, which is 4 m thick. Generally speaking, they are a little inferior to those of Yen-tung-shan region. These iron ore beds, quartzite, siliceous slate etc. thin out in lenticular shape remarkably even in iron ore-bearing member, and siliceous sandstone transits into ferruginous sandstone or sandy iron ore mutually as has been already stated. Accordingly one of two main iron ore beds sometimes thins out or transits into sandstone to leave another of the two. The combination of kidney, oolitic and sandy iron ores, composing iron ore bed, is not definite, but kidney portion is comparatively more persistent.

The upper part is mainly composed of dark purple colored siliceous slate, and intercalates only ferruginous sandstone and quartzite. This part is rich in sun cracks and ripple marks, and shows the Liesegang phenomenon of precipitation of iron. Sandy and oolitic iron ores are sometimes seen in this bed too.

The uppermost part consists of characteristic siliceous sandstone, about 5 m thick, as already stated, and forms often cliffs, and it is fine grained, compact, grayish white and banded with fine particles of iron, and is rich in cross beds, sun cracks and ripple marks. Green phyllite, lying directly upon an iron-bearing member, is eroded easily to expose this sandstone directly, so characteristic topography as flat platform or smooth slope along the strata, is formed. The lower part of this sandstone intercalates quartzite, about 1 cm thick or so, and kidney iron ore, 1 cm thick, occurs irregularly near the upper limit. This sandstone is developed similarly in Yen-tung-shan region too, but is lacking in Pang-chia-pu and Hsin-yao regions, and green phyllite bed in the upper horizon covers directly the dark purple siliceous slate of the upper part of an iron-bearing member.

Fig. 5. Iron ore beds, in San-cha-kou region of Hsin-yao concession. Kidney hematite and the state of alternation of siliceous slate and iron ore bed are seen distinctly. Left: M. FUJIWARA, Right: SHOJI.

3–1. *Iron Ore Beds*

The modes of occurrence of iron ore beds are as stated above. As to the studies from view points of ore deposit, petrology and mineralogy, detailed description has been already done by other authors. These topics are not the main object of this paper, so supplementary description only will be given in the following sections.

The iron ores can be divided into kidney, oolitic and sandy iron ores with naked eye, but there is no fundamental difference among them. Such differences are only due to the state of flow at the time of deposition, the difference in the supplied amounts between iron part and clastic materials,[6] and the difference in the velocities of feed. The origin of formation of oolitic iron ores is explained by many authors as follows: The iron part concentrates to form a film around the nucleus of a quartz particle suspended in water, and it becomes a small ball after rolling, and when it becomes a definite size (weight), it is deposited. In this process, if the iron part is too much and the flow is rather fast, deposition is narrowly performed, and starts only after the iron film gets thick. And if the feed of iron is much, kidney ore is formed. If the feed of clastic matters is much and the flow is slow, and deposition occurs previously before the iron film is formed, sandy iron ore, which is the mixture of oolitic and quartz particle, will be formed.

The oolitic hematite is an aggregate of oolites, 1–2 cm in diameter and equal size, it appears grayish black, and lustrous if fresh, but easily weathers into reddish brown color. Under a microscope, a quartz particle, fresh and rounded, is often seen in the center, but it is sometimes wholly lacking. The interstices among the oolites are often filled with similar quartz particles, but sometimes filled with calcites, M. WATANABE stated that the calcite deposited chemically from solution and always exists. But our comment is rather different from the above. Namely calcite appears as white veinlet in cracks of ore, and gets less in amount gradually away from this veinlet, and it cannot be found in that portion where there is no crack. Therefore the calcites seem to have percolated through cracks in groundwater secondarily, and has nothing to do with ore deposition.

KATO presented a mixture of hematite and clay as the cementing material, but clay could not be found under the microscope.

Quartz grains and quartz grains with their interstices filled with hematites are more in amount than calcite and clay in the cracks around oolites. Under a reflecting microscope, hematites are different to some extent in characters between the portion of oolites themselves and the portion filling their voids. The former is isotropic and tinted with gray color, while the latter is weakly anisotropic, and contains light colored portion, and the latter may be specularite.

After precise observation of the concentric bands of oolite, it is learned that minute needles of crystals radiate from the center of oolite. The whole part but the portion of quartz grain in the center, is composed of these crystals. The origin of bands is regarded as follows: If such crystals, to be formed in radiated shape from

6) Most of them are round particles of quartz.

the center, grows up to some certain length, namely, the film of crystal becomes thick to some extent, new crystal starts growing, and as a result, bands might be formed like annual rings.

The kidney hematite includes two types, i.e., a bamboo shoot-like one and mixed one of a bamboo shoot-like one and oolitic iron ore. The oolitic portion is as stated above. The bamboo shoot-like portion shows structure alike a pile of reverse cone of hematites, but particles of specularite like substance are found irregularly among hematites of this portion. The bamboo shoot-like bodies are arranged nearly in parallel to bedding plane, and each individual forms a gentle projection upward, and its upper surface appears kidney shape. This projection has parallel bands on its side plane, but minute needles of crystals develop perpendicularly to the bands, in the same with oolitic hematite.

The clastic materials[7] in these hematites are mostly quartz, but minute crystals of augite or zircon, commonly surrounded by hematite, are sometimes seen. These are rounded, but fresh. We did not find any feldspar.

The sandy hematite is an oolitic hematite rich in quartz grains so there is nothing to be stated specially. However, a thin vein, 5 mm long or so, of limonite was seen in the voids on the upper surface. The size is from 2 mm to 5 mm and O-plane and A-plane of octahedron are seen, so the crystal form is that of pyrite clearly and shows a hematite pseudomorph after pyrite. There are many examples of pyrite altered into limonite in Japan, but such examples are rarely found.

Table 2. Analyses of Lung-yen Iron Ores.

	Fe_2O_3	(Fe)	Si_2O	P_2O_5	S	$CaCO_3$	
Kidney Haematite	96.92	67.56	1.70	0.099	0.09	0.36	Extracting conical part, containing no oolite.
Oolitic Haematite	87.12	60.72	10.55	0.17	0.11	0.71	
Oolitic Haematite	78.89	54.99	9.40	0.17	Un-known	1.61	Lustrous, black

The results of chemical analysis are as shown in Table 2,[8] but as to kidney hematite, only a bamboo shoot-like body was picked up, and oolitic mixtures were excluded. Judging from the results, kidney hematite is almost pure hematite, as is shown by the results of microscopic examination. Oolitic hematite similarly contains rather large amount of SiO_2. Those indicated as black lustrous in the table occur in similar mode with hematite pseudomorph after pyrite as stated on the

7) According to KADOKURA (1939), 50% or so of the nucleouses of kidney hematites are quartz grain, 10% or so are amphibole and etc., 10% or so are magnetite or specularite, and the remaining 30% do not seem to have nucleous. Moreover, 90% of the nucleouses of oolitic hematites are quartz grain, 10% are amphibole, biotite altered into limonite, or clay grain. These clay grains may be orthoclase.

8) Analysed values and tenors are noted in details in many papers.

Table 3. Generalized Stratigraphic Order of Sinian System in Lung-yen Iron Ore Field.

System	Series	Formation	Thickness (m)	Lithic Character
		Mesozoic Volcanic and Sedimentary Rocks		Tuff, conglomerate and red sandstone
Sinian System	Pang-chia-pu Series	Upper Siliceous Limestone Member	1,500	Blackish gray-grayish white siliceous limestone, intercalating many blackish brown thin lenticular chert layers and reddish brown, blackish siliceous sandy shale.
		Siliceous Sandstone Member	125–150	Grayish white siliceous sandstone with ripple mark and cross-bed, intercalating light pink shale in upper part, limestone in middle and brown chert in lower.
		Lower Siliceous Limestone Member	95–160	Blackish-grayish white siliceous limestone in upper and lower parts, dark purple siliceous clay slate in middle part, containing Collenia? in lower limestone of the Member.
	Yen-tung-shan Series	Green Phyllite Member	10–90	Dark green-blackish phyllite intercalating light purple siliceous clay slate.
		Iron-bearing Member	5–25	Bluish gray-dark purple siliceous clay slate intercalating quartzite, ferruginous sandstone and 2–3 main iron ore beds. In Yen-tung-shan Concession, uppermost bed of this member is siliceous sandstone frequently cross-bedded, with ripple marks and suncracks.
		Quartzite Member	50–110	Hard compact white quartzite, intercalating dark purple siliceous slate, being rich in ripple mark, suncrack and in lower part, limonite spot 1–3 cm in diameter.
		Clay Slate Member	60–150	Mainly grayish green-blackish phyllitic clay slate rich in crossbed and ripple mark in upper part, siliceous sandstone in lower part.
		San-kan Gneiss System		

Table 4. Correlation Table of Sinian System in Lung-yen

		Lung-yen Iron Ore Field (Shoji and Yamazaki, 1951)	Nan-kou (Tien, C. C., 1923)	Western Hills of Pei-ping (Hsie, C. Y., 1936)
Cambrian				Man-tou Shale Mem.
Cambrian				Ching-erh-yu Limestone Mem. 100
Cambrian				Hsia-ma-ling Mem. 250–520
Sinian				Tieh-ling Limestone Mem. 300 Hung-shui-chuang 200
Sinian	Pang-chia-pu Series	Upper Siliceous Limestone Mem. 1,500	Upper Limestone Mem. 115–1,000	Wu-mi-shan Limestone Series 1,500
Sinian	Pang-chia-pu Series	Siliceous Sandstone Mem. 125–150	Quartzite Mem. 52	
Sinian	Pang-chia-pu Series	Lower Siliceous Limestone Mem. 95–160	Lower Limestone Mem. 78	
Sinian	Yen-tung-shan Series	Green Phyllite Mem. 10–90	White Quartzite Mem. 115	Huang-ling Quartzite Series 100–200
Sinian	Yen-tung-shan Series	Iron-bearing Mem. 5–20	Clay Slate and Shale Mem. 63	
Sinian	Yen-tung-shan Series	Clay Slate Mem. 60–150	White Quartzite Mem. 43	
	Sang-kan Gneiss System			

above. It appears on the surface of limonite filling cracks, and presents minute oolite, 0.5 mm, and kidney, 2 mm or so. They have a slightly resinous feel, and are purplish black in color, and not weathered even in outcrop. The analysed values show reduction of the amount of Fe, but no difference is found under a reflecting microscope. Besides, these analysed values are neither the average values nor those representative of the iron ore bed. They are for the small number of specimens now on hand.

4. *Green Phyllite Member*

This member is dark green partly dull colored characteristically, so it is clearly

Iron Ore Field and Ho-pei.

Chi-hsing-lung (Kao, C. S., 1934)		Ching-liang-shan (Ozaki, 1940)		
Man-tou Shale Mem.		Man-tou Shale Mem.		
Tsing-pei-kou Series	Ching-erh-yu Limestone Mem. 150	Ta-liu-shu Series	Up. Mem.	Limestone and Marl 190
	Hsia-ma-ling Mem. 360		Low Mem.	Shale, Sandstone and Conglomerate 85
Chi-hsien Series	Tieh-ling Limestone Mem. 350	Chao-bai-hu Series	Upper Mem.	Limestone 750
	Hung-shui-chuang Shale Mem. 200			Siliceous Sandstone 50
	Wu-mi-shan Limestone Mem. 1,150–1,500		Lower Mem.	Limestone 300
				Shale 300
	Yang-chuang Shale Mem. 410			Limestone 400
Nan-kou Series	Kao-yu-chuang Limestone Mem. 300–1,500	Ching-liang-shan Series		Siliceous Sandstone and Shale Mem. 195
	Ta-hung-yu Quartzite Mem. 50–400			
	Chuan-ling-kou Shale Mem. 480			Siliceous Sandstone and Conglomerate Mem. 300
	Chang-cheng Quartzite Mem. 650			
Tai-shan Gneiss System		Wu-tai System		

distinguished when viewed from a distance. It easily exfoliates along schistosity, and weathers into pieces. Naito (1938) described this as green clay slate in Yen-tung-shan, but we will assume it to be a phyllite member in order to match to the description of Hsin-yao and Pang-chia-pu. As already stated, it is eroded to large extent, and in extreme case, it is eroded out and limestone bed in the upper horizon covers directly the siliceous sandstone of the uppermost of iron-bearing member.

B. Pang-chia-pu Series

It overlies Yen-tung-shan series, consisting of clastic rocks, and is mainly composed of siliceous limestone, and intercalates siliceous sandstone, and amounts to several thousands meters in thickness. It is to be correlated to so-called Nan-kou limestone, in Han-kou valley, and this paper adopts the order of strata, already described in Pang-chia-pu and Hsin-yao for the type. NAITO proposed the Shui-mo member, new in Yen-tung-shan and correlated the underlying strata to Nan-kou limestone, but the Shui-mo member is clearly correlated to one part of the siliceous sandstone and upper siliceous limestone in Pang-chia-pu actually as seen in Table 1. And the Shui-mo member and its lower strata were summed in Pang-chia-pu series, because there is neither need nor reason to divide them into two.

This is correlated to Tien's order of strata in Nan-kou as shown in Table 4. The thickness of strata amounts to more than 1,000 m in maximum. The Pang-chia-pu series is covered by volcanic rocks or clastic rocks of the Jurassic or Cretaceous period in Yen-tung-shan and Pang-chia-pu, but it is confirmed that these younger deposits are lacking in this region, and upper siliceous limestone member extends, thickening southward, beyond this region.[9] However, we could not make a survey, because it was not the object of present investigation.

1. *Lower Siliceous Limestone Member*

This member mainly consists of siliceous limestone, and is from 95 to 110 m thick, and is exposed often in cliffs upon green phyllite members, and coincides more with the lower strata than the Shui-mo member after NAITO. It can be divided into three as NAITO did, but the boundaries are not clear on account of gradual transition.

About 35 m in the lower part is mainly composed of dull colored siliceous limestone, with intercalation of grayish green siliceous slate. The limestone is very siliceous, and is weathered to be light yellow colored. Siliceous slate increases gradually upward to form an alternation. The basal part of limestone shows concentric pattern of the Liesegang type in transverse section and reverse cone structure in longitudinal section, but these may be possibly *Collenia*. No one gave notice to *Collenia* in the Lung-yen iron ore field at that time, and at this juncture we can refer to only to TAKAHIRA's description that *Collenia* is thickly concentrated in this horizon and the upper horizon in Hsuan-hua. They seem to resemble in origin ferruginous concentric structure, seen in dark purple siliceous slate of the upper part of an iron-bearing member, already stated, and also to kidney hematite. If these are *Collenia* actual, a doubt may be dispelled about the idea that *Collenia* is due to algae. It is regrettable that there is no way to advance discussion with the data on hand.

About 30 m in the middle part is chiefly composed of dull or dark purple colored siliceous slate (varies into grayish green upward and downward), and intercalates thin bed of limestone.

The upper part is about 30 m thick too, starts from alternation of limestone and

9) See the article on the Sinian system as to the thickness used for the formation of geologic column and those simply measured.

grayish green siliceous slate, and changes into siliceous limestone with intercalation of thin bed of siliceous slate, rarely siliceous sandstone. The rock facies of limestone is equal to the lower part, but gets compact upward, and sometimes contains marly portion.

2. *Siliceous Sandstone Member*

This is thickly developed regularly to the south of the region. The strata are mainly composed of grayish white siliceous sandstone, and involves bands of thin beds of chert, brown or bluish green colored, compact, hard and sometimes irregular due to intraformational folding. As the result of selective weathering, chert is relieved to show clear pattern. This member has such characteristic bed as stated on the above, so it is easily correlated to other regions.

The upper part of this member includes so called red colored bed, including light red or purplish brown sandy shale, described in Hsin-yao and Pang-chia-pu, and suggests the deposits of specially dry climate. It is regarded as of Jurassic or Cretaceous period.

3. *Upper Siliceous Limestone Member*

This paper will not discuss the upper limit of this member, because it is in areas outside of this region, but the thickness of strata within this region amounts to more than 1,500 m. This member includes white chert, and sometimes the whole part is siliceous, and sometimes consists of dolomite or dolomitic rocks.

One of us (Shoji, 1950) has already published a paper describing briefly the rock facies and other aspects of this member.

IV. Correlation to Sinian System in Ho-pei Province

The order of succession of strata of this system within the Lung-yen iron ore field is correlated as shown in Table 1. This is further summed up in Table 3.

Many papers were published about the Sinian system of North China and the correlation to the strata in Manchuria and Korea, but there are many problems not yet solved. The object of this paper does not include the examination of these problems, so the correlation of those of Lung-yen iron ore field was done only with those of the Northern part of Ho-pei, such as Ching-liang-shan described by Ozaki (1941), Chi-hsien and Hsing-lung-hsien described by Kao (1934). The western hills of Peiping by Hsieh, etc., stratigraphical sequence of all of which were described recently and in details by Ozaki. The correlation among the above stated localities, except for Lung-yen, Chi-hsien and Hsing-lung-hsien had already been done by Ozaki. His correlation between Ching-liang-shan and western hills of Pei-ping is quite equal to Table 4. However, our comment is different from his, where he correlated so-called Nan-kou limestone by Tien to the whole of Chao-bai-hu series. It is stated in Article 3 B of the Pang-chia-pu Series, that Tien's Nan-kou limestone is correlated to the Pang-chia-pu. But Judging from order of succession, rock facies, thickness and etc., the lower part of the Chao-bai-hu series is correlated to the Pan-chia-pu Series. Consequently the lower part of the Chao-bai-hu, Nan-kou limestone and Pang-chia-pu series are arranged as shown in Table 4. Discussing further in detail, it follows that the shale of the lower part of Chao-bai-hu series is a heteropic facies of sandstone of the Pang-chia-pu series and quartzite of Nan-kou. Namely, all of them present distinct red color, indicating a dry climate, intercalate chert, have limestone in both upper and lower horizons, and include *Collenia* and chert. In short, they have many features in common. However, as to TAKAHIRA's *Collenia* from the lower limestone bed, TIEN (1923) observed them in the same horizon at Nan-kou too, but they are not described from Ching-liang-shan.

The correlation between KAO's Chi-hsien and Hsing-lung-hsien and Hsieh's western hills of Pei-ping is published as shown in Table 4 by the latter.

Comparing thickness of strata among the places in the table, KAO's complex, occupying the central portion of the area in the table, is remarkably thick, especially in the portion to be correlated to the Yen-tung-shan series. KAO emphasized the repetition, because of the two limestones, Kao-yu-chuang and Wu-mi-shan. But HSIEH (1936, 1937) could not distinguish two limestones from each other in the western hills of Pei-ping, so he summed them up in Wu-mi-shan limestone and did not state anything about the repetition. Anyhow, it shall be explained that the Pang-chia-pu series simply grew thicker in KAO's region.

If the above is true, the red shale member of Yang-chuang shall extend from east to west as it is, and shall serve as an index bed, even if it varies in its thickness.

The clastic rocks in the lower part of these thick limestone complexes are all correlated to the Yen-tung-shan series. HSIEH summed up in the Huang-ling quartzite the portion to be correlated to the Yen-tung-shan series after KAO in the western hills of Pei-ping because of thin thickness of the strata. KAO stated, after his inspection of the so called Yen-tung-shan series in Hsuan-hua, that the strata can be roughly correlated to the Chang-cheng quartzite and an upper member. OZAKI correlated the Ching-liang series to Huang-ling shale. Taking the above into consideration, quartzites in Nan-kou too shall be as a matter of course correlated to this horizon.

These are clastic complexes, so it is difficult to correlate them in detail in accordance with their rock facies only, but all are rich in cross beds, ripple marks and sun cracks, show shallow water facies and include characteristic limestone in the upper part, therefore these can be correlated roughly to each other. Iron ore beds seem to occur in the same horizon with that of the Yen-tung-shan series not only in the area cited on the table but all over North China. It is said that hematite occurs in Ching-hsing district and in Ho-shan, and according to TOMITA (1939). He discovered a boulder of kidney iron ore from the Nan-kou valley, and Li described a low grade iron ore, which transits gradually into septaria, 20 m thick, in the basal part of the Sinian system in the northeastern part of Ho-pei Province. These facts are interesting in showing the uniformity of rock facies.

Considering the thickness of these clastic rocks, the basin where these were deposited, has its center in Chi-hsien and Hsing-lung-hsien surveyed by KAO, and extended over to Nan-kou and Lung-yen in the west and further westward, to Ching-liang-shan in the east, and to Ching-hsing and Ho-shan in the south. And iron ores were deposited in various places, where the depths were moderate within the basin.

The base of the Sinian system consists of the Wu-tai system or Gneiss system, but the Wu-tai system as described by Tien at Nan-kou, has been amended by TOMITA, on the basis of a contact of intrusive rock of Post-Sinian period. Accordingly it was excluded from the table. Besides, according to him, he suspects that there is a similar case about the Wu-tai system in the base of the Ching-liang series.

The correlation of the upper strata than the Pang-chia-pu series is out of our scope of study, so the table was made in accordance with OZAKI's and HSIEH's.

However, LI found *Redlichia* of Lower Cambrian period from Ching-erh-yu limestone, and the limestone covers Hsia-ma-ling shale with conformity clearly. Therefore the para-unconformity lying beneath it was taken for the upper limit of the Sinian system.

The following is added, although all the occurrence are outside of the area concerned in this paper. YAMANE, HSIEH, KAO and WATANABE are not agreed, as to the correlation with each other of Tung-yu limestone, Tou-tsun clay slate or Tai-yang limestone, in Hu-to system by WILLIS and BLACKWELDER, and Sinian system of Shan-si Province.

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North Ta-tung Coal Field

Yoshio Onuki

I. Introduction

A. Location and Accessibility

The Ta-tung coal field is a general name of a coal-producing province lying southwest of the Ta-tung prefectural castle on the Pei-ching to Pao-tou railroad line. The coal field extends over Ta-tung, Tso-yun, Huai-jen, Shou-hsien, Ping-lu, and Yu-yu-hsien for about 150 km from northeast to southwest, and it varies from 17 km to 30 km in breadth from northwest to southeast. The total area is about 3,000 sq. km (See Fig. 1).

A branch line of the Pei-ching to Pao-tou line runs 20 km from the Ta-tung station to Kou-chuan in the northeastern part of the coal field; private tracks were laid for 4 km to Yung-ting-chuang, for 3 km to Mei-yu-kou, for 6 km to Pao-chin, and for 9 km to the Pai-tung mine. These lines still existed in 1945. The Ta-tung coal field lies to the west of Shuo-hsien on the North Ta-tung—Pu-chou line which extends from Ta-tung to Tai-yuan in Shansi Province. Coal mining is done by primitive methods in the western parts of Huai-jen, Tai-yueh-chen and Shou-hsien regions, and in the valleys which are located within an area tending from Ta-tung to Yun-kang to Tso-yun district of the coal field.

B. History of the Investigation of the Coal Field

1. *Investigation before the Mapping Survey*

Prior to 1937, the Tsin-pei Mining Bureau and the Pao-chin Co. operated mines at Yung-ting-chuang, Mei-yu-kou, and Pao-chin in the northeastern part of this coal field. In February 1938, the South Manchuria Railway Company was entrusted with the management of these mines, and the subsequent coal production increased. In January 1940, the Ta-tung Coal Mine Company was established, and the management was transferred from the South Manchuria Railway Co. to this new company. The Ta-tung Coal Mine Co. produced coal from the shafts at Yung-ting-chuang, Yu-feng (formerly Mei-yu-kou) and Pao-chin, and furthermore, opened new pits at Tung-chia-liang, Pai-tu-yao, Pai-tung, Pao-tsang and Showa (Chao-ho, in Chinese). The mines prospered to such an extent that the annual output amounted to 2,500,000 metric tons.

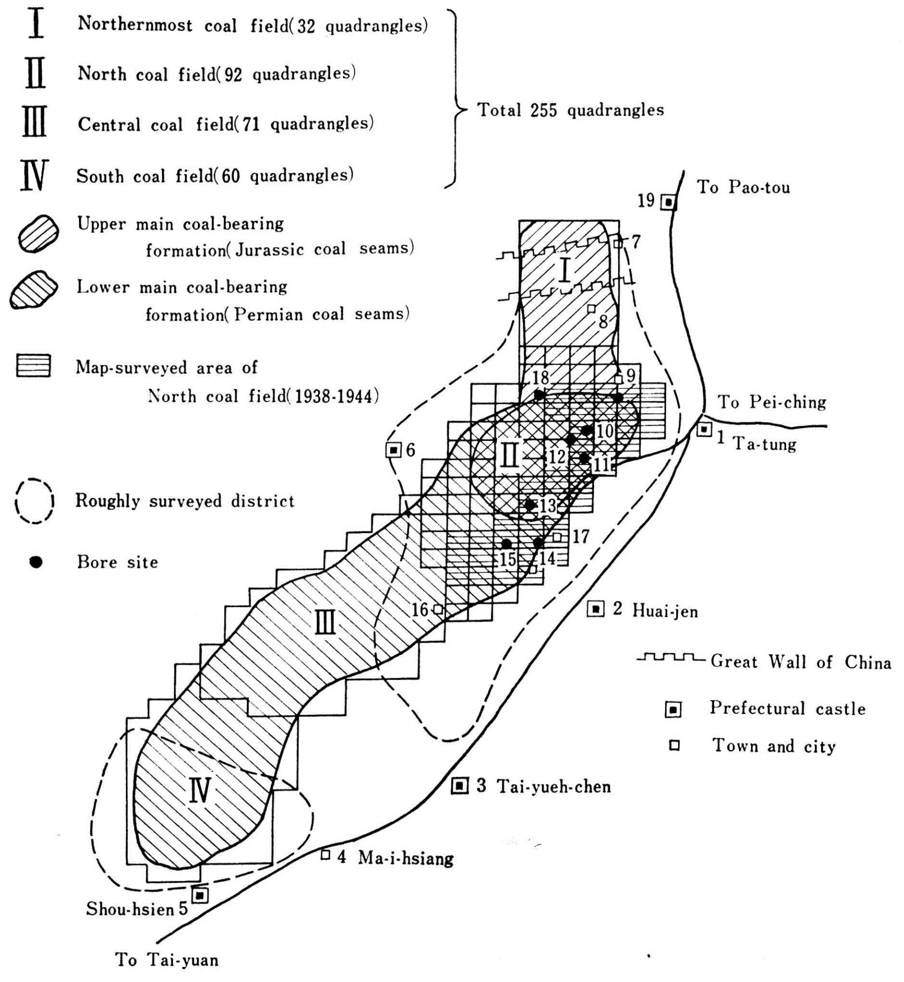


Fig. 1. Quadrangles of the Ta-tung coal field under survey (1938–1944).

1. Ta-tung
2. Huai-jen
3. Tai-yueh-chen
4. Ma-i-hsiang
5. Shou-hsien
6. Tso-yun
7. Kao-chia-yao
8. Chen-ho-pao
● 9. Yun-kang
● 10. Nan-hsin-chuang
● 11. Tiao-wu-tsui
● 12. Pai-tu-yao
● 13. Chang-liu-shui
● 14. Yao-tzu-tou
15. Wang-pien-chuang
16. Wu-chia-yao
17. E-mao-kou
● 18. Kao-shan-chen
19. Feng-chen

This coal field was first surveyed in 1919 by Sanno KADOKURA, a Japanese geologist, who pointed out its importance. Among the Chinese geologists, Wang Chu-chuan surveyed the entire coal field and reported the outline in 1921.

In 1936, Toshio TAKEYAMA, geologist of the South Manchuria Railway Co., surveyed the Kou-chuan district which is located in the northeastern part of this coal field. He discovered a kaolin deposit of superior quality in the Permian Coal Measure. In December 1937, Fusao UEDA, Hikoji MORITA, and Hajime YOSHIZAWA, geologists of the South Manchuria Railway Co., investigated the geology of the working areas of the Tsin-pei Mining Bureau and the Pao-chin Co. in the northeastern part of this coal field.

2. *Mapping Survey*

The detailed geological survey plan; for the overall coal field was established by the South Manchuria Railway Company in 1938, and the field party, the chief of which was Hikoji MORITA, was organized under the direction of Takao SAKAMOTO. According to this survey plan, the coal field was divided into 240 quadrangles each of which had an area of 12 sq. km.[1] These quadrangles were delimited by a set of parallel lines 4 km apart which estended from east to west and another set of parallel lines 3 km apart which extended from north to south. A detailed geological survey was scheduled to be performed in succession for every quadrangle. The field party was divided into the geology team, the surveying team and boring team. The surveying team made the topographic maps on a 1:10,000. After the actual surveying the geology team used these topographic maps for their general geological survey of which the primary purpose was the gathering of fundamental data for economic exploitation. This was done by emphasizing the modes of occurrence of the coal seams. Then, the boring team decided the bore sites and examined the boring cores. By 1940, the detailed survey of the following 13 quadrangles (156 sq. km) was completed, covering an area extending from Kou-chuan westward to Chang-liu-shui.[2]

1.	Yung-ting-chuang sheet	Hikoji MORITA
2.	Pai-tung-tsun sheet	Hikoji MORITA and Toshiji TAKAHASHI
3.	Yin-tang-kou sheet	Michisu MUKAI
4.	Ssu-lao-kou	Yoshio ONUKI
5.	Yen-yai sheet	Yoshio ONUKI
6.	Wei-chia-kou sheet	Yoshio ONUKI
7.	Lao-yao-kou sheet	Yoshio ONUKI
8.	Chang-liu-shui sheet	Yoshio ONUKI
9.	Mei-yu-kou sheet	Yoshio ONUKI
10.	Yu-feng mine sheet	Hikoji MORITA and Toshiji TAKAHASHI
11.	Pai-tu-yao sheet	Hikoji MORITA and Michisu MUKAI
12.	Pao-chin sheet	Chang LI-HSU
13.	Nan-hsin-chuang sheet	Chang LI-HSU

1) Up to 1943, the coal field was regarded as being 120 km long from NW to SE, 17–30 km long in breadth, and 2,400 sq. km in area. After investigations by H. Morita and C. Hasegawa in 1943–1944, the northern limit was widened and the area was greatly increased; total 250 quadrangles, 3,000 sq. km.

2) The stratigraphical results were compiled in "The Preliminary report of the Ta-tung Coal Field geologic survey party," and the outline was introduced by Chang Li-hsu in *Jour. Geol. Soc. Jap.*, vol. 48, no. 575, 147–150, 1941.

The results were published under the title of "The explanatory text to the Northern Ta-tung Coal Field geologic maps by the Industry Department, United Autonomies of Mongolia." The map survey investigators were Kenichi OKI, Kenkichi MASUBUCHI, Toshiji TAKAHASHI, Sakujiro KOIDE, Michisu MUKAI, Chang LI-HSU, and I, Yoshio ONUKI, and Hikoji MORITA who was chief of the party. I joined Hikoji MORITA in the Mongolian Resources Investigation Party, which was organized by the Mongolian government in 1939, and we surveyed the

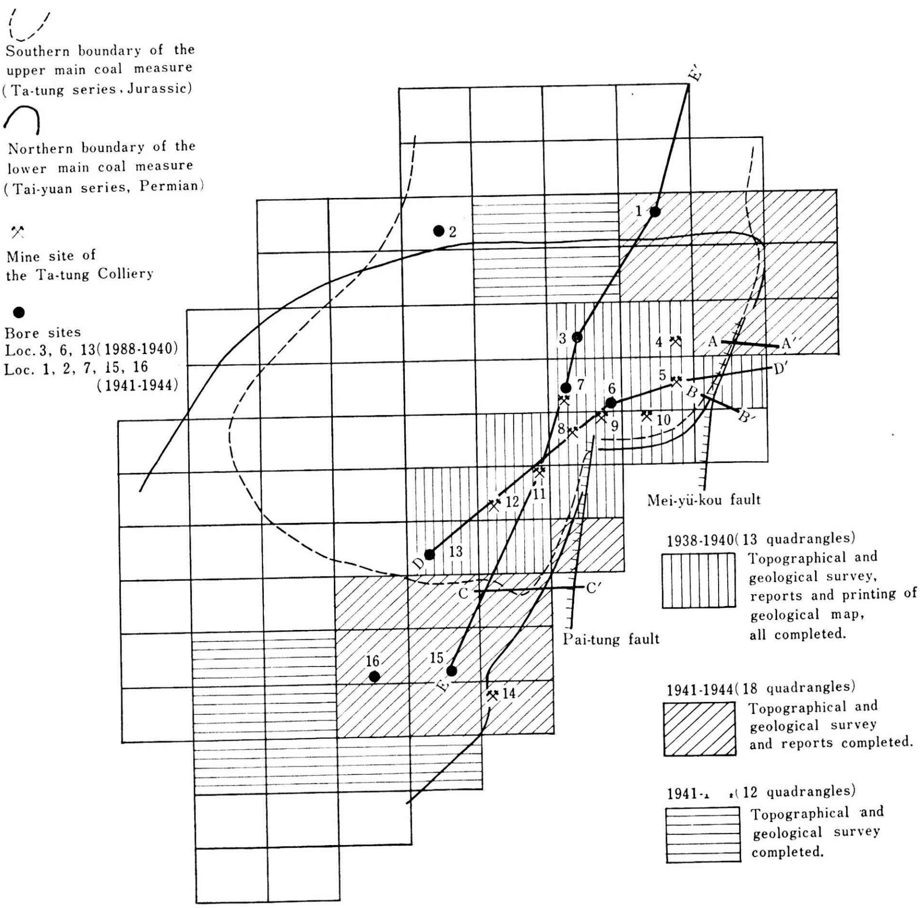


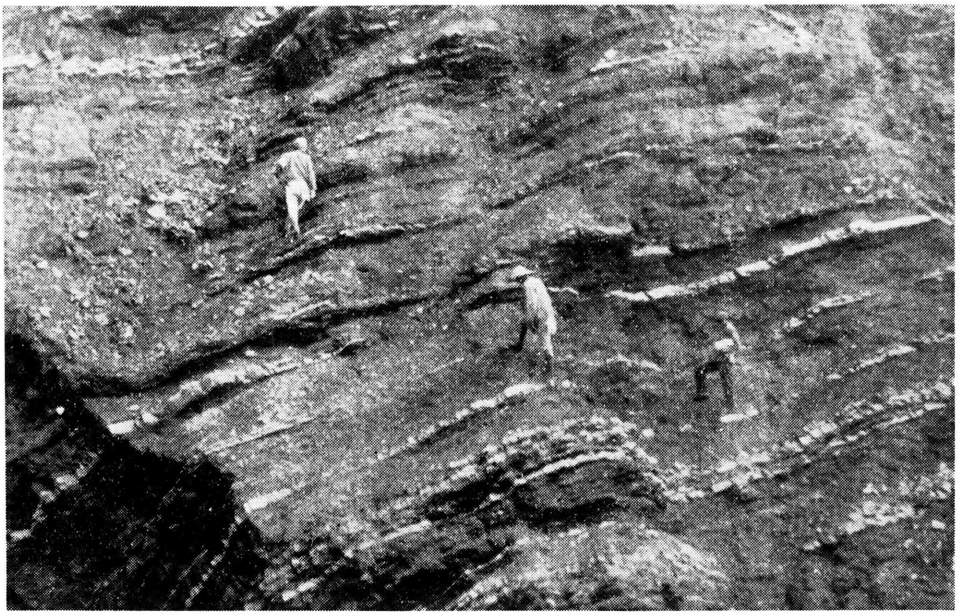
Fig. 2. Survey plan for making geological explanatory sheets (scale 1: 10,000) in north coal field.

● 1. Yun-kang
● 2. Kao-shan-chen
● 3. Nan-hsin-chuang
4. Pao-chin Mine
5. Yu-feng Mine
● 6. Tiao-wo-tsui
● 7. Pai-tu-yao Mine
8. Pai-tung Mine
9. Tung-chia-liang Mine
10. Yung-ting-chuang Mine
11. Pao-tsang Mine
12. Yen-yai
● 13. Chang-liu-shui
14. Shao-ho Mine
● 15. Yao-tzu-tou
● 16. Wang-pien-chuang

		(13) Nan-hsin-chuang B : 2.65 E : 5.88 d: 7.87 C: 0.73 E_1: 2.36 f : 7.20 D: 0.75 F : 3.58 D_1:1.20 G : 0.10	(12) Pao-chin B : 2.50 F : 1.20 d: 7.00 C: 1.00 G: 2.20 f : 5.00 D: 1.20 E : 4.00	
		(11) Pai-tu-yao B : 0.85 F : 1.20 b: 1.85 C: 1.10 G: 1.20 d: 15.15 D: 1.40 f : 3.80 E : 5.00	(10) Yu-feng coal mine A: 0.70 E : 3.50 b: 0.45 B : 1.60 F : 1.20 c : 0.85 C: 1.50 G: 1.20 d: 17.10 D: 1.80 e : 0.45 g : 3.80	(9) Mei-yu-kou B : 2.00 F : 1.30 d: 7.00 C: 1.50 G: 2.00 f : 3.50 D: 0.45 E : 2.80
	(3) Yin-tang-kou B : 1.00 F : 1.50 d: 15.00 C: 1.50 F_1: 1.50 f : 4.50 D: 1.00 G : 1.40 E : 5.00	(2) Pai-tung-tsun B : 0.85 F : 1.20 d: 10.00 C: 1.40 F_1: 0.55 e : 1.90 D: 1.80 G : 1.20 f : 3.80 E : 5.50	(1) Yung-ting-chuang B : 0.85 F : 1.20 b: 0.45 B_1: 0.50 F_1 : 0.55 c : 0.85 C : 1.40 G : 1.20 d:17.10 D : 1.40 G_1: 0.65 e : 0.45 E : 3.85 f : 3.80	
(6) Wei-chia-kou B : 0.80 F : 3.50 d: 15.00 C: 1.40 G: 2.00 f : 5.70 D: 0.50 E : 3.00	(5) Yen-yai B : 1.00 F : 2.00 d: 17.00 C: 1.60 F_1: 2.20 f : 6.00 D: 0.70 G : 1.70 E : 5.00	(4) Ssu-lao-kou B : 1.00 F : 3.00 d: 10.00 C: 1.60 G: 1.70 f : 4.50 E : 0.70 E : 4.00		
(8) Chang-liu-shui B : 0.80 F : 3.00 d: 15.00 C: 1.20 G: 3.00 f : 5.70 D: 0.50 E : 2.00	(7) Lao-yao-kou C: 1.40 G: 2.40 b: 0.60 D: 0.50 d: 18.00 E : 2.50 e : 1.50 F : 2.50 f : 8.00			

Coal seams of the Ta-tung series, Jurassic
A, B......G
Coal seams of the Shan-hsi series, Permian
a Upper No. 0 bed
b Upper No. 1 bed
c Upper No. 2 bed
Coal seams of the Tai-yuan series, Permian
d 20 meter bed
e Lower No. 1 bed
f 5 meter bed
g Lower No. 2 bed

Fig. 3. Thickness of coal seams (m) in each quadrangle of the north ta-tung coal field.



Outcrop of Tai-yuan "20m seam" at Chin-shan-ssu, Ta-tung coal field. (black: coal, white:kaolinite. The person in the middle is the writer.).

Wu-chia-yao district in the central part of the Shuo-hsien region in the southern coal field.

In 1941, the investigation work was assumed by the Investigation Bureau of the North China Development Co. and the survey was continued by Hikoji Morita, chief of the party, and others under the direction of Fujio Homma and Nobuo Yamanouchi. From 1941 to 1944, 12 sheets of maps for the area extending between Yun-kang-chen and Kao-shan-chen along the Shih-li-ho (144 sq. km), and 18 sheets of maps for the region extending from E-mao-kou in Huai-jen to Wang-pien-chuang (216 sq. km), were completed, and also the area extending from the north of the Shih-li-ho to the west of Feng-chen was surveyed in order to decide the northern limit of this coal field. The survey from 1941 to 1944 was chiefly directed by Hikoji Morita with Chozaburo Hasegawa and Kiyoto Kiyohara assisting; I examined some of the boring bores.

This survey work is summarized as follows (See Figs. 1, 2, and 3):

1938–1940

(a) Mapping survey of the Northern coal field between Kou-chuan and Chang-liu-shui, 13 sheets, 156 sq. km (See Fig. 3).

(b) Boring at three sites, i.e., Chang-liu-shui, Tiao-wo-tsui, and Nan-hsin-chuang.

(c) Rough survey of Wu-chia-yao district in the central coal field.

(d) Rough survey of the western region of Shuo-hsien in the southern coal field.

1941–1944

(a) Mapping survey of the area along the Shih-li-ho between Yun-kang-chen and Kao-shan-chen, 12 sheets, 144 sq. km.

(b) Mapping survey of the E-mao-kou—Wang-pien-chuang district in Huai-jen-hsien in the northern coal field, 18 sheets 216 sq. km.

(c) Rough survey of the western region of Feng-chen in the northernmost coal field.

(d) Boring at 5 sites, i.e., Yu-kang-chen, Kao-shan-chen, Pai-tu-yao, Yao-tzu-tou, and Wang-pien-chuang.

Table 1. Stratigraphic Order of Ta-tung Coal Field*

Period		Formation	Character	Thickness (m)
Quaternary		Alluvial formation	Loess, etc.	10–40
		Diluvial formation		2–80
			Conglomerate	2–5
			Basalt	40–100
Tertiary?		Tso-yun series	Red clay	150
Cretaceous?		Hun-yuan series	Andesitic agglomerate	5–30
		Nan-hsin series	Red shale and sandstone	25–160
Jurassic		Yun-kang series	White sandstone and conglomerate	30–100
Triassic (Uppermost)		Ta-tung series	Upper main coal measure	214–320
Permian	Upper	Huai-jen series	Red-colored rocks	0–340
	Middle	Shan-hsi series	Sandstone and shale	0–170
	Lower	Tai-yuan series	Lower main coal measure	0–130
Carboniferous	Middle	Ping-ting series	Shale and sandstone	0–45
Ordovician	Middle	Ordovician formation	Limestone and dolomite	0–300
	Lower			
Cambrian	Upper	Cambrian formation	Oolitic and worm-like limestone	35–450
	Middle			
	Lower	Man-tou series	Red shale and sandstone	0–170
Archeozoic		Sang-kan gneiss		

* This table is modified after Hikoji Morita. ········· Unconformity.

From 1938 to 1944, 43 sheets of maps totaling 516 sq. km were completed, and bores were made at 8 sites. Of the 43 sheets, printing of 13 with their explanatory texts were completed. Others were forwarded for printing or were being prepared for printing at the end of World War II so the report, unfortunately, was not completed. Moreover, Chozaburo HASEGAWA had summarized maps of 1:10,000 scale and made a geologic map of 1:50,000 scale, but this map was not printed.

II. Geology (I) Pre-Upper Paleozoic Era

A. General Remarks

Within this coal field and its marginal region, Sang-kan gneisses, Lower Paleozoic formations, Upper Paleozoic formations, Mesozoic formations, Tertiary complexes and Quaternary complexes were found. The nomenclature for these formations is shown in Table 1. The stratigraphic order and geologic structure of this coal field present an important key to the understanding of the general feature of the geologic order and of the crustal disturbance in North China.

B. Sang-kan Gneiss

This is the oldest rock series found in this coal field and is composed of granitic gneiss and schists of various kinds distributed on the eastern and the northern margin of this coal field.

C. Man-tou Series

This series consists of complex red-colored shale and sandstone belonging to the lower Cambrian period. It has conglomerate at the base, and it overlines the San-kan gneiss to form an angular unconformity. This series is distributed widely along the eastern margin of the coal field, and from a high point its distribution can be seen at a glance because the red-colored rocks are well exposed. This series has a zone containing pseudomorphs of salt discovered by Fusao UEDA in 1937 in the vicinity of Yao-tsu-fang on the southern foot of Chi-feng-shan (UEDA, 1939). The sandstone of this series sometimes contains ripple marks, which suggest the series was deposited in a wide lagoonal area at high temperatures and in a dry climate.

D. Middle and Upper Cambrian Formation

This formation consists of oolitic and worm-like limestone which occurs in zones in the eastern margin of the coal field, and forms the high and steep Kou-chuan mountains. It occurs with the dolomite and the limestone of the Ordovician period which will be described later. This series differs strikingly from the Man-tou series in its resistance to erosion, whereas the Man-tou series is brittle and weak and is apt to erode easily. When the Man-tou series occurs on a slope, the limestone of this series resting upon it forms conspicuous cliffs.

A fossil zone yielding *Ptychoparia orientalis* RESSER and ENDO, occurs in the upper horizon of the middle part of this series, and the upper part yield *Tsinania canens* (WALCOTT), *Prosaukia briioformis* ENDO, and *Eoorthis linnarssoni* WALCOTT.

This formation has a thickness of more than 300 m at E-mao-kou and the Kuo-chia-kou map sheet area west of Huai-jen, but it is approximately 50 m thick in the Ching-tzu-yao map sheet area along the Shih-li-ho west of Ta-tung. This may be due to erosion accompanied by crustal movement, as will be mentioned later. Much limestone of this formation is suitable for cement and iron manufacturing. The Mongolia Cement Co. is quarrying the limestone north of Ping-wang for the manufacture of cement.

E. LOWER AND MIDDLE ORDOVICIAN FORMATION

This formation is composed of dolomite and limestone, which contains *Collenia grandise* ENDO at the base. The limestone also yields *Maclurea* and primitive cephalopoda. This formation is 300 m thick in the southern part of the coal field and is found with Cambrian limestone, but it completely disappears in the northern part of the field as the result of erosion.

III. Geology (II) Lower Coal Measure

A. PING-TING SERIES

This name was recently given to the lower part of the old Pen-chi series. I divided the Pen-chi series in two; the lower part was renamed the Ping-ting series and the upper part the Ching-hsin series as the result of investigation of the Ching-hsing coal field. The Ping-ting series is well developed but the Ching-hsing series is absent in the North Ta-tung coal field. This series is composed mainly of shale and sandstone in alternation and intercalated with thin layer of limestone (Kou-chuan limestone); it covers the Ordovician formation unconformably, and the "G"-bed (a marker bed) of aluminous shale occurs at the base. A relation of unconformable overlapping between this series and the Lower Paleozoic formation changes gradually from south to north. Stratigraphically, this series overlies unconformably the Middle Ordovician formation in the south, and overlies the Cambrian formation in the north. The lowest stratum of this series outcrops in the south, and as one goes to the north, the strata of the upper horizons, resting upon the bed rock appear successively. It is thus clear that this series was deposited upon the Cambro-Ordovician formation from south to north in the state of overlap. This series is intercalated with limestone beds of 2.5 m to 4 m in thickness (Kou-chuan limestone) in the horizon from 12 m to 28 m above the base, and sometimes contains thin layers of coal seams which are unworkable. Within the surveyed area the Ping-ting series is 45 m thick in the south, and gets thinner toward the north, and disappears completely. This is due not only to deposition in the state of overlap, but also to erosion before the deposition of the Tai-yuan series, which will be described later.

The following fossils are known to be from the Kou-chuan limestone:

Ozawainella angulata (COLANI)
Fusiella typica LEE et CHEN
Fusulinella bocki MOLLER
Fusulinella Kon'noi (OZAWA)
Bradyina cf. *rothula* (EICHWALD)
Bradyina cf. *nautiliformis* MÖLLER
Bradyina sp.
Tetrataxis parviconica LEE et CHEN
Tetrataxis minima LEE et CHEN
Textularia cf. *exima* EICHWALD
Arachaenastraea manchurica YABE et HAYASAKA
Syringopora reticulata GOLDFUSS
Chaetetes penchiensis CHU
Spirifer cf. *nikitini* TSCHERNYSCHEW
Productus sp.

Among them, *Chaetetes* shows a characteristic mode of occurrence, and is yielded abundantly from masses of reefs. These masses are larger than a man's fist and are scattered like pebbles in the vicinity of the limestone which has been decomposed by weathering. It is known that this fossil occurs in the Nagaiwa series in the Kitakami district, Japan. There may be some stratigraphic relation between the two. This series is regarded as the same horizon as the Huang-lung limestone in Central and South China, and as the Pen-chi series[3] in Manchuria from the study of fusulinids, corals and brachiopods, etc.

B. TAI-YUAN SERIES

This series is mainly composed of shale and sandstone in alternation; the basal conglomerate which varies from 4 to 10 m in thickness, overlies the Ping-ting series with a disconformity in most places, but in the northern portion it unconformably overlies the Cambro-Ordovician formation. This series is intercalated with coal seams of the 20 m bed and the 5 m bed, but involves no limestone within the map survey area. The series includes two layers of marly limestone or calcareous shale which yields fossils of fusulinids, brachiopods and bivalves in the south area of this coal field and the Huan-yuan coal field. The states of the complex and the coal seams of this series are analogous to the Ta-tung and the Hun-yuan coal fields; the coal seams alternate with partings of kaolin; the maximum thickness amounts to 34 m. One of the seams is called "the 20 m bed", of which the coal is 8 to 10 m and the kaolin is about 12 m in thickness. This series is called the Lower main coal measure. According to the boring logs, this series is not developed northern area of the Ta-tung to Yun-kang to Tso-yun road. The Ta-tung series, which is the Upper main coal measure, extends northward to the west of Feng-

3) In Manchuria transgression happened earlier, and the lower limit is supposed to be older.

chen, so the area where both the Ta-tung series and this series is developed, is confined to the area west of Huai-jen to the Yun-kang—Tsu-yun road (See Fig. 1, and 6).

I collected the following fossils from the area between Kou-chuan and Chin-shan-ssu as well as from the map sheet area of Ssu-lao-kou and Lao-yao-kou:

1. *Tingia carbonica* (Schenk) Halle
2. *Tingia elegans* Kon'no
3. *Plagiozamites* cf. *oblongifolius* Halle
4. *Lepidodendron oculus-felis* (Abbado) Zeiller
5. *Stigmaria ficoides* Brongniart
6. *Annularia stellata* (Schlotheim) Woodward
7. *Calamites cisti* Brongniart
8. *Calamites Suckowii* Brongniart
9. *Sphenophyllum Thonii* Mahr
10. *Sphenophyllum emarginatum* Brongniart
11. *Sphenophyllum verticillatum* (Schlotheim) Brongniart
12. *Pecopteris hirta* Halle
13. *Pecopteris candolleana* Brongniart
14. *Pecopteris orientalis* (Schenk) Potonié
15. *Pecopteris arborescense* (Schlotheim)
16. *Sphenopteris tenuis* Schenk
17. *Sphenopteris* sp.
18. *Emplectopteris triangularis* Halle
19. *Cordaites principalis* Geinitz
20. *Cordaianthus* ? sp.

C. Shan-hsi Series

This series consists of sandstone and shale in alternation, and contains conglomerate at the base which has a maximum thickness of 20 m. This series appears as if it covers the Tai-yuan series with a disconformity. However, the outcrops of Tiao-wo-tsui, Yao-tzu-tou, and Chin-shan-ssu, and the bore logs of Tao-yao chu and Chang-liu-shui, revealed a shale bed, varying from 5 to 10 m in thickness, which rests upon the uppermost coal seam of the Tai-yuan series (20 m bed). On the other hand the outcrop of Lao-yao-kou and of the valley south of Kou-chuan, shale and the upper part of the coal seam are eroded so that the basal conglomerate of the Shan-hsi series directly overlies this coal seam (See Figs. 4 and 6).

The coal seams of this series are developed best in the map-sheet area of Lao-yao-kou, and these are named in order beginning with the youngest seam. They are the Upper No. 0 bed, the Upper No. 1 bed, and the Upper No. 2 bed,[4] but

4) At the boring of Tao-wo-chu No. 2, the coal seams were called the Upper No. 1 bed and the Upper No. 2 bed, but a new coal seam was discovered in the upper horizon during exploration of the Lao-yao-kou map sheet area, 0 bed was eroded out at the bore site of No. 2.

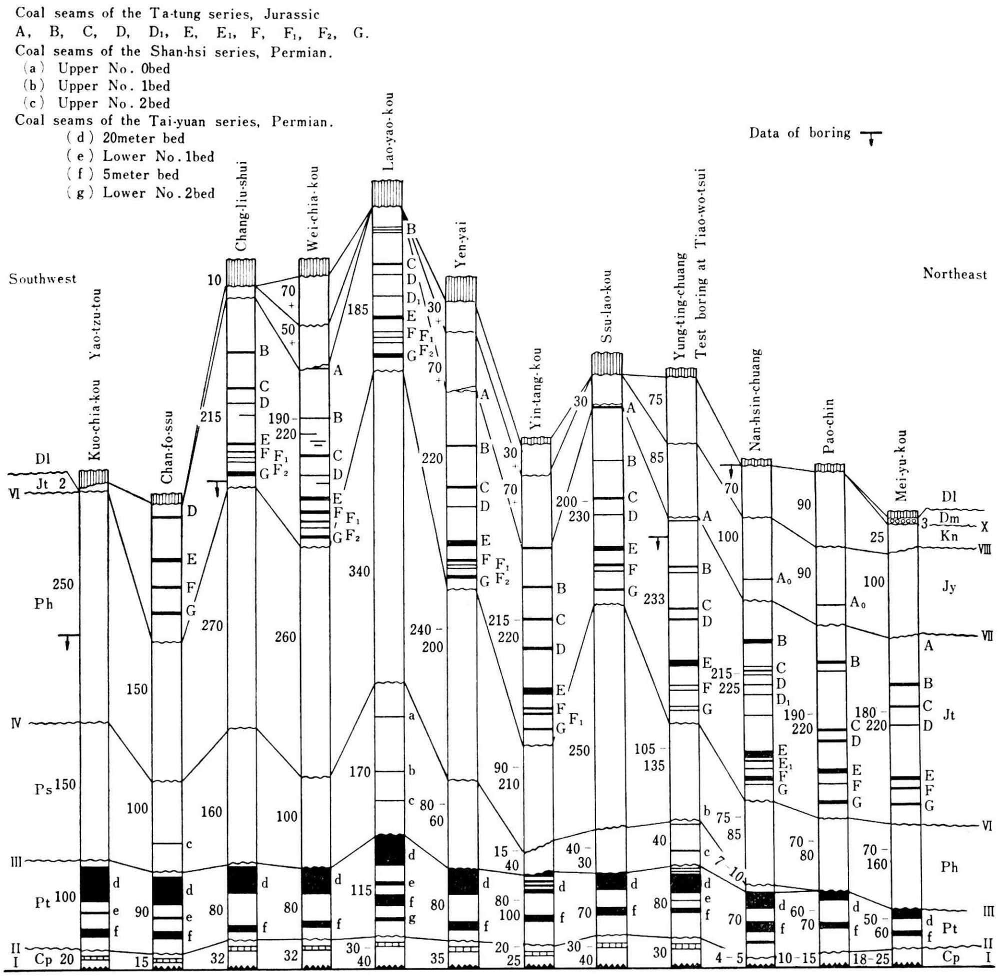
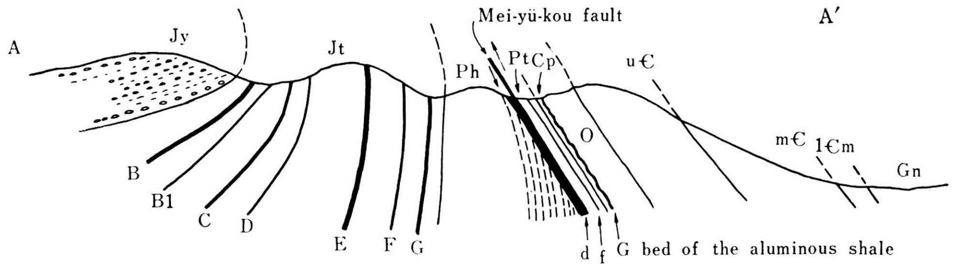


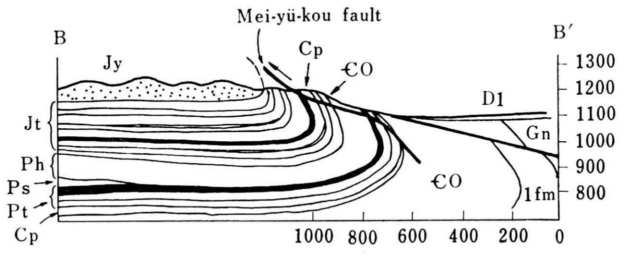
Fig. 4. Columnar-sections of the North Ta-tung coal field.

Dl: Quaternary, Loess
Dm: Quaternary, Mei-yu-kou Conglomerate
...... X (IX) ...... (Yen-shan movement)
Kn: Cretaceous, Nan-hsin series
...... VIII ...... (Feng-chen movement)
Jy: Jurassic, Yun-kang series
...... VII ...... (Pao-chin movement)
Jt: Jurassic, Ta-tung series (Upper main coal measure)
...... VI (V) ...... (Shan-tung movement)
Ph: Permian, Huai-jen series
...... IV ...... (Tsin-pei movement)
Ps: Permian, Shan-hsi series
...... III ...... (Chiao-tzo movement)
Pt: Permian, Tai-yuan series (Lower main coal measure)
...... II ...... (Tzu-hsien movement)
Cp: Carboniferous, Ping-ting series
...... I ...... (Tai-hang and Kai-luan movements)
CO: Cambro-Ordovician formations
Sequence determined by the test boring

A–A′: Section A–A′ is in the Lung-erh-kou map area which is bounded on the south by the Mei-yu-kou map area. The section was made from the photograph (taken by the author in 1939) of the north cliff of Lung-erh-kou as viewed from a point located on the western part of the boundary line which separates the above two map areas.



B–B′: E–W section in the Geological Map of Mei-yu-kou (After the author's original)



C–C′: E–W section in the Geological Map of Kuo-chia-kou

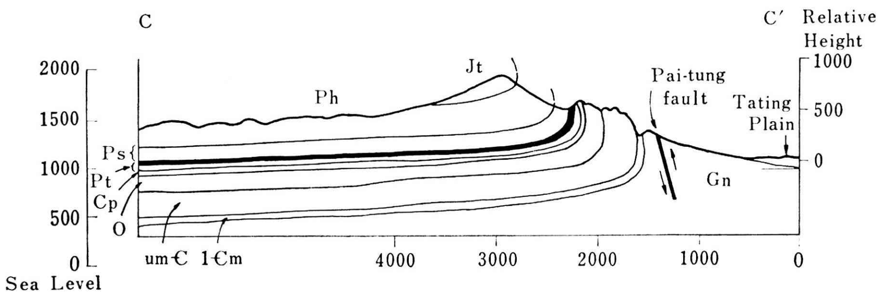


Fig. 5. Cross sections of the North Ta-tung coal field (1).

Dl : Diluvium or Alluvium (loess, etc.)
Jy : Jurassic, Yun-kang series
Jt : Jurassic, Ta-tung series
Ph : Upper Permian, Huai-jen series
Ps : Middle Permian, Shan-hsi series
Pt : Lower Permian, Tai-yuan series
Cp : Middle Carboniferous, Ping-ting series
O : Ordovician (Lower to Middle)
CO : Cambro-Ordovician
uC : Upper Cambrian
mC : Middle Cambrian
lCm: Lower Cambrian, Man-tou series
Gn : Sang-kan gneisses

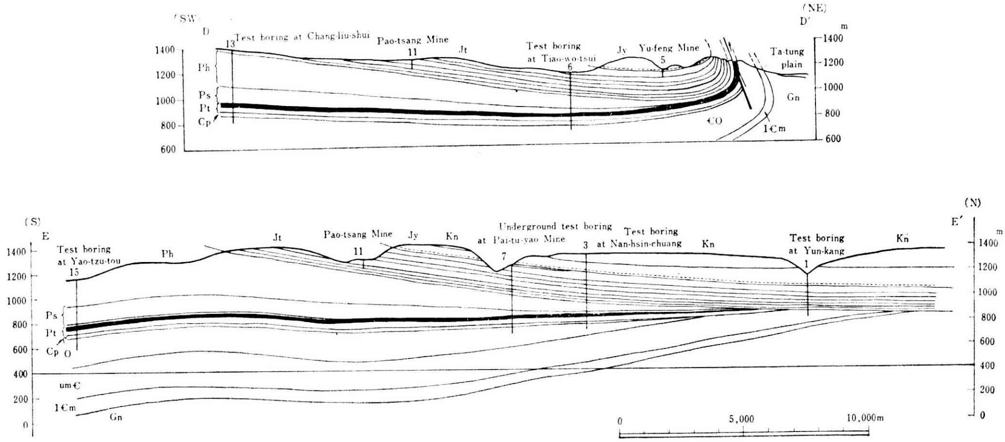


Fig. 6. Cross sections of the North Ta-tung coal field(2) (Legend: same as Fig. 5).

1. Test boring at Yun-kang
3. Test boring at Nan-hsin-chuang
5. Yu-feng Mine
6. Test boring at Tiao-wo-tsui
7. Underground test boring at Pai-tu-yao Mine
11. Pao-tsang Mine
13. Test boring at Chang-liu-shui
15. Test boring at Yao-tzu-tou

these are generally thin and less than 0.8 m in thickness. These change to thin layers of coal seams, to coaly shale, or they thin out completely in the area of Kuo-chia-kou map sheet, and in the bore of Chan-liu-shui.

A remarkable unconformity is seen between this Shan-hsi series and the Huai-jen series, which overlies the former. The Shan-hsi is about 170 m thick and intercalates the Upper 0 bed, the Upper No. 1 bed, and the Upper No. 2 bed in the area of Lao-yao-kou map sheet. The bore log at Tiao-wo-tsui shows that the thickness is reduced to about 40 m and that the Upper No. 0 bed has already disappeared. The bore log at Nan-hsin-chuang shows that the thickness is reduced to only several meters due to erosion, and finally in the area along the Yun-kang—Tso-yun road (boring at Yun-kang-chen and Kao-shan-chen) this series is completely eroded away. Therefore at this point the thickness of this series which has been eroded away is greater than 170 m.

I collected the following plant fossils from the Shan-hsi series while doing the exploration work for the Ssu-lao-kou and Lao-yao-kou map sheets:

1. *Plagiozamite* sp.
2. *Lepidodendron oculus-felis* (ABBADO) ZEILLER
3. *Stigmaria ficoides* BRONGNIART
4. *Lobatannularia* sp.
5. *Calamites cisti* BRONGNIART

6. *Calamites Suckowi* BRONGNIART
7. *Sphenophyllus Thonii* MAHR
8. *Sphenophyllum Thonii* var. *minor* STERZEL
9. *Protoblechnum* sp.
10. *Sphenopteris Gothani* HALLE
11. *Emplectopteris triangularis* HALLE
12. *Taeniopteris* sp.
13. *Cordaites principalis* GEINITZ
14. *Cordaites Schenkii* HALLE
15. *Pterophyllum nilssonioides* KAWASAKI

D. HUAI-JEN SERIES

This series, up to 1940, was called the "Shuang-chuan series" in the explanatory text of geologic map. It is a red-colored rock complex of shale, sandstone and conglomerate. A thick basal conglomerate occurs in the base of this series which covers the Shan-hsi series unconformably. The thickness of the Huai-jen series varies according to the relation of the unconformity to the lower complexes and the Ta-tung series in the upper horizon. The thickness is about 250 m in the map sheet area of Wang-pien-chuang and Yao-tzu-tou, and 150 to 340 m in the map sheet area of Lao-yao-kou, Chan-fo-ssu, and 270 m at the bore site of Chang-liu-shui, and 105 m or so at the bore site of Tiao-wo-tsui and 75 m at the bore site of Nan-hsin-chuang. The Huai-jen series does not exist in the vicinity of the Yun-kang to Tso-yun road. If this series is traced from south to north, the lower complexes which occur in the south are not found in the north, and it is suggested that the sedimentation of this series was started in the south, and a rather long time was needed before deposition occurred in the northern extremity (See Fig. 4).

No fossils were found in this series up to 1940, and the series was correlated with the Shuang-chuan series on the basis of the rock facies only. But Chozaburo HASEGAWA, geologist of the North China Development Co., discovered *Lepidodendron* in the northern area of Wang-pien-chuang within the map-sheet area of Wang-pien-chuang upstream from E-mao-kou in Huai-jen-hsien in 1942. There is a first fossil zone yielding *Lepidodendron* and *stigmaria* etc. abundantly in a horizon about 30 m below the base of the Ta-tung series, i.e. in the upper horizon of the Huai-jen series. A second zone which mainly yields Sphenophyllum and Pecopteris, occurs in a horizon 17 m below the zone mentioned above. A third Cordaites zone lies 70 m below it.

Hikoji MORITA identified the following fossils from the Huai-jen series:

1. *Tingia partita* HALLE
2. *Lepidodendron oculus-felis* (ABBADO) ZEILLER
3. *Lepidodendron Gaudryi* RENAULT
4. *Lepidodendron* sp.
5. *Sigillaria* sp.
6. *Stigmaria ficoides* (STERNBERG) BRONGNIART

7. *Annularia gracilescens* HALLE
8. *Annularia mucronata* SCHENK
9. *Calamites Suckowii* BRONGNIART
10. *Sphenophyllum Thonii* MAHR
11. *Sphenophyllum Thonii* var. *minor* STERZEL
12. *Sphenophyllum sino-coreanum* YABE
13. *Sphenophyllum verticillatum* (SCHLOTHEIM) BRONGNIART
14. *Pecopteris orientalis* (SCHENK) POTONIÉ
15. *Pecopteris arcuata* HALLE
16. *Pecopteris Anderssonii* HALLE
17. *Pecopteris Wongii* HALLE
18. *Pecopteris hirta* HALLE
19. *Pecopteris taiyuanensis* HALLE
20. *Pecopteris Norinii* HALLE
21. *Pecopteris (Ptychocarpus) unita* BRONGNIART
22. *Callipteridium trigonum* FRANKE
23. *Gigantopteris* ? sp.
24. *Sphenopteris pseudogermanica* HALLE
25. *Alethopteris ascendens* HALLE
26. *Protoblechnum Wongii* HALLE
27. *Taeniopteris latecostata* HALLE
28. *Taeniopteris multinervis* WEISS
29. *Pterophyllum nilssonioides* KAWASAKI
30. *Plagiozamites oblongifolius* HALLE
31. *Cordaites Schenkii* HALLE
32. *Cordaites principalis* GEINITZ

On the basis of these fossils, this series is correlated to the Upper Shih-ho-tzu series in Shan-hsi Province, the Tsai-chia series in Manchuria and the Kobosan (Kopansan) series in Korea, and is regarded now as the Upper Permian formation. Therefore this series which was treated as the Shuang-chuan (?) series in the past, now has the new name of the Huai-jen series given to it by Hikoji MORITA and Chozaburo HASEGAWA.

IV. Geology (III) Upper Coal Measure

A. TA-TUNG SERIES

This series consists of white or light brown sandstone and dark gray or black shale in alternation. It has the thickness of 220 m or so, and covers the Huai-jen series with a disconformity. The relation between this series and the underlying Huai-jen series was regarded as being conformable at the beginning of the map survey, but Chozaburo HASEGAWA observed that the basal conglomerate of this series overlies the Huai-jen series with a distinct unconformity in the upper reaches of E-mao-kou in Huai-jen Prefecture. The southern limit of this series is in Kuo-chia-kou northwest of Huai-jen and in the northern part of the map-sheet area of Ta-ching-kou, where only basal conglomerate remains to cap the mesas. This basal conglomerate changes gradually into conglomeratic sandstone toward the north. The relation between the Ta-tung series and the lower series of formations is not clear in their stratigraphical sequence in the E–W cross section, but is very clear in the N–S cross section. In the southern part of this coal field there is a stratigraphic gap between this series and the Huai-jen series. This gap (time-interval of a missing formation) corresponds to the Shih-chien-feng series of the Tai-yuan district. In the northern margin of the coal field the Ta-tung series directly overlies the Cambrian formation and gneiss and is lacking the formations below the Huai-jen series showing that the gap (hiatus) was very great before the deposition of the Ta-tung series (See Figs. 4 and 6).

The Ta-tung series contains coal seams A, B, C, D, E, F and G, all of which are important workable seams in the North Ta-tung coal field and forms a part of the Upper coal measure.

According to Nikoji MORITA the flora of this series are as follows:

1. *Cladophlebis shansiensis* PAN
2. *Cladophlebis haiburnensis* (LINDLEY and HUTTON)
3. *Cladophlebis gigantea* OISHI
4. *Coniopteris hymenophylloides* BRONGNIART
5. *Hausmania leciane* SZE
6. *Zamiophyllum Buchianum* (ETTINGSHAUSEN)
7. *Nillsonia simplex* OISHI
8. *Ginkgo magnifolia* (FANTAINE)
9. *Czekanowskia rigida* HEER
10. *Phoenicopsis speciosa* HEER
11. *Phoenicopsis angustifolia* HEER
12. *Elatocladus plana* (FEISTMANTEL)
13. *Pagiophyllum setosum* PHILLIPS
14. *Elatides obalis* HEER
15. *Elatides chinensis* SCHENK
16. *Podozamites lanceolatus* (LINDLEY and HUTTON)

The geologic age of the Ta-tung series is regarded roughly as the uppermost Triassic–Lower Jurassic (Rhaetic–Lias).

B. YUN-KANG SERIES

The Yun-kang series was divided into the lower and upper beds, but the lower bed only is now called the Yun-kang series because there is a striking difference between the upper and the lower bed in facies. The upper bed is now called the Nan-hsin series from the name of the bore site of Nan-hsin-chuang. The basal conglomerate of the Yun-kang series varies from 6 to 10 m in thickness and covers the

Ta-tung series unconformably. This unconformity is observed clearly in the valley of Pao-chin and coal seam "A" which is the uppermost seam in the Ta-tung series and the complex involving the seam were eroded away and were not found.

The Yun-kang series is composed of grayish-white sandstone or conglomeratic sandstone, and intercalates one or two layers of conglomerate, several thin layers of greenish-gray shale, and thin coal seams. The total thickness varies from 30 to 100 m, and the famous stone Buddha of Ta-tung is carved in the sandstone of this series at Yun-kang-chen.

Hikoji MORITA collected the following fossils from the horizon, 15–20 m above the base of the Yun-kang series.

1. *Cladophlebis* aff. *gigantea* OISHI
2. *Cladophlebis* sp.
3. *Coniopteris hymenophylloides* BRONGHIART ?
4. *Czekanowskia rigida* HEER
5. *Phoenicopsis speciosa* HEER
6. *Podozamites* ? sp.

There is a conspicuous unconformity seen between Yun-kang series and the Ta-tung series, but no remarkable difference is seen in the fossils and the geologic age is regarded as being Middle or Upper Jurassic period.

C. NAN-HSIN SERIES

This series is composed of sandstone, sandy shale and shale. The sandstone, often containing small bean-sized pebbles, is noticeably false-bedded and is parti-colored such as grayish white, greenish, yellowish brown, dark-reddish purple, etc. The shale and the sandy shale are on the whole conspicuous dark-reddish purple, often greenish, in color. The type of sedimentation differs even in the same horizon, and concretions of head size are found in some zones.

There are remarkable differences in rock facies and in the state of sedimentation between the Yun-kang series and the Nan-hsin series. The Yun-kang series contains coal, coaly materials and impressions of plant fossils. However, the Nan-hsin series contain no remains of plants. This is a remarkable contrast between the two, and these two series are regarded as forming a disconformity. The geologic age of this series is unknown, but it is provisionally correlated to the Cretaceous (?) Chiu-lung-shan series in Peking-Sishan.

V. Condition of Deposition and Crustal Movement

A. CONDITION OF DEPOSITION AND CRUSTAL MOVEMENT

The condition of deposition of the Upper Paleozoic formation, the Mesozoic coal measure, their relating complex, and the outline of the crustal disturbance will be noted.

The northern portion of this coal field stands on the northern margin of the deposition basin. The marginal facies were affected sensitively even by the slightest disturbance. This disturbance is shown by the unconformities found in every complex, and it is one of the criteria for the determination of crustal movements in the Paleozoic and the Mesozoic eras. Prominent deposition and crustal movements are listed as follows (See Figs. 4 and 6).

a. After the deposition of the Ordovician formation, the land was raised. The amount of upheaval in this movement increased toward the north. As the result, the Ping-ting series was deposited upon the Lower Ordovician formation in the north.

b. In the middle part of the Middle Carboniferous period, small transgression began gradually, and the Ping-ting series was deposited (Kai-luan movement).

c. After the deposition of the Ping-ting series, regression occurred. The Upper Carboniferous period was the time of erosion (earlier stage of the Tzu-hsien movement).

d. In the Lower Permian period transgression started and the Tai-yuan series was deposited in the state of overlap, and thick coal seams and kaolin beds were developed (later stage of the Tzu-hsien movement).

e. Next, regression took place again and erosion was carried out. All deposits thereafter in North China are terrigenous deposits (earlier stage of Chiao-tzu movement).

f. In the Middle Permian period, terrigenous overlapping took place and the Shan-hsi series was deposited. Several layers of thin coal seams were formed in this region too (later stage of Chiao-tzu movement).

g. After the deposition of the Shan-hsi series, epeirogenic movement occurred. The amount of movement was great toward the north. The Shan-hsi series, which is 170 m thick in the map-sheet area of Lao-yao-kou, is not developed from Nan-hsin-chuang to Yun-kang, and the Tai-yuan series, lying beneath the Shan-hsi series is partly eroded (earlier stage of Tsin-pei movement).

h. After this interval of opeirogenic movement and erosion, the Huai-jen series, an inland facies, was deposited (later stage of Tsin-pei movement).

i. After the deposition of the Huai-jen series, opeirogenic movement occurred again. The amount of movement increased from south to north also (earlier stage of the Shan-tung movement).

j. Thereafter, the formation of the basin on a large scale was carried on again, and the deposition of the Ta-tung series, which is the upper main coal measure of this coal field occurred. The Ta-tung series covers the Huai-jen series disconformably in the south, but as one goes to the north it directly covers complexes lower than the Huai-jen series in the area north of the Great Wall of China, it directly covers the Sang-kan gneisses (later stage of Shan-tung movement).

k. After the deposition of the Tai-tung series, this district was upheaved again and eroded. Thereafter, the Yun-kang series containing thin coal seams was deposited accompanied by subsidence (Pao-chin movement).

l. Then, the Nan-hsin series, which is composed of green-colored rocks in red-colored rocks and presents a land facies, was deposited. The age remains unknown because no plant remains have been found yet (Feng-chen movement stage).

m. Thereafter, crustal disturbance of small degree (Heng-shan movement) occurred, and the Hun-yuan series was deposited, which shows that the Yen-shan movement had started. The Yen-shan movement in the North China—the great disturbance which divided the Mesozoic era from the Cenozoic era—took place later.

B. Geologic Structure of the Northern Coal Field

Geological structure seen in the sections from east to west and from north to south will be explained for the purpose of understanding the general geologic structure of the North Ta-tung coal field (See Figs. 5 and 6).

1. *E-W Profile*

The Ta-tung series is deposited almost horizontally in the area from Yung-ting-chuang to Tiao-wo-tsui in the west and as one goes toward the eastern margin the dip to the west increases gradually to be vertical; then the dip changes to the east, and thus the lower horizon appears. Tracing this condition from Kou-chuan, on the eastern margin, to Ping-wang, a thrust structure whose hanging wall has moved from east to west is seen. Many faults striking E–W and dipping 15° to 30°E are found, and coal seams are often compressed to disappear (See Figs. 5 and 6 D–D′). The Ta-tung coal field region appears to be a tableland which has been elevated above the Ta-tung plain. This feature is due to the fact that a complex of hard limestone bent upward forms the eastern wing; this wing protects the coal seams in the west and forms a synclinal mountain.

The Ta-tung coal field, i.e., the Northern, Central and Southern coal fields, extends southwestward. Thrust faults, striking northeasterly are arranged side by side. Every fault is thrusted from the east; the amount of thrust increases toward the south and disappears toward the north. One hinge fault was found in the interior of the coal field (See Fig. 2).

Next, the E–W internal structure of the coal field area between Yung-ting-chuang and Chang-liu-shui will be discussed. The Ta-tung series is nearly horizontal between Yung-ting-chuang and Tiao-wo-tsui as already stated, but as one goes westward from Tiao-wo-tsui to Ssu-lao-kou, Yen-yai, and then to Chang-liu-shui, the rock series of lower horizons appear gradually, and gently dip to the east. Coal seam B occurs about 30 m above the bottom of valley at Tiao-wo-tsui, but coal seam D occurs about 10 m above the road in the vicinity of Ssu-lao-kou. Coal seams E and F appear in the vicinity of Yen-yai. Therefore, even if the difference of altitude above sea level of these points are considered, the Ta-tung series is dipping slightly to the east.

However, the E–W profile of the Tai-yuan series shows that the 20 m bed, which is exposed in Kou-chuan, appears at a depth of 330 m or so below the surface of the bore site at Tiao-wo-tsui, and also at a depth of 400 m or so in the bore at Chang-liu-shui. This results in a dip of 5 degrees or so to the west, even though the differences in altitudes of the bore sites are taken into consideration. The Tai-yuan series shows a dip contrary to the Ta-tung series, and it has been assumed that an unconformity is between the two.

2. *N–S Profile*

In the northern area of the valley from Yung-ting-chuang to Chang-liu-shui, the Ta-tung series is nearly horizontal but dips to northward in the southern area of this valley. As one goes further south the dip gradually increases.

Next, the structural state of the Tai-yuan series in the exposures at Yun-kang, Nan-hsin-chuang, Tiao-wo-tsui bore site and in the southern area south of Lao-yao-kou will be discussed. The series dips to the south in the northern area of Tiao-wo-tsui, namely, at Nan-hsin-chuang and Yun-kang, and it dips to the north in the southern area of Tiao-wo-tsui, and all complexes of the Upper Paleozoic formation generally got thick to the south and thin to the north. This happened because the amount of upheaval was by for bigger in the north than in the south. The northern portion was remarkably eroded before the start of sedimentation of the Upper Paleozoic formation. The overlap was carried on from south to north even at the time of sedimentation. As a result, the northern extremity of the Upper Paleozoic formation is the Ta-tung—Tso-yun road, but the Jurassic formation extends west of Feng-chen north of the Great Wall of China. It must be supposed that a disturbance took place before deposition of the Mesozoic formation. The Paleozoic formation was bent into a synclinal structure with its axis extending from ENE to WSW (See Fig. 6).

3. *General Structure*

The northern limit of the Upper Paleozoic formation in the Northern Ta-tung coal field is the Ta-tung—Tso-yun road. A synclinal structure lies a little south of Tiao-wo-tsui near the northern limit; the synclinal axis extend from ENE to WSW; it was formed before the deposition of the Mesozoic formation. On the other hand the Mesozoic formation forms a synclinal structure with its axis extending from NE to SW between Yung-ting-chuang and Tiao-wo-tsui. On the whole it is to be regarded as gently dipping from northwest to southeast. This synclinal structure in the Mesozoic formation is to be regarded as a local one governed by the thrust movement from east to west (See Fig. 5).

VI. Coal Seams

A. Introduction

The coal seams of this coal field are found in the Yun-kang, Ta-tung, Shan-hsi, and Tai-yuan series. The principal workable coal seams are intercalated in the Ta-tung and in the Tai-yuan series. The mode of occurrence will be discussed next (See Fig. 1).

B. Coal Seams of the Yun-kang Series

The Yun-kang series contains in the lower part two or three layers of thin coal seams, but these are not continuous and are too thin to be worked on a large scale. (Table 2)

Table 2. Modes of Occurence of the Coal seams of the Yun-Kang Series.

Length of exposures on the surface (m)	Thickness (m)	Location
200	1.10	Wu-tui-kou
280	0.65	Yung-ting-chuang, and Wa-yao-kou
120	0.50	SE of Mei-yu-kou
200	0.10–0.15	E. tributary of the Lang-yu-kou (Upper coal)
200	0.05–0.15	E. tributary of the Lang-yu-kou (Lower coal)
unknown	0.41	Pai-tu-yao, Hou-kou (upper coal)
	0.97	Pai-tu-yao, Hou-kou (lower coal)
	0.50	Pao-chin shaft (No. 1) (upper coal)
	0.40	Pao-chin shaft (No. 1) (lower coal)
Boring and shafts	0.90	Mei-yu-kou No. 1 bore (upper coal) of Old Paochin Co.
	0.40	Same as above (lower coal)
	lacking	No. 1 and No. 2 shafts of Old Paochin Mining Bureau
	0.50	No. 3 and No. 5 shafts of the above (one seam only)

C. Coal Seams of the Ta-tung Series

As already stated, the Ta-tung series varies from 214 m to 320 m in thickness, and contains coal seams, A, B, C, D, E, F and G in descending order. The thicknesses and the intervals of the coal seams are as shown in Table 3 (See Fig. 4).

Table 3. Modes of Occurrence of the Coal Seams of the Ta-tung Series.

Coal seams	Thickness (m)	Intervals (m)	Remarks
A	1.2–1.8		Sometimes lacking due to erosion
		45–60	
B	1.6–2.4		
		42–53	
C	1.3–1.6		
		6–10	
D	0.8–1.8		Seams get thinner in the west
		12–28	
E	2.8–4.5		
		20–25	
F	1.2		F_1 and F_2 occur below F in the west
		22	
G	1.2		G_1 occurs below G in the west

The important workable coal seams in this coal field are coal seams B, C and E. Coal seam A is sometimes eroded out because of the unconformity with the upper complex. One or two coal seams occur below coal seams D, F and G. As one goes from the south to the north, the Ta-tung series is deposited in overlap; the lower complex including coal seam G is not developed in the north, and thus coal seam G is not found.

The Ta-tung series, that is the Upper main coal measure, is distributed in the northern and the extreme northernmost regions of the North coal field.[5] It does not occur in the southern part of the North coal field, in the Central and in the South coal field.

D. Coal Seams of the Shan-hsi Series

The Shan-hsi series is 200 m thick at and immediate south of Kuo-chia-kou, and is 170 m thick in the map-sheet area of Lao-yao-kou, but it becomes thin toward the north and is only several meters at the bore-site of Nan-hsin-chuang because of the erosion. As the result among the Upper No. 0 bed, the Upper No. 1 bed and the Upper No. 2 bed, all which occur at Lao-yao-kou, but the Upper No. 0 bed and the complex including the bed are not developed at the bore-site of Tiao-wo-tsui and this series in completely absent at Nan-hsin-chuang. At the bore of Chang-liu-shui, the coal measure of the Shan-hsi series is found but no coal

Table 4. Modes of Occurrence of Coal Seams of the Tai-yuan Series.

Coal seams	Lao-yao-kou map sheet		Chan-fo-ssu and Kuo-chia-kou map sheet		Remarks
	Thickness (m)	Intervals between seams (m)	Thickness (m)	Intervals between seams (m)	
20 m bed	22–27		25–35		About 2 m of shale occur between the upper limit of this bed and the upper limit of this series at Chan-fo-ssu and Kuo-chia-kou. This bed is in direct contact with the Shan-hsi series at Lao-yao-kou.
		13–17		15–20	
Lower No. 1 bed	1.2–2.3		1.5±		
		12–15		15±	The distance from this bed to the lower limit of this series: Lao-yao-kou 50m; Chan-fo-ssu and Kuo-chia-kou 30m
5 m bed			5–6		

5) The north of E–W line connecting Kuo-chia-kou in the upper part of E-mao-kou, Huai-jen-hsien and the northern margin of the sheet map of western Ta-ching-kou.

Table 5. Coal Analysis of

Age	Places, collected	Coal seams	Water %	Ash %	Volatile meter %
Jurassic (Ta-t'ung series) coal	Pai-t'u-yao mine	A	3.92	4.88	29.40
	Pao-chin mine	B	3.92	5.08	32.72
	Yü-feng mine	B	4.23	6.03	25.91
	Yung-ting mine	C	3.16	4.41	28.61
	Tung-chia-liang mine	D	3.26	3.37	30.27
	//	E	2.94	4.83	28.89
	Pai-tung mine	E	2.76	4.86	28.85
	No. 1 well former Shan-ye Co.	F	3.80	4.06	31.74
	Chang-liu-shui Chuan-tze-kou pit	G	3.99	3.62	33.67
Jurassic (Ta-t'ung series) coal			2.67	10.85	28.70
		Ta-t'ung	3.48	15.37	27.24
			2.69	12.37	29.40
		coal	3.21	10.77	28.91
			3.01	12.74	27.86
		unscreened	4.31	9.53	31.29
			3.22	9.28	29.63
Permian (Ta'i-yuan series) coal	Showa mine, west of Huai-jen	No. 2 bed (20 m bed)	2.94	10.16	38.30
	//	No. 3 bed (20 m bed)	2.85	11.05	32.32
	//	No. 3 bed (20 m bed)	2.68	11.58	32.39
	West of Kou-chuan	20 m bed	2.49	12.82	33.36
	Bore, Tiao-wu-tsui	//	1.98	8.75	33.30
	//	5 m bed	1.64	12.85	32.26
	Bore, Ch'ang-liu-shui	//	1.34	17.12	30.36

* Ministry of Eastern Asia: Table of analysis of raw materials for iron

seam is seen and a thin layer of coaly shale occurs. Thus the coal seams of the Shan-hsi series are variable in both thickness and modes of occurrence. This is due to the fact that the Shan-hsi series is a terrigenous deposit. This phenomenon is common with other coal fields, so complete investigation is necessary before the

Ta-tung Coal Field.*

Fixed carbon %	Total sulphur %	Calorific value Cal.	Fuel ratio	Coking prop.	Remarks
61.80	0.38	7.640	2.10	Contract	Data of Ta-t'ung colliery
58.27	0.38	7.244	1.77	Weak coking	//
63.21	0.60	7.263	2.46	//	//
63.82	0.79	7.747	2.28	Contract	//
63.10	0.72	7.848	2.09	//	//
63.34	0.67	7.665	2.19	//	//
63.55	1.10	7.709	2.20	//	//
60.20	0.42	7.540	1.68	Weak coking	//
58.70	0.87	7.470	1.56	//	//
57.78	0.75	6,860	2.01	Slight coking	Analysed by North China Coal Sale Co.
53.91	0.64	6,463	1.98	//	//
55.54	0.65	6,662	1.89	//	//
57.11	0.30	6,703	1.98	//	//
56.39	0.74	6,697	2.02	//	//
54.87	0.43	6,870	1.75	//	//
57.87	0.76	6,924	1.95	//	//
48.60	0.40	7,040	1.25	Coking	Data of Ta-t'ung colliery
53.78	—	7,000	1.66	//	//
53.35	—	7,070	1.65	//	//
48.67	0.89	6,840	1.46	Swell coking	//
55.97	0.54	7,300	1.68	//	//
53.26	1.29	7,000	1.65	Strong coking	//
51.18	0.94	6,710	1.68	//	//

manufacturing, North China and Mong-chian.

start of operation. The coal seams of this series in this coal field have thicknesses varying from 0.2 m to 0.8 m, and is not good enough be worked.

E. Coal Seams of the Tai-yuan Series

This series forms the Lower main coal measure. Together with the Shan-hsi series all important coal seams of the Lower coal measure are included in this series. Namely the coal seams are, in descending order, the 20 m bed, Lower No. 1 bed, 5 m bed etc. Their modes of occurrence at Lao-yao-kou, at Chan-fo-ssu and in the sheet-map area of Kuo-chia-kou are as shown on Table 4.

The coal seams of this series alternate intimately with partings of kaolin varying from several cm to over 1 m and at times, even up to 12 m in thickness. These partings are of superior quality and nearly pure. Therefore, the actual thickness of the coal is reduced by 30 to 40%. It has been found advantageous to mine the coal together with the partings and then to dress the coal.

The Tai-yuan and the Shan-hsi series are unconformably related, and sometimes a shale bed, varying from 5 to 10 m, in thickness is formed upon the 20 m bed, and sometimes this bed is eroded and the Shan-hsi series is overlaid directly by the 20 m bed. This should be remembered during mining operations (See Fig. 4).

VII. Quality and Reserves of Coal

A. Quality of Coal

The result of the coal analysis from the Ta-tung coal field is shown in Table 5.

1. *Jurassic Coal (Ta-tung Series)*

Most of the coal is bituminous, of low grade and medium grade, extremely low in ash content, high in calorific value, good in ignition, weakly coking and excellent for fuel. And the coal is almost always in lumps, and needs to be crushed into smaller lumps for transportation.

2. *Permian Coal (Tai-yuan Series)*

This is low grade bituminous coal and is mined for lumps. It is high in calorific value and fit to be used as raw material for coke. The coal seam appears black or silver gray in color, and intercalates thickly with thin kaolin layers of a greasy luster so the ash content tends to be high. Thus this coal most be dressed. The ash which remains after burning is pure-white kaolin, and it is used for ceramics or as raw material for the chemical industry. Therefore the working of this coking coal will increase the profit by the sale of kaolin and burnt products. Table 6 shows an analysis outline of the kaolin.

Table 6. Analysis of the Ta-tung Kaolin.

Silica	Alumina	Ferric oxide	Lime	Magnesia	Titan	Ignition loss	Refractoriness
42%	40%	0.8%	Less than 1%	Less than 0.2%	Less than 0.4%	14%	SK 34–35

B. Characteristics, Viewed from Coal Mining

Being worked now are B bed, C bed and E bed of the Ta-tung series, and the coal seams of the Tai-yuan series are only partly bored. The advantages and disadvantages of these seams for the mining are as follows.

1. *Advantages*

a. The coal seam is hard and compact, which minimizes the consumption of timber, 0.8 sai per ton of coal (average consumption at collieries in North China is 5 sai, and average in Manchuria is 8 sai).

b. Combustible gas is not prevalent[6] so instead of electric safety lamps, carbide lamps can be used safely in most mines.

c. Yield of water from the mine is small. It is less than 100 cubic feet per minute in all pits (50 cubic feet in Yung-ting-chuang pit, 44 cubic feet in Mei-yu—Yu-feng pit, 27 cubic feet in Pao-chin pit).

d. The dips of the coal seams are gentle, and the faults are few, so the mining operations can be mechanized.

e. The coal seams of the Ta-tung series has few partings, and low in ash-content. Machine is needed only for sizing, and washing is not necessary.

Table 7. Probable Reserves of the North Ta-tung Coal Field (See Fig. 3).

No.	Sheet map	Probable reserves in metric tons			Surveyed by
		Jurassic coal	Permian coal	Total	
1	Yung-ting-chuang	53,640,000	225,230,000	278,870,000	MORITA
2	Pai-tung-tsun	145,390,000	220,150,000	365,540,000	MORITA TAKAHASHI
3	Yin-tang-kou	195,660,000	315,900,000	511,560,000	MUKAI
4	Ssu-lao-kou	44,070,000	89,660,000	133,730,000	ONUKI
5	Yen-yai-wei	140,960,000	372,600,000	513,560,000	〃
6	Wei-chia-kou	152,490,000	337,180,000	489,670,000	〃
7	Lao-yao-kou	79,970,000	447,870,000	527,840,000	〃
8	Chang-liu-shui	90,150,000	335,340,000	425,490,000	〃
9	Mei-yu-kou	21,170,000	40,820,000	61,990,000	〃
10	Yu-feng colliery	172,430,000	133,810,000	306,240,000	MORITA TAKAHASHI
11	Pai-tu-yao	250,900,000	254,340,000	505,240,000	MORITA MUKAI
12	Pao-chin	183,560,000	194,400,000	377,960,000	CHANG-Li-hsu
13	Nan-hsin-chuang	255,690,000	240,570,000	495,660,000	〃
Total		1,786,080,000	3,207,870,000	4,993,350,000	

6) Ground water gushed out of the Ta-tung series to a height of about 10 m during boring operations at Yun-kang-chen in the fall of 1941. The volume of water and its pressure were reduced shortly; the volume settled at 18 l/m, and remained constant for three years. The water was being used for drinking, miscellaneous uses, and for irrigation. It is noteworthy that combustible gas issued along with the water (according to Chozaburo HASEGAWA).

f. The coal seams of the Tai-yuan series contain kaolin, and if the run-of-mine is dressed by machine, raw material for ceramics of excellent quality can be recovered.

g. The coal of the Ta-tung series is steam coal, while the coal of the Tai-yuan series is coking coal. Thus, coals of two kinds are obtained in the same coal field.

2. *Disadvantages*

a. Working conditions are not good—80% of the native workers are opium-eaters; they are poor in persistence; and they go home during the farming season.

b. Materials are almost wholly dependent on outside sources.

c. Subsurface part of the outcrop has been mined to the depth of about 70 m by old primitive methods, and there are many old pits filled with water. Therefore sufficient investigation and time are necessary when opening new pits.

d. The exploitation area is confined in valleys because of topography; valleys are narrow and sites for surface installations are small, and discharge is temporarily large in the rainy season, often devastating surface installations.

e. The water is hard (over 35°) and damages the boiler facilities.

C. Coal Reserves

The reserves in this coal field were calculated in terms of coal seams and geologic age during the survey of the 13 sheet maps as shown in Table 6, but the values on the whole are only general estimates.

1. *North Coal Field*

a. Probable reserves of the sheet map area in the North coal field (13 map sheets) are as follows (See Table 7, Fig. 3):

Jurassic coal	1,800,000,000 tons
Permian coal	3,200,000,000 tons
Total	5,000,000,000 tons

b. Possible reserves of the remaining area in the North coal field are as follows:

Jurassic coal (34 map sheets)	4,000,000,000 tons
Permian coal (33 map sheets)	6,600,000,000 tons
Total	10,600,000,000 tons

2. *Northernmost Coal Field*

Possible reserves of the northernmost coal field are as follows:

Jurassic coal (32 map sheets)	3,200,000,000 tons

3. *Central Coal Field*

Possible reserves of the Central coal field are as follows:

Permian coal (71 map sheets)	12,700,000,000 tons

4. *South Coal Field*

Possible reserves of the South coal field are as follows:

Permian coal	9,000,000,000 tons

5. The total reserves of this coal field are estimated at over 40,000,000,000 tons, as shown in Table 8.

Table 8. Possible Coal Reserves of the Ta-tung Coal Field (ton).

		Permian coal	Jurassic coal	Total
Northernmost coal field			3,200,000,000 (32)	3,200,000,000
North coal field	(a)*	3,200,000,000* (13)	1,800,000,000* (13)	5,000,000,000
	(b)	6,600,000,000 (33)	4,000,000,000 (34)	10,600,000,000
Central coal field		12,700,000,000 (71)		12,700,000,000
South coal field		9,000,000,000 (60)		9,000,000,000
Total		**31,500,000,000** (177)	**9,000,000,000** (79)	**40,500,000,000**

* Probable reserves. (by ONUKI, 1945)
( ) Number of map sheets.

VIII. Conclusion

a. The Sang-kan gneiss and the Cambro-Ordovician formation form the basement of this coal field, and the Upper Paleozoic formation and Mesozoic formation are distributed upon them to form the Ta-tung coal field.

b. The Ta-tung coal field area is divided into the Northernmost coal field, the North coal field, the Central coal field and the South coal field. The Upper Paleozoic formation occurs in the North, the Central and the South coal field, and does not occur in the Northernmost coal field. The Mesozoic formation is developed in the Northernmost and the North coal field, but does not occur in the Central and the South coal field.

c. The Upper Paleozoic and the Mesozoic formations are distributed in the North coal field. This field is the most important for geological study; it is easily accessible, and is most suited for exploitation.

d. The Ta-tung coal field is located in the northern marginal region of the Great North China coal field, and from the viewpoint of sedimentary facies, it is situated in the southern foot-region of the Yin-shan mountain range, and appears on the marginal facies of a sedimentary basin. This means that the slightest crustal movement could affect this coal field much more than any other coal field. This coal field presents various kinds of data for the study of crustal movements.

e. The Upper Paleozoic formation is divided into the Ping-ting, Tai-yuan, Shan-hsi, and Huai-jen series; the Mesozoic formation is divided into the Ta-tung, Yun-kang, Nan-hsin, and Hun-yuan series. The Hun-yuan series does not occur in the Ta-tung coal field, but it is developed in the Hun-yuan coal field in the southeast.

f. Looking over the mutual relations among the complexes of all the series, the relations are always unconformable. This applies especially to the unconformity between the Upper Paleozoic formation and the Mesozoic formation which tells us the crustal movement at that time involved folding.

g. Coal seams are intercalated mainly within the Tai-yuan series and the Ta-tung series. The former is named the Lower main coal measure and the latter the Upper main coal measure.

h. The coal of the Tai-yuan series is coking coal, while that of the Ta-tung series is non-coking or weakly coking coal. Coals of two kinds are produced in the same coal field. This makes the coal field more important.

i. The reserves of this coal field are estimated at over 40,000,000,000 tons.

Reference

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Geology of the Yang-chuan Coal Field Shan-si, North China

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I. Location

The Yang-chuan Coal Field is situated in the eastern part of Shan-si province and forms the northeastern part of the great coal basin of the Tai-hang plateau which occurs widely in southern Shan-si. Yang-chuan station lies midway on the Cheng-tai Railway, which connects Shih-men (Shih-chia-chuang) and Tai-yuan and runs along the Mien-ho, also called Tao-shui. Yang-chuan station is also the center of the Yang-chuan Coal Field. The coal fields of Yu and Shou-yang lie to the northwest and the coal field of Ping-ting lies to the southeast of the Yang-chuan Coal Field. The authors investigated the southern part of the Yang-chuan Coal Field which extends from slightly east of Yang-chuan Station westward 8 km along the railway line to Sai-yu Station and from the railway line to a point 6 km south of that line.

II. Outline of Topography

Shih-nao-shan (1,174 m) which stands in the southwestern part of the field, is the highest mountain peak in this area. A mountain range extends from this peak toward the northeast and its extension reaches to south of Yang-chuan, where its altitude is about 700 m. A mountain range, which extends southward from Shih-nao-shan, occupies the southwestern part of the area (approx. 1,110 m height); it then swings to the east and forms the southern boundary of the Yang-chuan Coal Field. The average height of this range is 1,100 m, but the elevation of its eastern ends is less than 1,000 m. Thus, the mountain range has a shape similar to a horseshoe with its open end facing east. The Hsi-yu-ho flows eastward in the valley embraced by the horseshoe-shaped ridge, and turns to the northeast of I-tung-kou and joins the Mien-ho. A broad alluvial plain is developed along the Mien-ho which flows eastward along the northern border of the investigated area, and its elevation is 720 m in the western part and about 650 m in the eastern. The valleys of Hsi-yu-ho and Mien-ho were buried by loess and by the Mien-ho formation.

The present rivers are deeply entrenched in these deposits forming young valleys and terraces. The river terraces consists of two, the upper and the lower; the upper is more conspicuous and rises to 30–60 m above the flood plain while the lower rises about 10 m. Town of Yang-chuan stands on the lower terrace. The mountains which are not covered with loess and the Mien-ho formation, are generally dissected in the mature stage, and the stepped or table land topography is most characteristic.

III. Geology

The deposits distributed in the Yang-chuan Coal Field are as follows, in descending order:

Diluvium		Loess ~~~unconformity~~~ Mien-ho formation ~~~unconformity~~~
Middle & Upper Permian	Tse-shih series	Upper (reddish or yellowish brown rocks), 140 m thick Middle (reddish or yellowish green rocks), 160–175 m thick Lower (yellowish green rocks), 113 m thick
Lower & Middle Permian	Shan-si series (Upper coal measure), 100–120 m thick ~~~unconformity~~~	
Lower Permian	Tai-yuan series (Middle coal measure), 70–85 m thick ~~~unconformity~~~	
Moscovian	Pen-chi series (Lower coal measure), 50 m thick ~~~unconformity~~~	
Ordovician	Ordovician system	

The Ordovician to Permian formations occur in parallel, lower strata distributed in the east and upper ones in the west, thus assuming a monoclinal structure dipping gently to the west.

A. Ordovician System (Wang and Wang, 1930)

This system is composed of thick-bedded, light gray to gray limestone which is known as the Ki-chou limestone. Though this limestone is widely distributed and constitutes the basement of the coal field, its exposures are very scarce in the area surveyed. However, it does crop out on the right bank of the Mien-ho, about 2 km east of Yang-chuan near the eastern margin of the field and along the Yang-chuan to Ping-ting highway east of I-tung-kou. It is widely developed further east from these places.

B. Pen-chi Series

This series is limited to two places on a very small scale: the one is near Nan-chuang in the southeastern part of the field and the other is southeast of Yang-chuan city. It is typically developed south of I-tung-kou village along the Yang-chuan to Ping-ting highway, though it is outside the area dealt with here. The main constituents of the series of this region are shale, sandy shale, aluminous shale, limestone and marl, having a total thickness of about 50 m. The stratigraphic succession is as follows (in descending order):

8.	Upper shale	12 – 17 m thick
7.	Upper limestone	13 – 2 m thick
6.	Middle shale	7 – 12 m thick
5.	Middle limestone	1 – 1.2m thick
4.	Lower shale	8 – 12 m thick
3.	Lower limestone	9 m thick
2.	Aluminous shale (G bed)	4 – 6 m thick
1.	Iron ore	2.5m thick

The Pen-chi series rests unconformably upon the Ordovician limestone. This is a parallel unconformity (disconformity); the plane of the unconformity is highly uneven although it is on a small scale.

1. *Iron Ore*

On the top of the old erosion surface of the Ordovician limestone the Pen-chi series begins with layers of yellowish-brown and reddish-brown iron ore about 2.5 m thick. The ore is often deposited in the crevices or the hollow places of the limestone where the thickness often exceeds 3 m.

2. *Aluminous Shale (G bed)*

The Pen-chi series intercalates several layers of aluminous shale. The lowest layer is the thickest and is generally about 4 m thick, but its maximum thickness is 6 m. There is an abandoned mine of aluminous shale about 1 km south-east of I-tung-kou village. The aluminous shale is usually of light gray color and very fine clayey rock. It is very slippery and adhesive when wet. It is easily distinguished from the other rocks by these lithological characters.

3. *Lower Limestone*

This limestone is placed in the horizon 6–9 m above the base of the Pen-chi series and is about 9 m thick. This limestone generally consists of 3 or more separate layers of limestone, intercalating dark gray or black shales, having a thickness of about 30–40 cm. The limestone is gray to dark gray, compact and contains many nodules of chert, especially in the lower part.

4. *Lower Shale*

This shale intercalates one or two layers of marl in its upper part. The upper one (3.90 m) is thicker than the lower layer. As the result of weathering, the shale easily disintegrates into small fragments of angular polyhedrons and exfoliates to thin pieces of 0.2 to 1.0 cm thick where the rock is sandy or sandy shale. The shale is usually gray, dark gray and black, but occasionally brown when it is associated with thin layers or nodules of ferruginous shale.

5. *Middle Limestone*

This limestone is found in the middle portion of the Pen-chi series. Its maximum thickness is about 1.2 m, and it often lies in a row of nodule having a diameter of 0.25–0.70 m. It is usually dark gray and yields many fossils.

6. *Middle Shale*

This consists mainly of shale and is associated with sandy shale, aluminous shale, coal and iron ore. The shale is generally dark gray to black and well stratified. When the rock is sandy, it weathers easily and exfoliates into thin pieces. The dark-colored shale often contains many poorly preserved plant fossils. The sandy shale is usually gray to dark gray and has a lighter shade than the shale, but it is occasionally bluish gray. Thin layers and nodules of iron ore are often found in the bluish-gray sandy shale. Three beds of light gray to white aluminous shale occur in the upper part of the shale, and attain a maximum thickness of 4.8 m. Two thin coal seams, about 10 cm thick each, are interbedded.

7. *Upper Limestone*

Though the Upper limestone is dark gray and compact very similar to the Middle limestone, the former is thicker (1.30 to 2.00 m) than the latter. It occurs as a single layer, but is occasionally intercalated with several thin layers of chert. The limestone yields fossils of Foraminifera and Brachiopoda.

8. *Upper Shale*

This is mainly reddish-purple shale, occasionally associated with sandstone and sandy shale. Being very hard the shale often forms steep cliffs along the mountain slopes and characterizes the upper part of the Pen-chi series. The shale is distinctly stratified due to alternation of coarse-grained parts and fine-grained parts. When weathered it easily exfoliates into thin tabular pieces. The sandy shale is usually of light gray color. The sandstone is gray or bluish gray, fine-grained and arkosic, occurring as single or two layers with a total thickness about 80 cm. The reddish-purple shale often contains nodules and lenses of iron ore and yields many plant fossils. Brachiopods and pelecypods were collected from the lower part of this shale at a place about 1 km northeast of Nan-chuang.

The Pen-chi series is divisible into 8 members as stated above, and is easily distinguished from other series by the characteristic limestones. Three thin coal seams, though not workable, are intercalated in it.

The Pen-chi series of this region is well developed in the area from near Nan-chuang to south of I-tung-kou village. The strike and dip of the strata are variable and anticlines and synclines of low angle alternate, with the axes trending not only N–S but also E–W and the maximum dip about 30°. However, at a point about 500 m southeast of I-tung-kou the Lower limestone and the underlying strata are

Columnar section of the Pen-chi Series in descending order
(southeast of I-tung-kou)

	Thickness (m)
1. Reddish-purple shale and sandy shale in alternation	12.00
2. Gray fine sandstone	0.80
3. Dark-gray shale	4.40
4. Yellowish-brown marl	0.60
5. Limestone (Lh_1)	0.80
6. Black chert	0.35
7. Limestone	0.35
8. Black chert	0.35
9. Limestone (Lh_1)	0.20
10. Black chert	0.10
11. Limestone	0.20
12. Black chert	0.20
13. Aluminous sandy shale	0.80
14. Black chert	0.30
15. Coal	0.10
16. Aluminous shale	1.30
17. Aluminous sandy shale	1.80
18. Coal	0.10
19. Aluminous shale	0.90
20. Gray sandy shale	0.20
21. Dark-gray shale	0.90
22. Iron ore	0.10
23. Limestone (Lh_2)	1.20
24. Coal	0.10
25. Aluminous shale	0.60
26. Yellowish-brown marl	1.90
27. Dark-gray or brown shale	2.20
28. Iron ore	0.20
29. Gray or black shale	1.30
30. Black shale	0.80
31. Iron ore bearing limestone	0.40
32. Limestone (Lh_3)	2.20
33. Gray shale	0.40
34. Limestone (Lh_3)	2.30
35. Black chert	0.30
36. Limestone (Lh_3)	2.50
37. Aluminous shale	0.80
38. Light-gray, aluminous sandy shale	1.40
39. Aluminous shale	1.60
40. Iron ore	2.50

intensely folded and dip about 90°. Significant faulting is rare in the area, except for a few faults with a displacement less than 1 m.

The limestones of the Pen-chi series yield many fossils, consisting of Foraminifera, Anthozoa, Brachiopoda, Pelecypoda, Gastropoda, Crinoidea and Trilobita, and the Upper shale contains Brachiopoda and Pelecypoda. We found many plant fossils in the shale of various horizons of the Pen-chi series, but they were not well preserved. The identification of these fossils has not been finished yet, but the Brachipoda are as follows:

Meekella exima Eichwald
Camarophoria sp. a
Chonetes platti Davidson
Chonetes sp.
Productus gruenwaldti Krotow
P. gratiosus Waagen var. *occidentalis* Schellwien
Enteletes lamarki F. de Waldheim
Enteletes sp.
Linoproductus cf. cora d'Orbigny
Marginifera sp.
Choristites wongchichuensis Chao

Foraminifera (Lee, 1927) are as follows:

Fusulina pankouensis (Lee)
Bradyina nautiliformis Moller

The fossils collected from the Pen-chi series have not yet been fully investigated but there is no doubt that they are equivalent to the fauna of the Pen-chi series of the type locality. Hence it is fairly safe to say that the Pen-chi series of the Yang-chuan Coal Field is Moscovian in age.

C. Tai-yuan Series

The main distributions of the Tai-yuan series are limited to two regions: one is the neighborhood of Nan-chuang in the southeastern part of the field, and the other is the northern marginal portion of the field from south of Yang-chuan city to pit No. 1.

It is composed chiefly of gray to black shale, intercalating sandstone, limestone and coal seam, and its total thickness is 70–85 m. Subdivision of the Tai-yuan series, in descending order, is as follows:

7.	Upper shale and sandstone	1.30 – 5.00 m thick
6.	Upper limestone (Hou-shi)	0.60 – 2.00 m thick
5.	Middle shale and sandstone	9.00 – 40.00 m thick
4.	Middle limestone (Chien-shi)	1.10 – 1.60 m thick
3.	Lower shale and sandstone	21.00 – 25.00 m thick
2.	Lower limestone (Su-chieh)	5.00 m thick

1. Lowest coal-bearing shale and sandstone 20.00 – 25.00 m thick

1. *Lowermost Coal-bearing Shale and Sandstone*

The main rocks are gray to dark-gray shale and sandy shale to sandstone in alternation, intercalating coal seams. In the lower part, peculiar fine greenish-gray sandstone of 1–3 m thick occurs, containing iron ores of granular or oolitic structure and is overlain by the shale of gray to black color. This shale occasionally becomes reddish where it contains nodules of iron ore. A coal seam 4–8.8 m in thickness occurs in the middle part and is called coal seam E (E bed), or commonly Chang-pa-mei.

Most of the coal of this coal field is exploited from E bed. A dark gray shale 8–10 m thick overlies the coal seam. It is partly reddish purple or partly brown, well stratified, and easily exfoliates to thin pieces. A thin coal seam is occasionally intercalated in the upper part of the shale.

2. *Lower Limestone*

The Lower limestone is about 5 m thick and is usually separated into two layers by a thin intercalation of shale. The lower part is 1.4–1.8 m thick and is also often separated by thin bands of shale. The upper part is 2–2.8 m thick. The shale intercalated between two layers of limestone is gray or black color and often intercalates thin bands of cherty shale 1–1.5 m thick. The limestone is gray or dark gray and contains many fossils that comprise Foraminifera, Anthozoa, Crinoidea, Ammonoidea, Brachiopoda and Trilobita. The limestone is usually divided into three layers, which are called Ku-shih, Su-chieh-shih and Yao-ku-shih in descending order, or collectively called Su-chieh-shih. The limestone has characteristic lithology and remarkable continuity.

3. *Lower Shale and Sandstone*

This member is composed of the alternation of shale and sandstone between the Lower and Middle limestones. Its mean thickness is 23 m. The shales are gray or black and well stratified; the sandstones are medium-grained and are usually gray, often brownish gray or yellowish gray. The thickness of the sandstones is generally several meters, maximum 7.6 m.

4. *Middle Limestone*

The Middle limestone is a single bed 1.1 to 1.6 m thick. It is dark-gray, compact, and yields many fossils. Irregular shaped nodules of black chert are often contained in it. Fossils occur mostly in the upper and lower parts of the limestone and occasionally many Brachiopod and other fossils are obtained from the calcareous shale which overlies the limestone. The fossils are Foraminifera, Brachiopoda, Anthozoa, Bryozoa, Crinoidea, Pelecypoda, Trilobita, and Ammonoidea. The limestone is commonly called Chien-shih.

5. *Middle Shale and Sandstone*

This member consists of shale and sandstone interbedded between the Middle and Upper limestones. It is generally 20 m thick, but the thickness varies with locality. The main component of the lower half of this member is yellowish-gray, coarse- to medium-grained sandstone. The sandstone east of pit No. 1 is 22 m thick. The lower part of the sandstone is generally massive and coarse-grained and gradually becomes stratified and fine-grained upward. The main rocks of the upper half are gray to black shales and sandy shales with many intercalations of thin bands or lenses of sandstone. The stratification of the shales and sandy shales is usually distinct. A coal seam of 1.0 to 1.5 m thick is intercalated in the upper part of the member, about 8 to 10 m below the base of the Upper limestone.

6. *Upper Limestone*

The Upper limestone is usually about 1 m thick (0.6 to 2.0 m) and often separated into two layers by the intercalation of iron ore or calcareous shale. The limestone is dark gray to black and compact, yielding many fossils such as Anthozoa, Crinoidea and Brachiopoda. Besides these, Foraminifera and Bryozoa have been collected also. The limestone is commonly called Hou-shih. A coal seam usually occurs directly under the Upper limestone, between the limestone and the Middle shale and sandstone. It is 5 to 40 cm thick.

7. *Upper Shale*

The Upper shale, which overlies the Upper limestone, consists mainly of gray or black shale. It is 1.3 to 5.0 m thick and often intercalates thin layers of sandstone and sandy shale. A coal seam 20 to 50 cm thick occurs in its upper part.

The coal seams of the Tai-yuan series occur in the following five horizons (in descending order):

5. The uppermost horizon of the Upper shale	0.20–0.50 m thick
4. The horizon below the Upper limestone	0.05–0.40 m thick
3. The upper part of the Lower shale and sandstone (D bed)	1.00–1.50 m thick
2. The upper part of the Lower shale and sandstone	0.75–0.80 m thick
1. The middle part of the lowermost coal-bearing shale and sandstone (E bed)	4.00–5.50 m thick

The Tai-yuan series, overlying the Pen-chi series, crops out in the southeastern and northern margin of the area and generally dips 5 to 30° SW with gentle folding. The axial trend of the folds is diversified, changing from N–W to E–W. The shale of the Tai-yuan series yields many well-preserved plant fossils in several horizons. The investigation on these fossils is not yet finished, but *Cordaites* is the predominant genus among them. The limestones and associated calcareous shales contain many marine fossils such as Foraminifera (LEE, 1927), Anthozoa, Brachiopoda (OZAKI, 1931) and Trilobita. Important species, especially Brachiopoda, are as follows:

On the basis of these fossil contents this series can be correlated with the Tai-yuan series of the Tai-yuan region, and is assigned to the Lowermost Permian (Sakmarian) age.

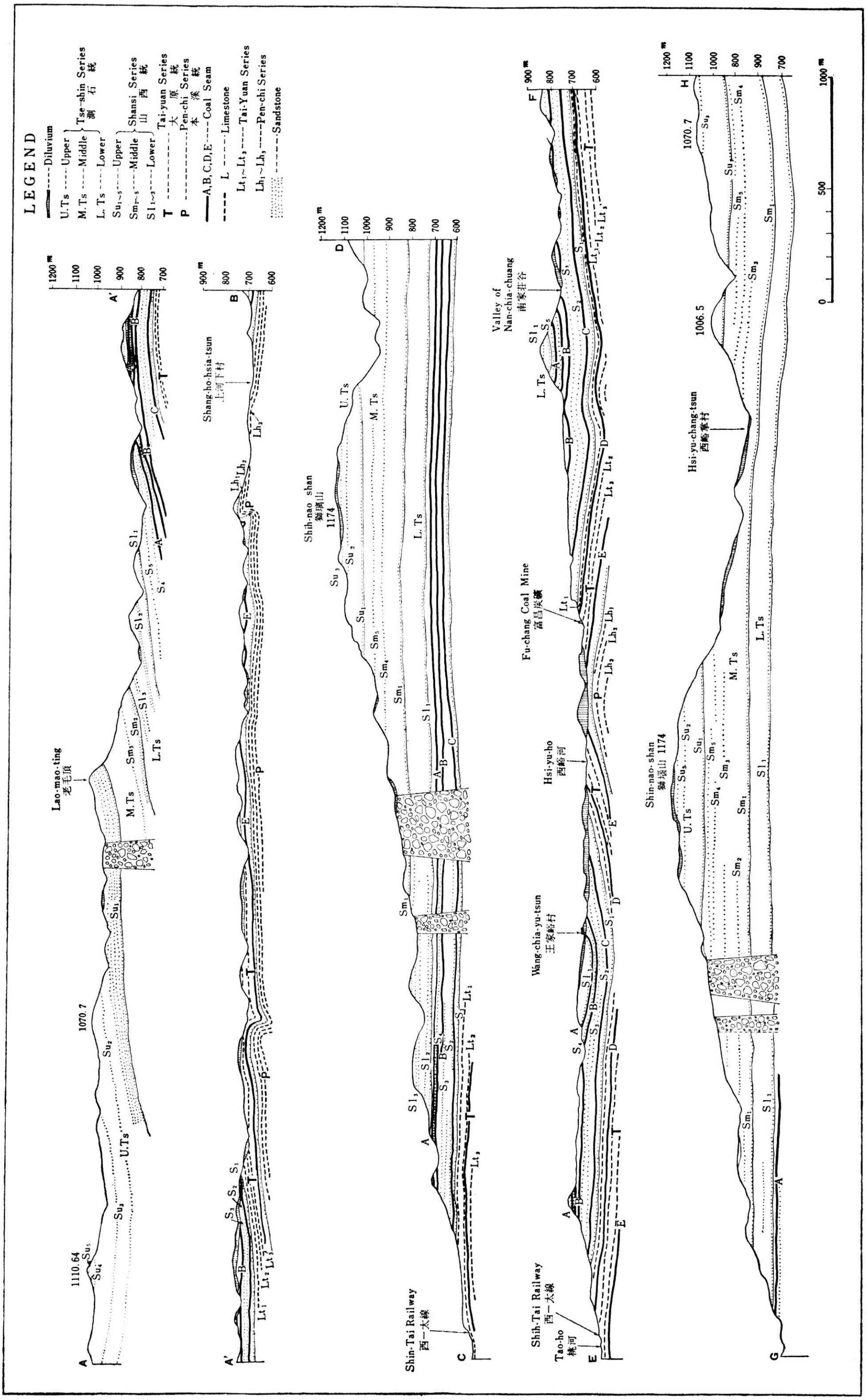

Fig. 1. Geological profiles of the Yang-chuan coal field, Shan-si, North China.

Columnar section of the Tai-yuan series in descending order (from south of Hsiao-yang-chuan to southwest of I-tung-kou).

	Thickness (m)
1. Coal	0.40
2. Black or gray shale	2.40
3. Limestone	0.20
4. Iron ore	0.15
5. Limestone (Lt_1)	1.20
6. Coal	0.15
7. Grayish-brown, fine sandstone	0.50
8. Gray shale	2.90
9. Coal	0.30
10. Gray shale	3.50
11. Black shale	1.30
12. Grayish-brown, fine sandstone	6.30
13. Yellowish-gray, medium-grained sandstone	9.00
14. Dark-gray shale	3.00
15. Black shale	0.85
16. Dark-gray, calacareous shale	0.10
17. Limestone (Lt_2)	1.40
18. Dark-gray, calcareous shale	0.40
19. Coal	0.75
20. Clay	0.10
21. Gray shale	1.40
22. Yellowish-gray, fine sandstone	3.00
23. Fine sandstone	4.20
24. Light-gray shale	5.60
25. Bluish-black limestone (Lt_3)	2.80
26. Dark-gray shale	1.30
27. Bluish-black limestone	1.80
28. Gray shale	1.00
29. Calcareous shale	0.30
30. Coal	0.15
31. Reddish-purple or dark-gray shale	6.00
32. Coal (E)	4.00
33. Gray shale	1.00
34. Coaly shale	0.80
35. Dark-gray shale	3.50
36. Gray shale	1.50
37. Grayish-brown, fine sandstone	0.20
38. Black shale	0.60
39. Gray sandy shale	0.20
40. Bluish-gray, fine sandstone	2.00

	Lower limestone	Middle limestone	Upper limestone
Schizophoria indica WAAGEN		×	
Streptorhynchus cf. *pectiniformis* DAVIDSON			×
Chonetes latesinuata SCHELLWIEN	×		
Chonetes cf. *buchiana* de KONINCK		×	
Chonetes cf. *hardrensis* PHILLIPS	×		
Chonetes chonetoides (CHAO)			×
Chonetes sp.	×		
Products uralicus TSCHERNYSCHEW			×
Productus moerri STUCKENBERG	×		
Productus intermedium var. *subplicatilis* FRECH			×
Productus manchuricus CHAO			×
Echinoconchus cf. *punctatus* (MARTIN)		×	
Waagenoconcha sp.	×		
Marginifera typica WAAGEN			×
Marginifera longispinus var. *lobata* SCHELLWIEN			×
Marginifera pusilla SCHELLWIEN	×		
Camarophoria schansiensis OZAKI		×	
Camarophoria meyeri var. *tetraplicata* OZAKI		×	
Spirifer fasciger KEYSERLING		×	
Choristites abnomalis CHAO	×		
Choristites jigulensis STUCKENBERG		×	
Choristites yanghukouensis CHAO	×		
Choristes trautsholdti STUCKENBERG	×		
Choristites paichingiensis OZAKI			×
Choristites pavlovi STUCKENBERG	×		
Choristites cf. *wynnei* (WAAGEN)			×
Choristites cf. *rectangulus* KUTORGA mut. *triplicatus* (MANSUY)	×		
Munella nikitini TSCHERNYSCHEW			×
Munella nikitini var. *tschernyschewi* OZAKI			×
Brachythyris cf. *schansiensis* CHAO	×		
Eliva cf. *mignon* GRABAU		×	
Martinia semiplana WAAGEN		×	
Martinia corculum KUTORGA		×	
Squamularia perplexa McCHESNEY		×	
Spiriferina cf. *cristata* SCHLOTHEIM	×		

The boundary between the Tai-yuan series and the Pen-chi series is tentatively placed at the base of the coarse-grained sandstone which occurs at about 10 m below E bed. The strata above and below the boundary plane are quite parallel and no stratigraphic break could be ascertained in the field, but the fossils indicate the age of Lowermost Permian. As the underlying Pen-chi series is Middle Carboniferous (Moscovian) in age, a faunal break should exist between the two series, and consequently the boundary is a disconformity.

D. Shan-si Series

The Shan-si series is widely distributed from Sai-yu at the northwest end of the report area to the southeast and along the eastern foot of Shih-nao-shan. South of the Tien-lu-kang pit the whole succession of the series can be observed. The Shan-si series consists mainly of sandstone and shale, intercalated with several coal seams. Development of sandstone is especially remarkable, occurring in six beds which are designated S_1, S_2, S_3, S_4, S_5 and S_6 in ascending order. The sandstone forms steep cliffs along the mountain slope as the rock is usually harder than other rocks. By these sandstone beds the Shan-si series, 100 to 120 m thick, is divisible into the following three members:

3.	Upper member (S_5 and above)	25–38 m thick
2.	Middle member (S_3 to base of S_5)	25–38 m thick
1.	Lower member (S_1 to base of S_3)	30–40 m thick

1. *Lower Member*

The sandstone S_1 at the base of the Lower member is 5 to 15 m thick and continues horizontally without much variation of thickness; it is usually underlain by a thin coal seam belonging to the uppermost part of the Tai-yuan series. The sandstone S_2 is 2 to 4 m thick and occurs in the horizon 5 to 8 m above S_1. The rocks occurring between these two sandstones are gray to black shale accompanied by thin sandstone, sandy shale and coal seams. The shale contains many small nodules of iron ore along the bedding plane. Iron ore occasionally forms layers less than 20 cm thick. Coal seam C (C bed) occurs in the upper part of the shale. The upper part of the Lower member, above S_2, consists chiefly of gray to black shale containing thin beds of sandstone, sandy shale and coal seam. Black or dark gray shales often yield plant fossils. In the horizon 4 to 5 m above S_2 a coal seam occurs, and its thickness is about 45 cm south of pit No. 1.

2. *Middle Member*

The sandstones S_3 and S_4 of the Middle member are 6 m and 1–5 m thick respectively and occur in the lower horizons and they are occasionally united into one layer. They are grayish-white, coarse-grained quartzose and occasionally contain small pebbles of quartzite or grade into conglomeratic sandstone. A gray to black shale, which is intercalated between these two sandstones often contains a thin coal seam. The upper horizons of the Middle member above S_4 mainly consists of gray to black shale intercalating sandy shale, coaly shale and coal seams. The coal seams are 0.65–1.70 m thick and can be broadly traced in the field.

3. *Upper Member*

The Upper member is the part above S_5 and consists of sandstone and shale intercalating coal seams. The sandstone S_5 is white, medium- to coarse-grained, quartzose and 1.3–8.0 m thick. The upper and lower parts of the sandstone are stratified, medium-grained, and has a maximum thickness of 8 m while the middle part is massive, coarse-grained and often shows good cross-bedding. The sandstone S_6 is gray, fine- to medium-grained, stratified and is 3–7 m thick with intercalations of thin gray to black shale, sandy shale and coal seams. The shale and sandy shale, associated with the coal seams, yield many *Annularia* and other plant fossils. A coal seam 0.75–1.20 m thick occurs in a horizon about 2–5 m above S_6 and can be broadly traced. The part above S_6 consists mainly of shale.

Columnar section of the Shan-si series in descending order
(south of Tien-ku-kang pit).

	Thickness (m)
1. Gray shale	4.50
2. Yellowish-green sandstone	0.20
3. Gray shale	0.80
4. Sandy shale	0.80
5. Gray shale	4.10
6. Coal	0.10
7. Clay	0.10
8. Gray shale	3.00
9. Sandstone	0.40
10. Coal	0.10
11. Clay	0.15
12. Gray shale and sandy shale in alternation	5.20
13. Yellowish-brown marl	0.15
14. Sandy shale	1.50
15. Gray shale	0.60
16. Coal	0.50
17. Clay	0.10
18. Gray shale	0.30
19. Stratified sandstone (S_6)	3.00
20. Gray shale	0.25
21. Coal (A)	0.50
22. Dark-gray shale	0.20
23. Coal	0.15
24. Gray shale	1.60
25. Yellowish-gray sandstone (S_5)	1.30
26. Dark-gray or light-gray shale	0.80
27. Coal	0.07
28. Dark-gray shale	0.60
29. Light-brown, sandy shale	0.50

	Thickness (m)
30. Dark-gray or light-gray shale	1.00
31. Gray sandy shale	8.00
32. Light-gray or dark-gray shale	0.80
33. Coal (B)	0.90
34. Dark-gray or brownish-gray shale	1.60
35. Coal	0.07
36. Dark-gray shale	6.00
37. Coal	0.10
38. Gray sandy shale	2.50
39. Grayish-white coarse sandstone (S_4)	5.00
40. Gray or black shale	1.80
41. Grayish-white sandstone (S_3)	5.80
42. Gray shale and sandy shale in alternation	4.40
43. Stratified sandstone	1.00
44. Gray-sandy shale	1.00
45. Black shale	15.00
46. Coal	0.12
47. Coaly shale	0.70
48. Coal	0.20
49. Black shale	1.00
50. Gray-sandy shale	0.60
51. Grayish-brown, sandy shale and gray shale in alternation	4.20
52. Black shale	0.30
53. Coal	0.45
54. Gray shale and sandy shale in alternation	3.20
55. Gray medium-grained sandstone (S_2)	2.00
56. Coal (C)	0.20
57. Coaly shale	0.15
58. Coal (C)	0.25
59. Coaly shale	0.15
60. Coal (C)	0.18
61. Black shale	2.30
62. Sandy shale	0.30
63. Gray shale	2.00
64. Grayish-white, medium-grained sandstone (S_1)	6.20

The shales of the Middle and Lower members of the Shan-si series are gray to black, but the color gradually changes to yellowish-brown toward the Upper member. The yellowish-brown shale occasionally intercalates several thin coal seams and sandstones which are not extensive. Sandstones are fine-grained, well stratified and yellowish gray to grayish brown.

Considering the relation between the Shan-si series and the Tai-yuan series, the former always overlies the latter with sandstone S_1 at its base. The boundary plane is distinct at every outcrop and both strata are usually parallel and apparently conformable. The top bed of the Tai-yuan series, which is overlain by the Shan-si series with sandstone S_1 at its base, is not always uniform lithologically and its stratigraphic position is variable. Sandstone S_1 is conglomeratic in places and often contains many pebbles of shale and sandstone which probably have been derived from the Tai-yuan and the Pen-chi series. Judging from these facts it is probable that the relationship between the two series is a disconformity rather than being conformable.

E. Tse-shih Series

The Tse-shih series, which overlies the above-mentioned Shan-si series, consists of yellowish-green to yellowish-brown or reddish-purple rocks and was named by us (Fujimoto, 1943) after the type locality Tse-shih on the Cheng-tai Railway. It is widely distributed from the west to the southwestern part of the field. The series is a continuous deposit, but is divisible into Lower, Middle and Upper according to lightological characteristics.

1. *Lower Member*

The Lower member is typically developed 20–120 m above the level of the Cheng-tai Railway along the northern slopes of the Shih-nao-shan and westward from pit No. 5 (Tsai-wa-keng). It is about 100 m thick at this place and is composed of the alternation of dark gray to black shale and yellowish-green shale, intercalated with quartzose coarse-grained sandstone (3 layers), a thin coal seam at the lower part, and iron ore and aluminous shale in several horizons. Three layers of sandstone, Sl_1, Sl_2 and Sl_3, are 3–10 m thick each, horizontally continuous, usually coarse-grained, quartzose, and white to light-gray. They occasionally show conglomeratic texture and cross-bedded structure here and there. The quartzose sandstones are very hard and massive, so that they usually form steep cliffs along the slopes. The base of these sandstones is usually very clear, so that the distinction between the sandstone and the underlying shale is easy, but the upper part grades into sandy shale.

Considering the color of the shale of this member there are two types; one is gray to black and the other is yellowish green to yellowish brown. The former is predominant in the lower part and the latter in the middle and the upper parts. The latter is also usually massive and shows a tendency to be yellowish green in the middle portion and becomes yellowish brown in the upper portion. The shale often grades into sandy shale which consists chiefly of finely alternating yellowish-green, finegrained sandstone and light-gray shale.

2. *Middle Member*

This member, which overlies the Lower member, is about 175 m thick and consists chiefly of the alternation of yellowish-brown to yellowish-green shale, and speckled brown to reddish-brown shale with five layers of quartzose and coarse-grain sandstones. These sandstones are called Sm_1, Sm_2, Sm_3, Sm_4 and Sm_5, in ascending order. The member often intercalates thin layers of iron ore and aluminous shale, and sometimes gray shale in the lower part, while the coal seam and the black shale cannot be observed. The above-mentioned sandstones are quartzose, coarse-grained and conglomeratic like those of the underlying series. They are 3–10 m thick, and generally white to light gray, but sometimes yellowish green. Sandy shale is occasionally found; it is not thick and merges into yellowish brown shale. There are two types of shale, yellowish brown to yellowish green and speckled brown to reddish brown, the latter is characteristic of this member and gradually increases upward.

3. *Upper Member*

The Upper member, which overlies the Middle member, consists chiefly of the alternation of yellowish brown shale and speckled brown or reddish brown shale, and constitutes the summit part of Shih-nao-shan. It also intercalates four layers of thick, coarse quartzose sandstones which are called Su_1, Su_2, Su_3 and Su_4 in ascending order; of these, Su_1 is thickest, about 10 m, and forms precipices at the summit. Thin aluminous shale occurs in the upper part of the member.

The Tse-shih series extends from the western part of the area southward and forms the mountains including the Shih-nao-shan and its extensions. The strike is on the whole NW–SE, with a dip of 5–15°S or E, presenting a monoclinic structure. The series locally dips to the north or west and is gently folded.

This series yields many plant fossils in the Lower and Middle members. The important fossils collected from the Lower, especially in the gray to dark-gray shale, are *Pecopteris* sp., *Cordaites* sp., *Tingia* sp., and *Plagiozamites*; those from the Middle, mainly in the gray or dark-gray shale and sometimes in the yellowish-green, sandy shale are *Cordaites* sp., *Taeniopteris* sp., *Pecopteris* sp., *Annularia* sp., *Neuropteris* sp., *Gigantopteris* sp., and *Lepidodendron* sp. These fossils have not yet been fully investigated, but there exists little doubt that the series is equivalent to NORIN's Shih-ho-tzu series (NORIN, 1922) and is thought to be Middle Permian in age, according to lithic character and the order of succession of beds.

The location of the boundary plane between the Tse-shih series and the Shan-si series is a difficult question, because field observations show that the former conformably overlies the latter. For convenience' sake, we classified the Tse-shih series mainly on the basis of distribution of coal seams and yellowish-green to yellowish-brown rocks, and of good continuity of sandstones.

F. CHIN-CHUAN SERIES AND SI-LO-CHEN SERIES (FUJIMOTO, 1943)

After the geological survey along the Cheng-tai Railway, the writers suggested that the Tse-shih series is overlain by the Chin-chuan series, which in turn is covered conformably by the Si-lo-chen series.

The Chin-chuan series consists mainly of reddish-purple shale and reddish-purple, sandy shale; the Si-lo-chen series consists of reddish-purple sandstone and reddish-purple shale and yields *Lepidodendron* sp. and other plant fossils in its upper-

Columnar section of the Lower Tse-shih series in descending order (south of Yen-tzu pit).

	Thickness (m)
1. Yellowish-brown shale	2.60
2. Aluminous shale	0.25
3. Yellowish-brown shale	0.80
4. Yellowish-green sandstone	0.20
5. Reddish-purple shale	0.30
6. Yellowish-brown shale	3.00
7. Yellowish-brown sandstone	0.50
8. Gray aluminous shale	0.50
9. Yellowish-brown shale	5.00
10. Yellowish-green, coarse sandstone	2.50
11. Yellowish-green, sandy shale	4.90
12. Dark-green sandstone	0.60
13. Yellowish-green, sandy shale	6.00
14. Yellowish-brown, fine sandstone	2.20
15. Yellowish-green shale	10.40
16. Yellowish-green, coarse sandstone (Sl_3)	5.80
17. Gray aluminous shale	0.02
18. Yellowish-brown shale	22.50
19. Yellowish-green sandstone (Sl_2)	8.50
20. Yellowish-green, sandy shale	1.60
21. Dark-gray shale	0.20
22. Yellowish-green, sandy shale	1.20
23. Dark-gray shale	0.20
24. Yellowish-green, sandy shale	1.80
25. Black shale	0.20
26. Gray shale	1.00
27. Yellowish-green shale	1.50
28. Gray shale	2.80
29. Yellowish-gray sandstone and yellowish-green sandy shale in alternation	1.80
30. Gray shale	1.50
31. Yellowish-brown sandstone	0.30
32. Gray shale	2.00
33. Yellowish-brown sandstone	0.60
34. Coal	0.10
35. Black shale	0.20
36. Yellowish-green, sandy shale	4.50
37. Yellowish-green, quartzose sandstone	1.00
38. Gray shale	7.30
39. White or light gray sandstone (Sl_1)	5.50

Columnar section of the Middle Tse-shih series in descending order
(along the north slope of Shih-nao-shan).

	Thickness (m)
1. Reddish-purple shale	2.00
2. Yellowish-brown shale	2.50
3. Reddish-purple shale	2.30
4. Yellowish-green shale	3.20
5. Dark-gray shale	0.50
6. Gray shale	0.80
7. Yellowish-brown shale	1.00
8. Reddish-purple shale	0.50
9. Yellowish-green shale	1.20
10. Reddish-purple shale	4.90
11. Yellowish-green sandstone (Sm_5)	10.00
12. Gray-shale	3.20
13. Yellowish-brown, stratified sandstone	1.00
14. Yellowish-brown shale	3.00
15. Reddish-purple shale	1.00
16. Yellowish-brown shale	3.00
17. Reddish-purple shale	8.70
18. Yellowish-brown shale	7.20
19. Reddish-purple shale	1.50
20. Yellowish-green, sandstone (Sm_4)	8.70
21. Yellowish-brown shale	3.00
22. Grayish-white, coarse sandstone	0.40
23. Yellowish-brown shale	3.50
24. Reddish-purple shale	2.00
25. Yellowish-green shale	4.30
26. Reddish-purple, sandy shale	0.20
27. Yellowish-green, sandy shale	2.60
28. Dark-green, fine sandstone	0.40
29. Yellowish-brown shale	3.70
30. Yellowish-green, sandy shale	0.70
31. Reddish-purple, sandy shale	0.30
32. Yellowish-green shale	2.20
33. Iron ore	0.20
34. Yellowish-green shale	0.50
35. Yellowish-brown, sandy shale	1.50
36. Dark-gray shale	1.00
37. Gray aluminous shale	0.15
38. Yellowish-brown shale	3.60
39. Yellowish-brown sandstone (Sm_3)	2.80
40. Yellowish-brown shale	1.80

	Thickness (m)
41. Yellowish-brown, sandy shale	0.80
42. Yellowish-brown shale	1.20
43. Yellowish-brown sandy shale	1.50
44. Yellowish-brown shale	2.00
45. Reddish-purple shale	1.80
46. Yellowish-brown sandy shale	1.20
47. Yellowish-green fine sandstone (Sm_2)	7.00
48. Reddish-purple shale	1.50
49. Yellowish-brown shale	3.50
50. Reddish-purple shale	0.40
51. Yellowish-brown shale	2.80
52. Grayish-white, aluminous shale	0.10
53. Yellowish-brown shale	0.60
54. Reddish-purple shale	0.30
55. Yellowish-brown shale	0.70
56. Reddish-purple shale	0.20
57. Yellowish-brown shale	0.30
58. Reddish-purple shale	4.00
59. Yellowish-brown shale	2.70
60. Reddish-purple shale	1.20
61. Iron ore	0.30
62. Yellowish-brown shale	1.00
63. Reddish-purple shale	3.20
64. Gray-shale	0.10
65. Reddish-purple shale	0.90
66. Grayish-white, quartzose, fine sandstone	1.00
67. Yellowish-brown shale	10.30
68. Yellowish-brown, sandy shale and gray sandy shale in alternation	4.70
69. Yellowish-green shale	6.00
70. Reddish-purple shale	4.10
71. Yellowish-brown shale	0.70
72. Gray shale	0.60
73. Yellowish-green, sandy shale	3.00
74. Dark-green, fine sandstone	0.30
75. Yellowish-green sandstone (Sm_1)	4.70

Columnar section of Upper Tse-shih series in descending order (South of Siyu Ho).

	Thickness (m)
1. Grayish-white, quartzose sandstone (Su_4)	10.00
2. Gray aluminous shale	0.05
3. Reddish-purple shale	7.25
4. Reddish-purple, sandy shale and yellowish-brown sandy shale in alternation	1.30
5. Yellowish-brown, sandy shale	5.00
6. Reddish-purple shale	3.50
7. Reddish-purple, sandy shale	2.50
8. Reddish-purple shale	5.00
9. Yellowish-brown, sandy shale	1.50
10. Yellowish-brown shale	1.50
11. Reddish-purple shale	2.70
12. Yellowish-brown shale	0.70
13. Yellowish-green sandstone	1.00
14. Reddish-purple shale	2.00
15. Reddish-purple, sandy shale	1.10
16. Reddish-purple shale	2.10
17. Reddish-purple, sandy shale	2.10
18. Reddish-purple shale	2.80
19. Yellowish-brown shale	0.90
20. Reddish-purple shale	1.50
21. Yellowish-brown shale	1.10
22. Reddish-purple shale	0.90
23. Reddish-purple, sandy shale	0.60
24. Reddish-purple sandstone	0.60
25. Reddish-purple shale	4.20
26. Reddish-purple, sandy shale	1.00
27. Reddish-purple, stratified sandstone	1.00
28. Yellowish-brown shale	3.20
29. Reddish-purple shale	1.00
30. Reddish-purple, stratified sandstone	0.60
31. Reddish-purple shale and yellowish-brown, sandy shale in alternation	2.20
32. Yellowish-green, sandy shale	1.00
33. Grayish-white, quartzose sandstone (Su_3)	7.80
34. Reddish-purple shale	13.00
35. Reddish-purple, sandy shale	1.90
36. Yellowish-brown, quartzose sandstone	1.40
37. Reddish-purple shale	1.00
38. Yellowish-brown shale	2.00

	Thickness (m)
39. Reddish-purple shale	6.00
40. Grayish-white, quartzose sandstone	2.50
41. Reddish-purple shale	2.30
42. Reddish-purple sandstone	0.20
43. Reddish-purple, sandy shale	1.20
44. Grayish-white, quartzose sandstone (Su_2)	5.80
45. Reddish-purple shale and yellowish-brown shale in alternation	2.30
46. Grayish-quartzose sandstone (Su_2)	3.10
47. Yellowish-brown, sandy shale	1.90
48. Yellowish-brown sandstone	1.90
49. Reddish-purple shale	2.30
50. Yellowish-green, sandy shale	1.20
51. Sandstone and shale in alternation	0.90
52. Grayish-white, quartzose sandstone	1.00
53. Reddish-purple shale	1.60
54. Yellowish-brown, sandy shale	1.90
55. Yellowish-brown shale	2.30
56. Grayish-white, quartzose sandstone (Su_1)	8.50
57. Yellowish-green, sandy shale	1.20
58. Grayish-white, quartzose sandstone	1.50
59. Yellowish-brown shale	1.60
60. Yellowish-green sandstone and yellowish-green, sandy shale in alternation	2.10
61. Grayish-white, quartzose sandstone (Su_1)	8.60

most horizon. The stratigraphical relation between the two series was not ascertained on account of the Shou-yang basin between them. Afterwards we had the good fortune to study the Liu-chu-tsun to Shan-yen-shan district south of Tse-shih and to clarify this question. Mt. Shan-yen is about 500 m above the level of the Cheng-tai Railway. The boundary between the Tse-shih series and the Chin-chuan series can be determined at Lang-yu village south of Tse-shih, and the boundary between the Chin-chuan series and the Si-lo-chen series can be determined south of Liu-chu village which is the entrance to Mt. Shan-yen. The Chin-chuan series observed along the route is an extension from its type locality; and lithologically, the Si-lo-chen series is certainly correlated with the type section west of Shou-yang basin.

When the Chin-chuan series and the Si-lo-chen series are compared by means of the lithological and paleontological data and the sequence of coal seams in the Tai-yuan district, they seem to correspond to the Shih-chien-feng series of NORIN (1922).

IV. Coal Seams

The workable coal seams occur in the Tai-yuan and the Shan-si series.

A. Coal Seams of the Tai-yuan Series

There are four workable coal seams. The Horizons of these coal seams are easily identified by means of three characteristic limestones (Su-chieh, Chien-shi and Hou-shi) as key beds. Thickness, distance between the coal seam and the limestone, and between the coal seams are enumerated as follows:

	thickness	distance between coal seam and limestone	distance between coal seams each other
Hou-shi limestone (Lt_1)			
		0.00–0.20 m	
Hou-shi coal seam	0.04–1.00 m		
		9.90–11.02 m	5.00–9.70 m
Coal seam D	0.85–1.75 m		
		3.60–31.05 m	
Chien-shi limestone (Lt_2)			5.20–31.85 m
		0.00–1.50 m	
Chien-shi coal seam	0.10–1.30 m		
		11.10–30.80 m	
Su-chieh limestone (Lt_3)			29.30–40.05 m
		9.30–13.39 m	
Coal seam E	3.65–8.80 m		
		7.55–10.20 m	
Basal sandstone			

Coal Seam E.

Commonly called Chang-pa-mei, this is the thickest and the most important coal seam of the field; its areal distribution is also the greatest. The thickness varies from 3.65 to 8.80 m and the average thickness is 5.00 m. The variation of thickness is not notable over the whole area and the partings are comparatively small. (Percentage of thickness of the workable coal to that of the coal seam as a whole is 88%).

Chien-shi Coal Seam

This coal seam lies below the Chien-shi limestone with gray shale about 1.5 m thick in between. The thickness is highly variable (0.10–1.30 m), and it gradually decreases east and southeastward. Outcrops of this coal seam trend in the same direction as the Chien-shi limestone.

Coal Seam D

This coal seam, commonly called Hsiao-tan or Ssu-chih-mei, is 0.85–1.75 m in thickness; it occurs between the Chien-shi limestone and the Hou-shi limestone, that is, at a horizon 3.61–31.05 m above the former and 9.90–11.02 m below the latter.

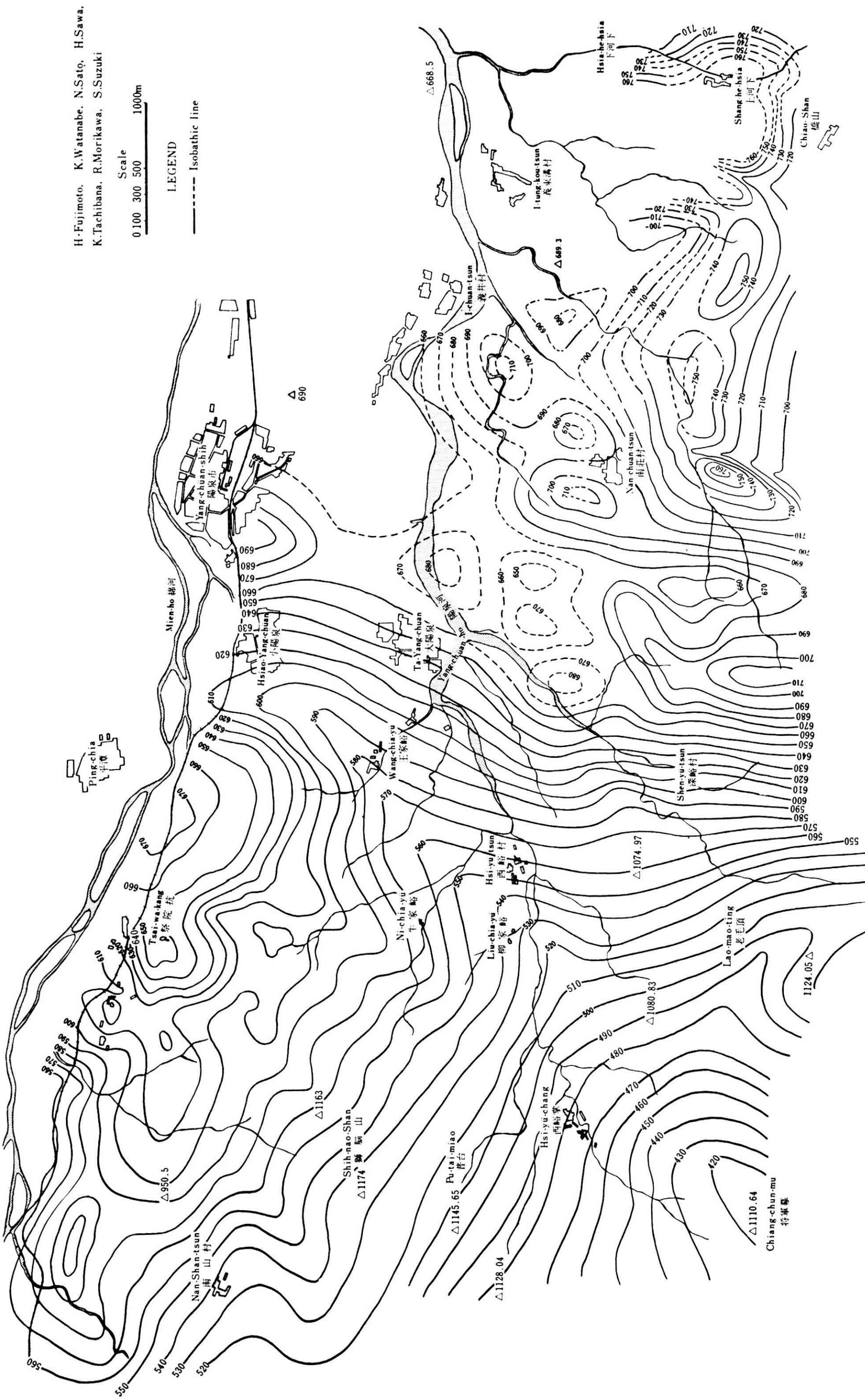

Fig. 2. Map showing the isobathic line of coal seam E in the southern area of the Yang-chuan coal field, Shan-si, North China

Hou-shi Coal Seam

This coal seam, commonly called Hsiao-tan or San-chih-mei, lies beneath the Hou-shi limestone, with thin shale about 0.20 m thick in between. It is usually 0.10–0.40 m and often 0.70–1.00 m thick.

B. Coal Seams of the Shan-si Series

There are five coal seams. The horizons of these coal seams are easily identified by means of the characteristic sandstones S_1, S_2 and S_3 which are intercalated in the lower part of the series and the basal sandstone (Sl_1) of the Lower Tse-shih series. Thickness, distance between coal seams and the sandstones, and the distance between the coal seams are as follows:

	thickness of coal seam	distance between coal seam and sandstone	distance between the coal seam
Basal sandstone Sl_1			
S_6		0.00–32.18	
Coal seam A	0.50–2.70	32.98–48.70	
S_5		26.16–36.07	12.30–20.70
Coal seam B	0.90–3.29	10.21–20.40	
S_3			37.95–56.93
S_2			
Coal seam C	0.30–1.40	0.00–8.60	
S_1		3.00–8.00	

Coal Seam C

This coal seam is not important, because it is usually about 0.5 m thick with many intercalations and does not have horizontal continuity.

Coal Seam B

This coal seam is uniform in thickness and has horizontal continuity, so that it is workable and is now being worked at Ta-nan and Hsiao-nan.

Coal Seam A

This coal seam has many intercalations and the aggregate thickness of the workable coal is 0.34–1.30 m. The percentage of the thickness of the workable coal to that of the coal seam as a whole is 53.7–73%. This coal seam is generally workable because it is uniform in thickness and has horizontal continuity.

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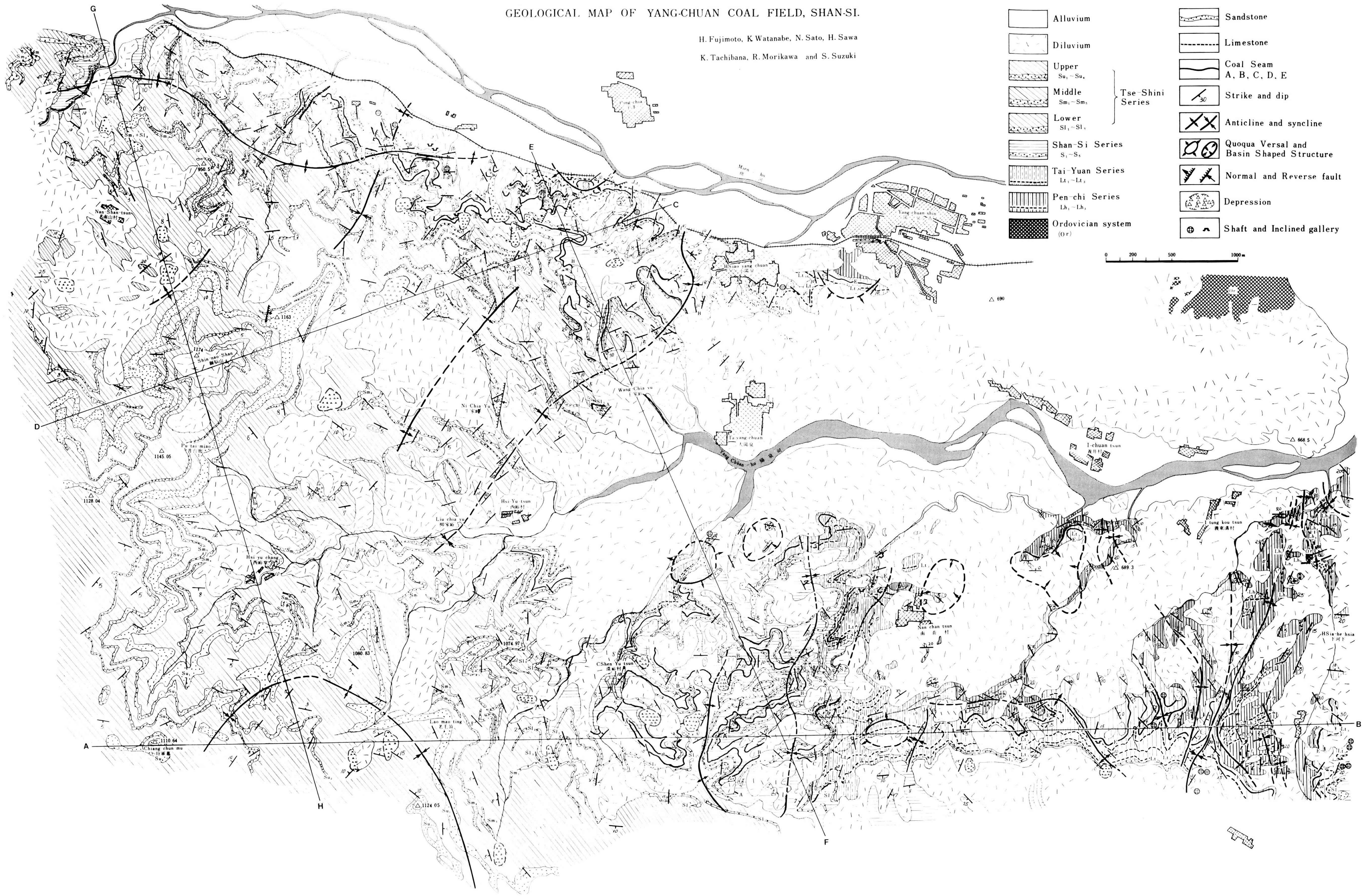

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Topography and Geology of Fu-chien Province

Kin'emon Ozaki

I. Topography

The Fu-chien Province is located on the southeastern coast of China and comprises a few mountain ranges that trend from northeast to southwest. The general topography shows a step structure which is high in the west and low in the east where the land faces the sea. The coast shows a ria shoreline. In summary, the province belongs to what Li Ssu-kuang called the "folded mountainland", and closely resembles in topography the southern region of Che-chiang Province.

The longest river of this province is the Min Chiang which flows in the northern central part of the province, and traverses, nearly at right angles, the mountain ranges which trend from northeast to southwest. Hence, its tributaries run from northeast to southwest or from southwest to northeast, parallel to the mountain ranges.

II. Mountain System

The Hsien-hsia-ling Mountains which form the provincial boundary between Fu-chien and Chiang-hsi and run from northeast to southwest are called the Wu-i Mountains in the southern region, and the Feng-ling Mountains in the Che-chiang borderland. The eastern part is called the Yen-tung-shan Mountains.

Hsien-hsia Ling, the main peak of the Hsien-hsia-ling Mountains, rises on the boundary of three provinces, Chiang-hsi, Che-chiang and Fu-chien. In the south in the neighborhood of Chiao-ling, a branch range trends in a north-south direction. In the area between Pu-cheng and Chung-an there are many peaks such as Hsin Ling, Tou-chu Ling, Yang-yuan Ling, Ku-chu Ling, Shuang-ting Ling and Wu-chia Ling, but their heights are only 500 to 900 m above sea level. Wu-i Shan is located southwest of Chuang-an Hsien, and its southern extension is called the Wu-i Mountains which branch out into two parallel ranges, one stretching from Tung-an-kuan northeast of Shao-wu Hsien and the other stretching from Chou-ssu-ling southwest of Shao-wu Hsien, with the river Fu-tun-chi in between. The southeastern end of the mountains reaches Nan-ping and Shun-chang.

The Wu-i Mountains in the neighborhood of Kuang-tse have several peaks, namely, Niu Ling, E Shan and Hsiang-ya Feng in the west, Chiu-lung Feng in the south, Shang-kao Shan in the east, Ching-yun Feng and Chin-ling Shan in the north, and Ku-y Ling in the northeast. The height of the last peak is more than 1,000 m above the level of Kuang-tse Hsien.

On the west and south borders of Shao-wu Hsien there are peaks called Chiao-feng Shan, Pai-hu Shan, Yun-chin Shan and Kao-po Ling, and at Tai-ning is found the Ta-shan Feng. A branch range rises north of Ning-hua Hsien and extends northeast, and near the border of Chien-ning Hsien it further branches into two ranges, one trending east-northeast and the other trending southeast, with a peak called Pi-chia Shan. Northwest of Kuei-hua it branches again into three directions; one branch continues to trend southeastward and reaches west of Nan-ping, passing through the northern part of Kuei-hua. The Wu-i Mountains diverge into two systems south of Ning-hua. One of the systems, which raises the peak Ching-chun Shan northwest of Chang-ting, runs between Chang-ting and Lien-cheng and diverges again a southeast range south of Lien-chang; the southern extension of this range is called the Po-ping-ling Mountains which form a watershed of the Chiu Chiang, Chiu-lung Chi and Min Chiang. The other range diverges in the south of Lien-cheng, runs east-northeast, and branches again in the northeast of Nin-yang; one branch runs north-northeast and ends on the south bank of the Min Chiang north of Yu-chi, and the other crosses the Tsai-yun-shan Mountains south of Ta-tien and reaches the coast of Chang-lo by way of Yung-chun and Te-hua prefectures. In the southwestern corner of the province the Wu-i Mountains diverge into two ranges, one extends to Wu-ping and the other to Chang-nan.

Moreover, there are the Tung-kung-chiu-feng Mountains on the north bank of the Min Chiang, which runs from east of Ching-yuan of Che-chiang Province to the south, and diverges at Tung-kung Shan which is located north of Ping-nan; one branch reaches the Min Chiang and stands opposite the Tai-yun Mountains beyond the river, while the other branch further diverges at the Shuang-chi Shan, both parts running southeast, and one ends in the east of Fu-chou and the other ends on the coast southeast of Ning-te.

III. Drainage System

The Hsien-hsia-ling and Wu-i Mountains, which bound Fu-chien and Chiang-hsi provinces, form watersheds for the two provinces. There are few large rivers in Fu-chien except for the Min Chiang. The drainage area of the Min Chiang is comparatively wide and constitutes two-thirds or more of the whole areal extension of the province.

The watershed between the Min Chiang and other rivers is the mountain range which diverges from the Chang-chun Shan, southwest of Ning-hua, and reaches Chang-lo, passing south of Lien-cheng and north of Ning-yang and running between Te-hua and Yung-chun. In the area south of this watershed are found three small river systems, namely, the Chiu Chiang, the Chiu-lung Chiang and the Lan Chi. The watersheds of these rivers are the Po-ping-ling Mountains and the southern Tsai-yun-shan Mountains.

A. Min Chiang

The uppermost drainage of the Min Chiang consists of the following three streams: The Chien Chi, which originates in Chien-ning-fu and flows down to Nan-ping after gathering the Nan-pu Chi, the Chung Chi and the Tung Chi; the Shao-wu Chi, which joins the Fu-tun Chi and the Chin Chi at Shuan-chang and reaches Nan-ping and the Sha Chi that rises in Chang-chiang-fu and reaches Nan-ping after gathering many small tributaries.

The main stream joins the above-mentioned three rivers and flows eastward, then it gathers the Yu Chi and the Ku-tien Chi and turns toward southeast. At the Min-hou-cheng delta, it diverges into two distributaries, the Nan-tai Chiang on the north and the Tao Chiang on the south, and after gathering these rivers it separates again until it pours into the sea.

The volume of the river water differs by season, extremely decreasing in winter and increasing in summer when the current becomes so swift that the navigation is very difficult. However, the water in the lower reaches below Nan-ping is abundant in all seasons and the current is gentle. The total length from the mouth of the river to the upper reaches of the Chien Chi is said to be 568 km.

1. *Chien Chi*

The upper drainage of the Chien Chi is composed of three headwaters. The stream on the west is called the Chung Chi and takes in the water from the Wu-i Shan in Chung-chi Hsien, and flows southeastward meandering through Chien-yang and Chien-ou, then it joins the Tung Chi; the central stream is called the Pu Chi which takes in the water from the Hsien-hsia-ling and runs southward from Pu-cheng and then joins the Chung Chi at about 2.6 km east of Nung-lo-chieh; the one on the east is called the Tung Chi which accepts the water from the west slope of the Chiu-feng Mountains and runs northward to Cheng-ho, turns south and joins the Chung Chi at Chien-ou.

2. *Shao-wu Chi*

The Shao-wu Chi has two tributaries. The Fu-tun Chi on the north gathers the Hsi Chi and the Pei Chi of Shao-wu-fu, and flows southeastward until it reaches Shun-chang; the other consists of the Ning Chi and the Chih-hu Chi that originate in Ting-chou-fu and join in the southwest of Chiang-lo, and flows eastward to join the above-mentioned Fu-tun Chi at Shun-chang.

3. *Sha Chi*

The Sha Chi gathers the waters in the south of Ning-hua, and flows eastward and then to the southeast at Ching-liu. It joins the Wen-chuan Chi which comes from the southwest, and flows eastward until it joins the Yen-shui Chi in the west of Yung-an where it turns to the northeast. Then, after joining the Fang Chi at Kung-chuan, the Ta-chi Chi at Shui-lou, the streams north and east of Kuei-hua several miles west of Sha-kou, and the Hsi-hsia-shui south of Sha-kou, it flows northeastward and enters Sha Hsien.

B. Chiu-lung Chiang

The Chiu-lung Chiang is also called the Lu Chiang and comprises the north and south tributaries which join at Chiang-tung-chiao east of Lung-chi.

The north tributary rises in Lung-yen-chou, and joins such streams as the Chiu-peng and the Lei Chi (Fei Chi) in the north and the Chih-wang Chi in the south. It passes Chang-ping and reaches Hua-kou where it joins the Chi-nan Chi from the north, and turning to the south, it reaches Chiang-tung-chiao. The west tributary has three headwaters; the Kao-shan Chi which comes from Ping-ho on the southwest, and Leng-shui Chi which flows in the central part, and the Yung Chi and the Ho Chi from the northwest. These three streams join in the west of Nan-ching, and after passing through Chiang-chou it joins the north tributary at Chiang-tung-chia.

C. Chiu Chiang

The Chiu Chiang belongs to the upper reaches of the Han Chiang, and originates in the Chiang-chu Shan north of Chang-ting. After passing through Lung-men, and the Chang-ting castle, water of the river comes so abundant that it is navigable by big boats of several thousand pounds (in Chinese weight). Farther south, the river joins many streams such as the Hsi Chi, Huang-feng Chi, Cho-tien Ho, Yang-chueh Chi, Hsiao-lan Ho and Lien-cheng Ho, and enters Kuang-tung Province.

IV. Sea Coast

As already mentioned, the coast of Fu-chien Province shows the ria-type subsiding topography and abounds in sinuations, so there are many ports. Among the numerous bays, San-sha Bay, Fu-chou Bay and Hsia-men (Amoy) Bay are especially noticeable as they are large enough for the anchorage of big ships. Other and minor bays are Sha-cheng Chiang (Kang), Fu-ning Bay, Hsing-hua Bay, Ping-hai Bay, Mei-chou Bay and Chuan-chou Bay. There are also numerous islets along the coast, attaining 599 in number. The principal ones are the Hsi-tan Island and the Chin-men Islands (Amoy and Quemoy), the former covers an area of 290 km^2 and the latter about 124 km^2.

Each bay has a plain on its west stretching almost northeast. The relationship between the bays and the plains is as follows:

1.	San-sha Bay	Fu-an Plain
2.	Mouth of the Tai Chiang	Lien-chiang Plain
3.	Fu-chou Bay	Fu-chou Plain
4.	Hsing-hua Bay	Hsing-hua Plain

5.	Chuan-chou Bay	Chin-chiang Plain
6.	(Montane basin)	Yung-chun Plain
7.	Wei-tou-ou	An-hai Plain
8.	Ku-an Channel	Tung-an Plain
9.	Chang-chou Channel	Chang-chou Plain
10.	Mouth of the Chang Chiang	Yun-hsiao Plain

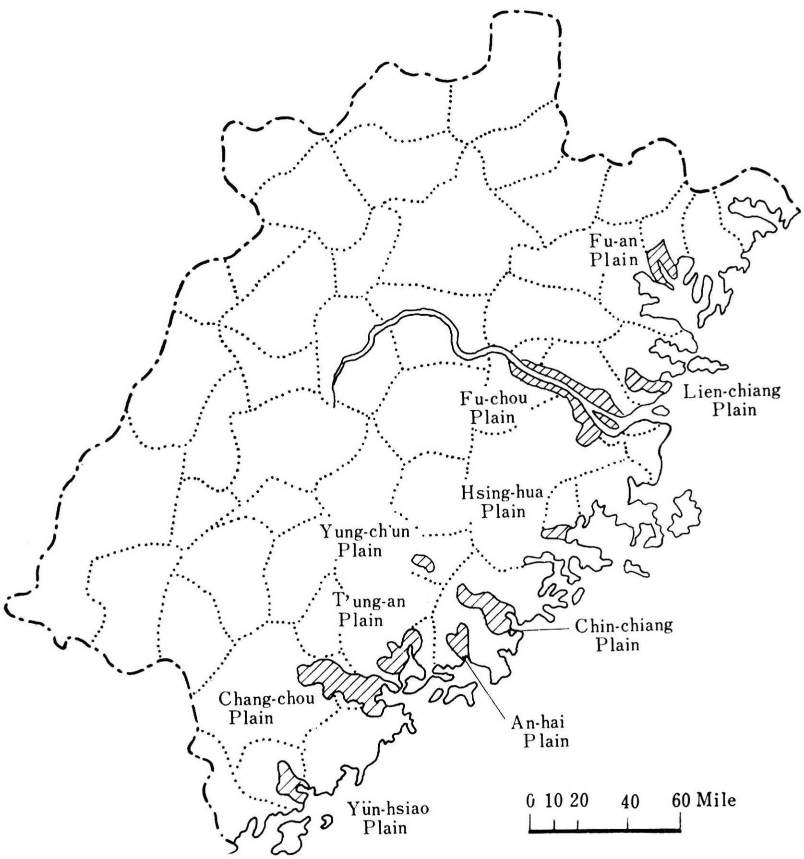

Fig. 1. Distribution of coastal plains of Fu-chien province.

V. Geology

As the geology of the province has not been surveyed to a satisfactory extent, it is impossible to describe it in detail. However, the existing reports present some very interesting facts. I could refer to only a few reports but they are reliable enough to be used as the basis of a gelogic study of the province.

In the north and east coastal regions, no strata corresponding to the Lower

Paleozoic, i.e., Cambrian to Devonian, have been discovered as yet, while in the southwestern part of the province, namely, the prefectures of Shang-hang, Lien-cheng, Chang-ting, Ning-hua, Ching-liu, Kuei-hua, Yung-an and Sha-hsien, the existence of the whole Paleozoic formations, though intermittently, was reported by S. W. WANG. No fossils have been found in the Cambrian to Devonian formations, so the formations were lithologically correlated chiefly with the groups in Che-chiang Province. T. F. HOU, Y. L. WANG and C. C. CHANG maintain that the formations which were correlated with the Cambrian to Devonian by S. W.

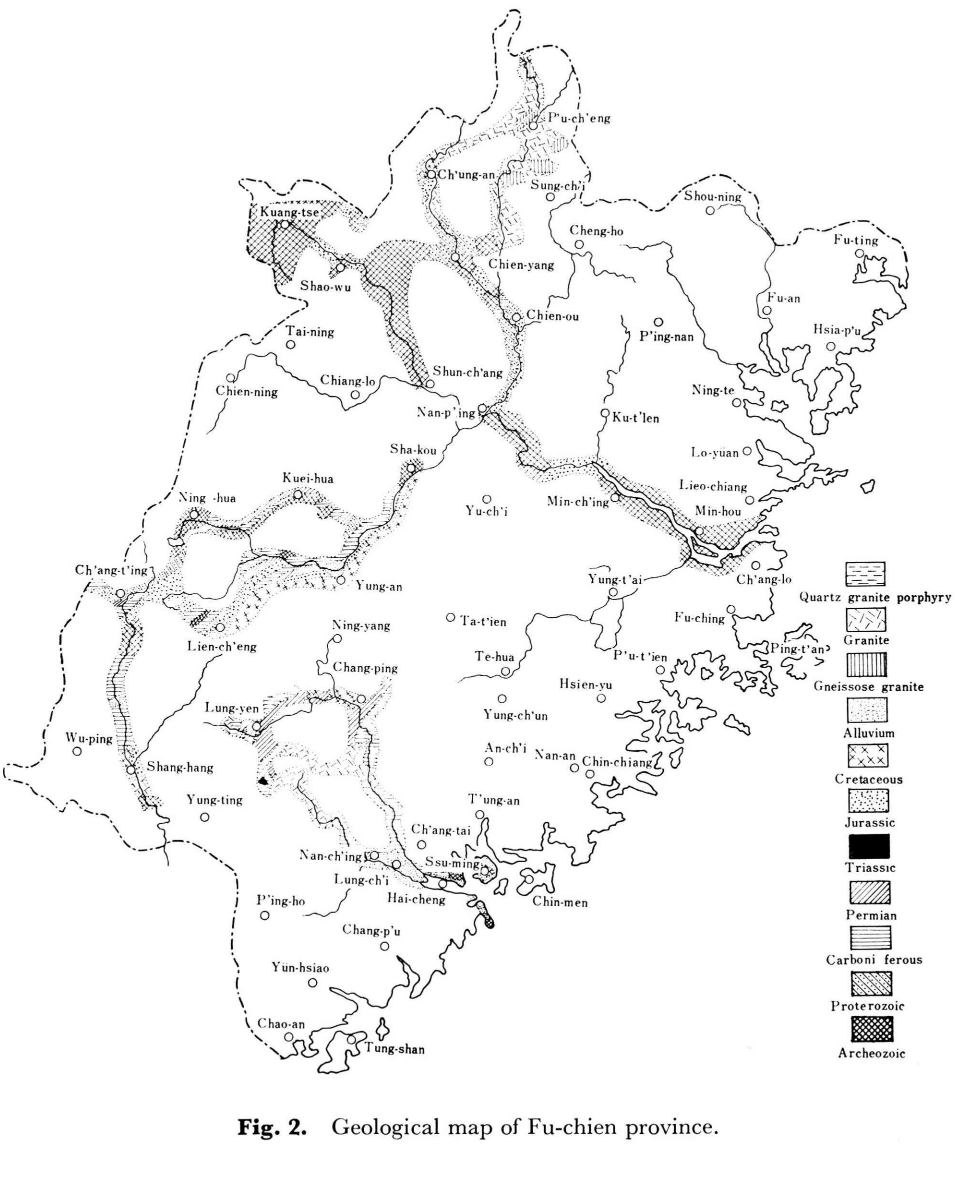

Fig. 2. Geological map of Fu-chien province.

WANG should be Carboniferous in age. Unfortunately, I have no data to judge these two opinions, so I introduce here both theories and discuss the age of the formations in the section on geologic history.

A. ARCHEAN GNEISS

The distribution of the Archean gneiss is comparatively wide, stretching over the Shan-kuan-ling Mountains on the border between Chiang-hsi and Fu-chien provinces, as well as in the area between Chien-yang and Chien-ou and in the prefectures of Chang-ting, Ning-hua and Sha-hsien.

In the Shan-kuan-ling Mountains, it is called the Shan-kuan series and is composed chiefly of granitic gneiss, pegmatitic gneiss and mica gneiss, markedly intercalated with igneous intrusive bodies. The gneiss exposed in the southwestern area, that is, Lien-chang, Chang-ting and Ning-hua, is called the Hu-mang-tung gneiss. The rock character of this gneiss is the same as that of the Shan-kuan gneiss, although the former is not intruded by igneous rocks.

B. PROTEROZOIC CRYSTALLINE SCHIST

The Proterozoic crystalline schist is correlated with the Lin-chuan series which is exposed in Lin-chuan Hsien of Chiang-hsi Province. It is composed chiefly of schist, often associated with gneiss and phyllite. In the area covering Nan-ping and Tsai-tou, a white marble, with a light greenish yellow or pink tint, is well developed, alternating with quartzite and crystalline schist. It is occasionally associated with small igneous intrusives. In the southwestern region, which includes Ning-hua (or Lung-ti), Yung-an (or Pu-tou), Sha-wu-tang and Chang-ting (or Shang-tu-li), a chlorite schist, corresponding to the Proterozoic crystalline schist, is exposed. It is called the Lung-ti schist.

C. CAMBRIAN (CARBONIFEROUS?) FORMATION

This formation is not distributed in the northern and eastern parts of the province, and is found only in the southwestern region. The type locality is Nan-tien-pu, 13.2 km east of Chang-ting, where the formation is called the Nan-tien-pu formation. The lower part of the formation is composed chiefly of volcanic tuff or breccia, and the upper part is a complex of dark sandstone, pale green shale, and fine-grained sandstone. The distribution is limited only in Nan-tien-pu of Chang-ting, and its western area including Niu-wei on the east flank of the Ta-ling-ai—Ku-mang-tung geanticline. Since no fossils have been found in this formation, the geologic age is not determined as yet, but S. W. WANG lithologically correlated it with the Tao-shui-wu formation of Che-chiang Province.

D. "ORDOVICIAN" (CARBONIFEROUS?) FORMATION

This formation also is not found in the north and east regions of the province. Its occurrence is reported in the southwest region, but it was confirmed not by fossils but by lithology which S. W. WANG correlated with the Yin-chu-pu series and the Yen-wa-shan series of Che-chiang Province. WANG named the former the Chi-kou formation and the latter the Lo-feng-chi phyllite.

1. *Chi-kou Formation*

The lower part of this formation is composed of black shale and black earth, intercalated with coal seams; the middle part consists of impure platy limestone, and the upper part consists of laminated sandstone, phyllite, etc., but the outcrops are very few. The coal seams in the lower part are correlated with the coal in the Yin-chu-pu series of Che-chiang Province and their age is thought to be Lower "Ordovician."

The area of distribution is comparatively limited, and the formation is exposed between Lo-feng-chi and Ta-ling-wei of Yung-an, and at San-chien-nao of Chang-tien.

2. *Lo-feng-chi Phyllite*

The Lo-feng-chi phyllite is exposed in the area 2 km northwest of Yung-an and An-hsi, in the Yu-hua-hsia gorge and Lai-fang, at Chung-ting, and at Tsao-hsieh-ling and Tsui-feng, northeast of Ching-lin. The formation is composed entirely of phyllite, and the lowermost part is grayish green while the upper part is generally purplish. No fossils have been found in this formation, but from the lithology and from the fact that the formation overlies the Chi-kou formation, it is correlated with the Yen-wa-shan formation of Che-chiang Province. The geologic age of the formation was assigned by WANG to Middle Ordovician.

E. "GOTLANDIAN" (CARBONIFEROUS?) FORMATION

The formation was named the Yang-ku-luan shale by S. W. WANG and was tentatively assigned to the Gotlandian age. The formation consists of yellowish green sandstone that is slightly schistose, resembling the Feng-chu shale of Che-chiang Province. The formation is distributed in the area between Tzu-chin-shan and Shui-kou in the drainage basin of the Chiu Chiang and in the prefectures of Ching-liu and Kuei-hua.

F. "DEVONIAN" (CARBONIFEROUS) FORMATION

By the lithologic character this formation is divided into two parts; the lower part is chiefly sandstone and the upper part is siliceous sandstone. S. W. WANG named the lower part the Niu-wei sandstone and the upper part the An-sha siliceous sandstone. While the distribution of the former is very narrow, the latter is widely distributed.

1. *Niu-wei Sandstone*

This formation is well developed on the east and west flanks of the Hu-mang-tung geanticline and consists chiefly of sandstone. It is divided into upper and lower parts. The lower part is hard, compact, somewhat siliceous, grayish green, and at the bottom intercalated with a bed of purple sandstone. The upper part consists of micaceous sandy shale or sandstone, and the color is grayish green which becomes reddish when weathered. This formation is correlated with the

Chien-li-kang sandstone of Che-chiang Province and is supposed to be Lower Devonian in age.

2. *An-sha Siliceous Sandstone*

As already mentioned, the distribution of this sandstone is fairly wide, spreading from Mei-li-sha-kou of Sha Hsien to south of Ching-lin and north of Yung-an, and reaching both flanks of the Hu-mang-tung geanticline. It also occurs in the area between Tzu-chin-shan and Shui-kou of the Chiu Chiang basin. The rocks constituting the formation are chiefly siliceous sandstone and siliceous conglomerate, the former predominates in the upper part and the latter becomes predominant in the lower part.

Since no fossils have been found the exact geologic age cannot be determined, but S. W. WANG opines that it probably corresponds to the upper Chien-li-kang sandstone and is Upper Devonian in age.

G. CARBONIFEROUS FORMATION (according to T. F. HOU, Y. L. WANG and C. C. CHANG)

The beds belonging to the Carboniferous formation are widely distributed in the southern part of the province, but are more restricted in the north. The beds are known as the Nan-ching quartzite group and are often metamorphosed by intrusion of granites. From the lithology the beds can be divided into three parts.

The lower part consists chiefly of thick white and pink quartzite, intercalated with thin shale, and is distributed in the area north of Fu-nan along the Pei Chi and in the area upstream of Nan-hsi along the Hsi Chi.

The middle part consists of shale, schist, clay slate and quartzite; it is well developed near Sha-kuan along the Pei Chi, and at Shui-wei and Hsi-shan between Yung-fu and Lung-yen.

The upper part is an alternation of gray and black sandy shale, coaly shale and siliceous sandstone, and crops out at Hsi-ling of Shui-wei, Lung-yen, and in Pi-chien Shan of Lung-men.

According to T. F. HOU, Y. L. WANG and C. C. CHANG, this formation belongs to the Carboniferous period and includes S. W. WANG's Chi-kou formation, the Lo-fang-chi phyllite, the Yang-ku-luan shale, the Nin-wei sandstone and the An-sha quartzite. The Carboniferous Tzu-shan coal series is not exposed in the province.

H. PERMIAN FORMATION

The Permian formation is comparatively well developed in the southeastern region of the province. It is divided into the Hsi-hsia flinty limestone, the *Gigantopteris* coal series, the Tsao-yuan limestone and the Nu-lou limestone. The Fei-lai-feng limestone of Nan-ping is correlated with the Hsi-hsia flinty limestone.

1. *Hsi-hsia Flinty Limestone*

Outcrops of the Hsi-hsia flinty limestone are generally sporadic, seldom continuous, and the thickness varies from several meters to 100 m. Lithologically the limestone is pure, fragile and laminated. The lower part is gray and the upper part is black. The limestone contains flint concretions. The localities of the limestone are as follows: Tieh-shih-yang of Lung-yen, Lung-yen-tung, north of Shih-chung, south of Tsao-yang of Chang-ping Hsien, Tsao-yen of Yung-an Hsien and west of Lien-cheng.

2. *Gigantopteris Coal Series*

All coal measures in southern China, such as Lo-ping, Hsuan-ching, Lung-tan, Lai-pa-kou and Lao-hu coal series, are correlated with the *Gigantopteris* coal series. Although they may somewhat differ in the mode of deposition, they usually contain fossils of *Gigantopteris*. The distribution of the coal series is wider in the southeast, and the known localities are the Lung-yen region, the eastern and southern Chang-ping Hsien and the Hua-an region. At Lung-yen this series consists of shale and sandstone and is intercalated with coal seams, the thickness of which varies by places but usually between 0.5 and 1.6 m. Locally the coal seams thin out entirely.

3. *Tsui-ping-shan Shale*

This is a series of shale and sandstone, overlying the *Gigantopteris* coal series. The type locality is Tsui-ping Shan east of Lung-yen. The lower part consists of greenish gray or yellowish brown shale, intercalated with sandstone; the upper part is rich in thinly-bedded sandstone and poorer in shale.

Generally the fossils are found in the lower part. The fossil fauna is locally marine and locally fresh-water. Plant fossils are also found though on rare occasions, which suggests that this series is a shallow water deposit.

I. Triassic? Formation

The Yang-ping shale is thought to be Triassic in age, but because of the poorly preserved fossils contained therein it is difficult to determine the exact geologic age. The shale crops out at Yang-ping west of Shih-chung of Lung-yen Hsien and on the west coast of Sung-hsu. The shale is yellowish brown, reddish brown, red or greenish gray, and is intercalated with thin sandstone. The shale is sometimes calcareous. Most of the fossils are marine bivalves, but fragments of fossil plants are occasionally found.

J. Jurassic Formation

The Jurassic formation is widely distributed in the north and southwest regions of the province. In the north it is divided into three groups which are called the Li-pi-chiao, Chung-jen and Jung-shan formations.

1. *Li-pi-chiao Formation*

This formation is developed comparatively widely in eastern Chiang-hsi Province. It consists of shale and sandstone; the former is thin muddy black or gray shale intercalated with coal seams, and the latter is gray or grayish white fine-grained sandstone. According to S. W. Wang, the Tung-tzu-yen coal series exposed west of Yung-an and Lien-chang is correlated with this formation, and consists mainly of brown coarse-grained sandstone intercalated with black shale which contains a coal seam more than 1 m thick.

2. *Chung-jen Formation*

This formation corresponds to the upper part of the Jurassic coal-bearing formation and consists of sandstone and shale, rarely intercalated with conglomerate. Occasionally quartzite intercalated with metamorphosed shale is observed to be developed very well. There are several coal seams, whose thickness ranges from 16 cm to 3.53 m. Coal is locally metamorphosed into graphite. The formation is distributed in Shao-wu, Chien-ou, Nan-ping and Min-ching. In the vicinity of Kuei-tou between Lien-cheng and Chang-ting is found the Kuei-tou sandstone which is correlated with this formation by S. W. Wang.

3. *Jung-shan Formation*

This formation overlies the Jurassic coal-bearing formation and does not contain coal seams. It consists of white or grayish white coarse-grained sandstone alternating with reddish brown or greenish gray muddy shale. However, very few beds corresponding to this formation are found in the province. As the Yen-fang tuffaceous sandstone, named by S. W. Wang, is supposed to be Upper Jurassic in age, it may be correlated with the Jung-shan formation.

K. Cretaceous Formation

The Cretaceous formation corresponds to the Wu-i formation in the north and to the Kuan-chai red sandstone in the southeastern part of the province, as well as to the Nan-cheng formation of Chiang-hsi Province. It is widely distributed in the Chung-an—Chih-shih-chieh region, the Chang-tai region south of Shao-wu, Kuan-shai of Lien-cheng, and also at Shang-kan, Cheng-peng-yen and Chih-mien-shan of Yung-an. The formation consists chiefly of red sandstone, locally intercalated with conglomerate and shale.

L. Tertiary Formation

S. W. Wang studied a red soil and an orange-yellow soil in the southwestern part of the province, and correlated them with the red soil of North China which is believed to have been formed in the Tertiary period. The soils are more than 20 m thick and are fine-textured and very plastic.

M. Quaternary Formation

The Quaternary formation includes clay, soil, sand and gravel, as well as lacustrine and fluviatile silts of recent deposition. They are unconsolidated, and the thickness is usually several to ten meters, very rarely exceeding 50 m.

N. Igneous Rocks

The distribution of igneous rocks in the province seems to be very extensive, but due to the incompleteness of the geological survey it is very difficult to know even an outline of the distribution. On the whole, the presence of granite, quartz porphyry and olivine basalt has been confirmed.

1. *Granite*

There are two kinds of granites. One is salmon pink, fine equigranular in texture, and partly grades into granite porphyry. Its distribution is quite wide, and the greater portion of granite in the province belongs to this kind. The other kind is hornblende granite of narrower and later intrusion than the former. The two kinds of granites are distributed in the following areas; Pu-cheng, Chien-ou and Chung-jen in the north, Chang-chou, Yung-fu, Chin-shan and Hsiao-chi west of Lung-yen in the southeast, Chang-fang-tan and Che-tan south of Shang-kou in the southwest.

2. *Quartz Porphyry*

The quartz porphyry is seen to have intruded in many places in southern Fu-chien Province. In the area between Amoy and Chung-fang it intrudes the granite and the Mesozoic shale, and forms a great intrusive body extending NE–SW along the coast. The rock also intrudes the Nan-ching quartzite between Nan-ching and Lung-shan, and intrudes the granite at Yung-chi, Pa-yao and Ching-yang. The intrusion of this rock can be seen also at Chien-ou and Kuang-tse in the north. The time of intrusion seems to be somewhat later than that of the granites and nearly contemporaneous with that of the Cretaceous igneous rocks.

3. *Olivine Basalt*

The olivine basalt occurs as dikes or sheets in the southern region. The constitutent minerals are plagioclase, augite, hornblende and mica, accompanied by olivine and magnetite. There are no traces of intrusion of this rock into granites or into rocks older than Early Mesozoic.

VI. Useful Minerals

As mentioned already, Fu-chien Province belongs to the southeastern coastal folded region, and is markedly intruded by the Yen-shan granite and other igneous rocks. Nevertheless, occurrence of useful minerals is very poor in comparison with other provinces. As the known metallic ore deposits there are iron ore, silver-lead-zinc ore, molybdenum ore and cobalt ore. Nonmetallic ore deposit is represented by coal.

A. Iron Ore Deposits

There are two kinds of iron ore deposits in the province, magnetite and placer. In the mode of occurrence, the magnetite ore deposits are grouped into the following four types:

1. Occurring in the Proterozoic gneiss and schist.
2. Occurring in the Paleozoic limestone, sandstone and shale.
3. Occurring in the Mesozoic sandstone and shale.

4. Occurring in granite.

Deposits of type 1. are found at Hui-tou-shan in Fu-ching prefecture, and at Lao-fu-shan and Hou-men-shan in Pu-tien prefecture. The type 2. deposits are known at Chen-ti in An-chi prefecture, Lo-yang in Hua-an prefecture, Tsao-tsin in Chang-ping prefecture, and Ta-pao-lin in Lung-yen prefecture. Deposits of type 3. are found at Pan-tien in An-chi prefecture, and the type 4. deposits at Tan-lin of Lung-chi prefecture.

Placer iron deposits and the so-called Fu-chien iron sand are found at Sung-yuan-tsun of Chien-ou prefecture, Hsu-tsun of Pu-tien prefecture, and Huang-ken of Kuei-chou prefecture.

B. Silver-lead-zinc Ore Deposits

Most of the silver-lead-zinc ore deposits are of epithermal or mesothermal origin. They are distributed in the following prefectures; Min-hou, Chien-chiang, Ku-tien, Ping-nan, Fu-an, Shou-ning, Hsien-yu, Yung-chun, An-chi, Te-hua, Ta-tien, Ning-hua, Lien-cheng, Lung-yen, Ping-ho, Lung-chi, Fo-cheng, Sung-chi and Cheng-ho. They usually occur as veins penetrating quartz porphyry, and are found also in sandy metamorphic rocks, shale and limestone, though on rare occasions.

C. Molybdenum Ore Deposits

In the molybdenum-yielding area between Ta-kou and Chiao-keng of Yung-tai prefecture, the igneous complex consisting of tuff, agglomerate, porphyrite and rhyolite is widely distributed. In the area between Pu-pi-tsun and Chiao-keng, an intrusive body of the Yen-shan granite is found. The granite is accompanied by veins of pegmatite and quartz which contain molybdenum. In the vicinity of Pu-pi-tsun are found important molybdenum localities, namely, Li-pi-keng, Chiao-keng, Ssu-chien-keng and Ku-ling-keng, all being located not far from the granite.

1. *Li-pi-keng*

This locality is about 1.3 km northwest of Pu-pi-tsun. Details of the ore deposits are unknown, but judging from the waste scattered around an old pit, the molybdenum is fine-grained or is composed of radially aggregated crystals. A coarse-grained granite is exposed in the neighborhood, suggesting that the granite is the country rock of the ore veins. Pyrite is found as an accessory mineral.

2. *Chiao-keng*

This is located at about 6.6 km north of Pu-pi-tsun. There are no outcrops of the ore deposits, but judging from the waste of the previous year's mining the greater portion of the ore occurs in pegmatite and part of it occurs in quartz veins.

3. *Ssu-chien-keng*

This is at about 1.3 km southeast of Chiao-keng-tsun. The area is composed of fine-grained granite intruding the igneous complex. There are some outcrops of pegmatite which, however, does not contain much molybdenum.

4. *Ku-ling-keng*

The locality is about 6.6 km north of Pu-pi-tsun. The country rock is fine-grained granite containing much muscovite. Molybdenum in this area is not worthwhile mining.

In addition to the above four localities, occurrence of molybdenum deposits is known at Tsao-keng, Su-keng and Tao-keng, where the country rocks are pegmatite and quartz veins.

Geologic Correlation of Fu-chien Province

Era	Period	East region	Southwest region
Cenozoic	Recent	Alluvium	
	Quaternary	Sand and gravel	
	Tertiary	Red soil, sand and gravel Liu-huei-sha basalt	Red soil formation
Mesozoic	Cretaceous	Tou-tou igneous rocks Pei-sha red sandstone and shale	Kuan-chai red sandstone
	Jurassic	Jung-shan formation Chung-jen formation Li-pi-chiao formation	Yen-fang formation Kuei-tou sandstone formation Tung-tzu-yen coal series
	Triassic	Yang-ping shale	
Paleozoic	Permian	Tsui-ping-shan shale *Gigantopteris* coal series Hsi-hsia flinty limestone	Hu-kou coal series Tsao-yuan limestone
	Carboniferous	Nan-chin quartzite	
	Devonian		An-sha siliceous sandstone Hui-wei sandstone
	Gotlandian		Yang-ku-luan shale
	Ordovician		Lo-feng-chi phyllite Chi-kou formation
	Cambrian		Nan-kou-pu formation
Proterozoic		Lin-chuan System	Lung-ti schist
Archeozoic		San-kuan System	Hu-mang-tung gneiss

D. Cobalt Ore Deposits

Cobalt ore deposits are found in the neighborhood of the Weng-yao Shan and Ta-chi-pien in Fu-an prefecture. The country rock is usually quartz porphyry(?), but due to advanced weathering the rock is decomposed and the cobalt ore occurs as large lumps, 2 to 3 inches in diameter, scattered in the soil. In the Li-chia valley of Ching-lin prefecture and in the Chiang-fang region, cobalt-manganese ore is found and its country rock is rhyolite, unlike the former type.

VII. Geologic History

In the north and southeast regions of the province, the Cambrian to Devonian rocks are entirely absent. In the west region, however, S. W. Wang identified strata of all stages of the Paleozoic era. On the other hand, T. F. Hou, Y. L. Wang and C. C. Chang correlated S. W. Wang's Nan-tien-pu formation, Chi-kou formation, Lo-feng-chi phyllite, Yang-ku-luan shale, Niu-wei sandstone and An-sha siliceous sandstone with the Nan-ching quartzite and assigned them to the Carboniferous age. Should the correlation be correct, it is inferred that no deposition of the beds ranging in age from Cambrian to Devonian took place in this region, or that such beds were deposited but were eroded away completely. At any rate, the geologic history of the Cambrian to Devonian period remains unknown due to the absence of corresponding strata. However, it is evident that intrusion of igneous rocks took place after the deposition of the San-kuan series and again after the Lin-chuan series which underlies the Nan-ching series. An exact age of intrusion cannot be determined. The igneous intrusion was supposed to have been followed by diastrophism called the Caledonian folding, but no beds corresponding to the movement are found in the province, making any inference impossible. With the presence of the Nan-ching quartzite, it is evident that terrestrial deposition took place beginning with the early part of the Lower Carboniferous period. Moreover, the Middle Permian transgression resulted in the deposition of the Hsi-hsia flinty limestone. It was succeeded by the regression which accounts for the terrestrial *Gigantopteris* coal series and the neritic Tsui-ping-shan shale. During the Triassic period no conspicuous changes may have occurred; for instance, the Triassic beds at Yang-ping-tsun contain bivalve fossils, and those at Shih-chung contain similar fossils and also fragments of plant fossils. After the deposition of the Triassic Yang-ping shale, there occurred the so-called Yen-shan movements which extended from Jurassic to Late Cretaceous, resulting in the NE–SW folds. In the Middle and Late Tertiary, faulting took place and caused the gentle tilting of the land. Then, the period of diluvial and alluvial deposition began.

Geomorphology of Taiwan

Yoshirō Tomita

I. Introduction

About two-thirds of the area of Taiwan is occupied by high rugged mountainous districts. The highest peak, Yushan rises 3,997 m above sea level. The peaks around this mountain in the same chain are more than 3,000 m above sea level and form a great barrier (Fig. 1).

In contrast to these high peaks, an abyssal submarine trough 5,000 m deep lies within a distance of several tens of km off the east coast of the island. It has been said that the ruggedness of the topography of Taiwan is believed to be unequalled in any part of the earth's crust. The island belongs to a young orogenic zone which was formed in the Tertiary along the Circum-Pacific geosyncline, and the rugged topography and the complicated geologic structures are due to severe crustal movements, as folding, thrusting and faulting. This complicated structure is reflected in the relief of the land, and very rugged topographic expressions can be found in many places throughout the island. Such a rugged topography is thought to have resulted from the rejuvenation of down-cutting of rivers accompanying the recent uplift. The down-cutting of river bottoms has become more and more intensified and the mountains have become higher and higher, so that the fluvial erosion topography accompanying the land uplift represent practically all the types of topographic expression. Moreover, each topographic form is preserved very clearly so that for any one who wishes to study geomorphology, Taiwan is thought to be the best for field work.

The fluvial erosion topography accompanying the land uplift can be classified into "old" and "young." It remains to be decided whether the old and young topographies were formed during continuous uplift or whether the two are divided by a period of pause. In some cases, consideration must be given to other influencing factors in the activity of river cutting during the time of land uplift. The differences of hardness of rocks also must be considered. It is not always an easy matter to explain the order of development of the topographic groups which have been formed up to the present even though each retains its characteristic form. Besides uplifted topographic types, in various places some land forms remain which had existed before the land was uplifted. These topographic forms, combined with the

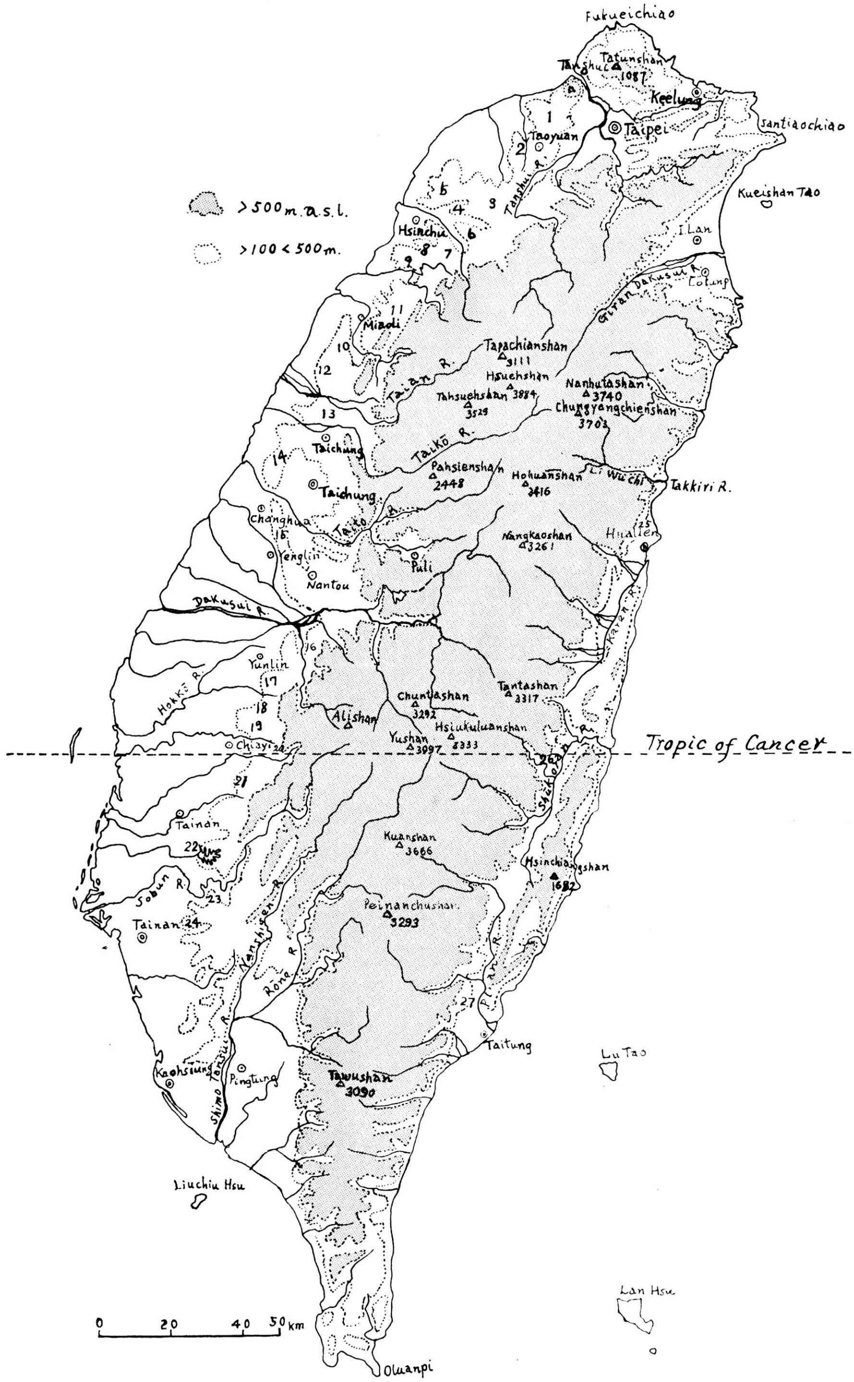

Fig. 1. Relief Map of Taiwan.

development of the submarine topography in the nearby Sea of Taiwan, are to be taken into account for a startling episode in the history of physiographic development.

Herein, I intend to discuss the geomorphology on the bases of data furnished by the actual land forms in their limited sense. In a broad sense the geology should be considered before the topography, and the original topography should be discussed by tracing past geologic time, starting with the deposition of formations and their later denudation. These discussions, however, belong to the sphere of historical geology rather than the sphere of physiography so that in their place I intend to discuss the very recent history of physiographic development in a rather narrow sense.

II. Kinds of Fluvial Erosion Topography and their Correlation

Among various fluvial erosion topographic groups, one of the most noticeable features in lowland districts is the steep slopes. But as mountainous areas consist mostly of slopes, the noticeable feature is, conversely, flat surfaces or gentle slopes. If the study is pursued along the line of how and in what order these surfaces and gentle slopes were developed, and if the study is linked with other developments of topographic forms, then the sequence of topographic development of the whole mountain zone can be elucidated. The flat surfaces and gentle slopes are particularly important, because these land forms are not only prominent in the mountain topography, but at the same time they serve to correlate one form with another.

In the mountain zone of Taiwan, the flat and gently sloping surfaces that are situated in the lower position consist of river terraces or alluvial fans, but those located in high places consist of mountain spurs and shoulder-shaped plane surfaces or ledges developed on the mountain spurs, or gently sloping surfaces as are developed on the mountain sides. At the same time, a flat plane on the crest of a high mountain is thought to be a remnant of a flat-topped peak. The mechanics of the formation of flat and gently sloping surfaces are varied, but confusion must be avoided at the time of correlation so that first the classifications of land forms must be made clear in each case (Tomita, 1939, 1941).

A. Fluvial Terraces

The topographic surface that is the most typical as well as the most common feature is the fluvial or river terrace. Moreover, the fluvial terraces often occur as several step-like forms at one place and their formational sequence is shown clearly, and is important study material for the standardized classification of topographic forms.

The fluvial terraces observable in Taiwan can be classified broadly into two types on the basis of topographic forms, namely "higher and lower terraces." The classification of these two types of terrace surfaces is based first on the relative height from the river bottom; second, by the grade of dissection of the terrace surfaces is based first on the relative height from the river bottom; second, by the grade of dissection of the terrace surface, third, by the kinds of rock and soil which compose the terrace surfaces. First, as to the relative height, the kind of terrace can be determined roughly if one draws a longitudinal section of each river bottom then projects it to the terrace (see Fig. 2). However, the relative height formulated by this method occasionally may be almost worthless for correlation. The first reason for this may be due to the knickpoint (Wendepunkt). The second reason is more common: a narrow canyon is often dammed by a landslide, and a lake is formed in which material is deposited. If this lacustrine deposit subsequently became land the terraces may have been formed by the progressive dissective activity of rivers on this older lacustrine deposit.

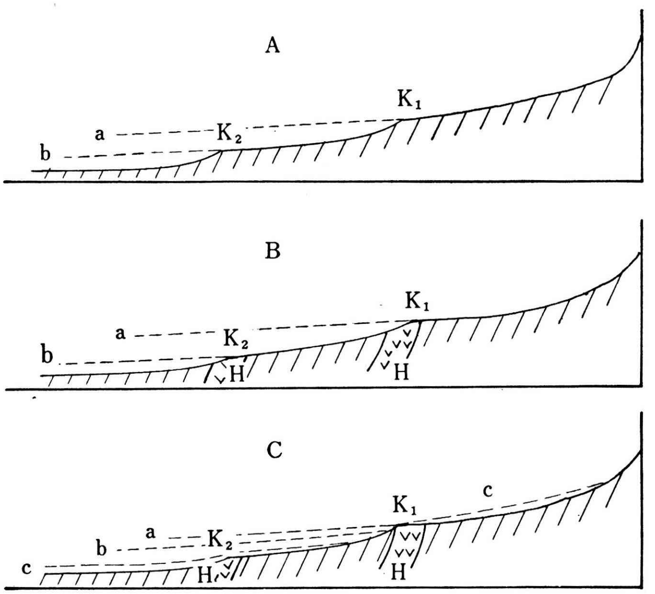

Fig. 2. Hypothetical Longitudinal Profile of a River Bottom.
K Knickpoint H Hard rocks a,b,c Terraces

As the knickpoint can be drawn on the longitudinal profile, it indicates the steep slope at a certain point on the river bottom. That indicates (1) a lowering of the base level of the river or, conversely, uplift of the land; or (2) an increase of flow in the river, the increase being due to an increase in precipitation because of climatic change or enlargement of the drainage area by capture or by joining of tributaries; (3) the existence of rocks that have a higher resistance against erosion. These varying factors play independently or in combination.

In Fig. 2–A, the location of the knickpoint is determined only by the seocnd uplift so the point moves gradually upstream and the portion below the knickpoint forms two step terraces, "a and b," representing a part of the river bottom before uplift B was started. Then the position of the knickpoint was determined by the presence of hard rock formation. But the appearance of a and b terraces formed by the second uplift is the same as in A. In each case, the uplift, or in other words, the lowering of the river base level, is achieved, so that upstream from the knickpoint a nondissective equilibrium drainage channel is created. In C, equilibrium is not achieved in the upper drainage channel, so cutting of the river bottom continues, as is often visible in Taiwan. In this case terrace surface a below the knickpoint K_1, as is shown in Fig. 2, originally formed the balanced drainage channel with the new low terrace plane c upstream from K_1. Therefore, this plane is considered as the same land surface. But on the basis of the time of formation of the land surface, terrace plane c was recently formed by advancement toward the upper stream channel through further down-cutting, crossing over the knickpoints $K_{1\text{-}2}$ after the formation of terrace planes a and b. A good example of this type of terrace is observable in the terraces on the bank of the Rōnō River (Fig. 3).

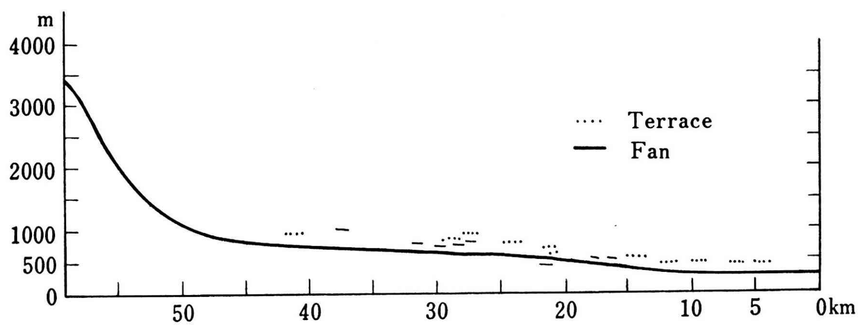

Fig. 3. Profile of the Rōnō River with Terraces and Fans.
A Convergence of knickpoint B Divergence of knickpoint

The relation between the times of formation of the young and old terrace levels on the one hand, and the differences in height of plane on the other may not be conformable in some cases. For example, in case the graded river channel as has been attained before the uplift of the terrace plane a at K, in Fig. 2–A, the river floor farther upstream must be looked upon as the same topographic plane. If, however, the river did not maintain a drainage channel at equilibrium, the down-cutting activity in the river channel above the knickpoint might have continued and the terrace forming process might have been continuous even after the uplift. If the uplift movement affected the entire drainage area and the land showed an increased tilting movement, the gradient increased throughout the drainage area, and the terrace-forming process was much activated by the simultaneous down-cutting process of the river. As a result, the formation of terraces increased. The age of terraces and the topographic positions have no relation, so that in the terraces connected with river valleys, the degree of dissection and the topographic position are considered as different problems.

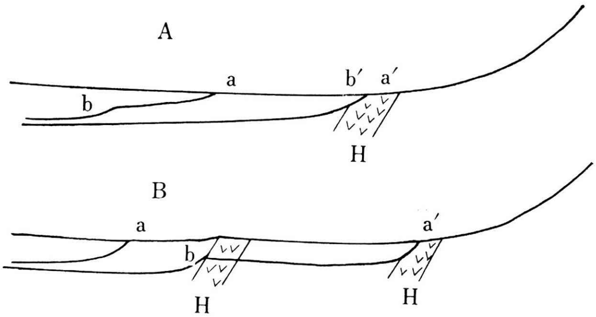

Fig. 4. Hypothetical Longitudinal Profile of a River Bottom Showing Convergent and Divergent Knickpoints.
H Hard rocks

The next case is that the knickpoint is located at a place where hard rock is exposed. The knickpoints are formed at the two points a and b by two successive elevations in case A, as shown in Fig. 4. The progressive dissective activity was retarded by the presence of hard rocks, and the knickpoints a′ and b′ have been combined into the knickpoints a″ and b″. Or as indicated in B, only one knickpoint was formed by a single uplift, but it has diverged into two knickpoints where hard rocks are exposed in two places just as if two upliftings had occurred.

The correlation of the terrace planes formed by the above-mentioned processes is very complicated and is difficult to explain plausibly. However, it is not always complicated nor strange, and its explanation may not be difficult. But precaution must be exercised in order to evade the major fallacies incurred by a simple judgement based on the relative height in the topographical map and the degree of river dissection.

In order to determine, on the basis of a profile of the river bed, how far the present river bed is from the profile of equilibrium, and where the point of change in gradient is located, as well as to compute the amount of uplift and the relative height of the terraces from the past equilibrium channel, an equilibrium curve should be drawn for each river (in its state of equilibrium). In the computation, it is considered very convenient to use the logarithmic curve formula proposed by J. F. N. Green (1936).

$y=a-k \log (p-x)$

p=Length of river channel

a=Height of headwaters

x=Distance of a given location of river floor from the mouth of river

y=Height of river bed at location x

k=Constant (see Fig. 5)

The surface of the fluvial terrace is regarded as a base plane of a river bed as compared to the topographic plane. All the river terraces, however, do not always represent the basal plane of drainage channel of equilibrium so that it is necessary

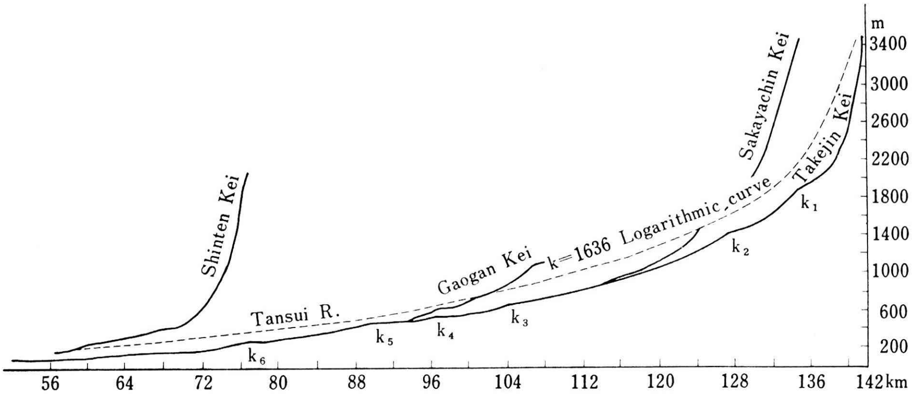

Fig. 5. Profile of Water Courses of Tansui River and the Approximate Logarithmic Curve.

to study what kind of river terraces one is dealing with. In order to select a suitable terrace plane for study, it is necessary to have some appropriate classification.

Bruno Dietrich (1911) proposed to broadly classify terraces into "durchlaufend Terrasse" and "Lokal terrasse." The former are arranged continuously along the drainage channel, and its terrace plane is considered to indicate the "ruhe phase" of the previous river bed. The latter is only of local distribution so he contended that it has only a secondary significance in geomorphology.

De la Mothe (1915) divided the terraces into "terrasses de régulieres ou du principales" (principal terraces), "terrasses de secondaires" (secondary terraces), and "fausses terrasses" (false terraces). The first two conform with the classification proposed by Dietrich, but the third, "fausses térrasses", are those formed by the retrogressive dissection of the main river on a portion of the alluvial plain or fan (deposited by a tributary) at the point of confluence of the tributary with the main river bed. These terrace planes do not indicate a part of the main river bed. E. Chaput (1924) called the terraces developed on both the Seine and Garonne Rivers "terrasses polygeniques." These indicate a series of equilibrium phases (due to a series of uplifts), but in this case show a continuous sloping terrace plane resulting from several phases of equilibrium completed after a series of uplift movements. They correspond to the so-called slip-off slope (formed by incised meanders). This type of terrace is also the same as that of the "amphitheatre terrasses" proposed by H. Miller.

J. Hanson-Lowe (1938) has proposed the following new classification:

Significant terraces	Principal erosion terrace Principal aggradational terrace
Relatively insignificant terrace	Secondary, or meander terrace False terrace (slip-off slope terrace)

I propose the following classification which is based on the idea that the terrace surface indicates a topographical plane formed at the base level of the river as a standard.

Standard terraces............... { Perfect / Partial } — { Standard depositional terrace / Standard erosional terrace }

Subordinate or Supplementary terraces .... {
- Meander terrace
- Slip-off slope terrace
- Fan terrace
- False terrace
- Polygenic terrace

A terrace used in topographic correlation must be, at least, a standard (key) terrace. Of course, it is rather rare to find a terrace that can be traced completely along the major part of a river channel of equilibrium. Thus, in most cases we have to select certain standardized terraces of a partial nature.

Subordinate terraces developed along the river channel of equilibrium may be correlated with those mentioned above by using the curve of equilibrium as an accessory medium. The meander terraces often retain the value of partial standard terraces. In the slip-off slope terrace, each surface is more or less flat, as is observable along the middle portion of the Tansui River. In the vicinity of the entrance of the Kappan-san Canyon or Rahau, each surface appears roughly level so it can be said to have the quality of a partial standard terrace as long as it is bounded clearly by a terrace scarp (see Fig. 6).

A fan terrace is formed by the interaction of a tributary with the depositional processes of the main river. Its surface extends downstream along the main river bank from the point of confluence, so that it looks extraordinarily prolonged. It might be said that the fan had been converted into a terrace.

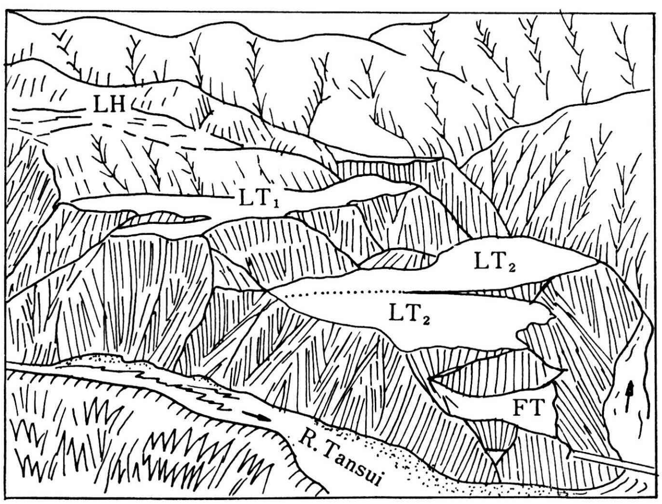

Fig. 6. Keikōdai Terraces Opposite Kappanzan.

A fan may even become an accessory to a standard terrace formed at the point of confluence of each tributary, as is the case of the upper part of the Girandakusui River. Herein is a very good example that the relative height of each terrace does not always indicate relative age. In Takkiri River on the east coast of Taiwan, there is a terrace called Burowan terrace on which an aborigine village of the same name is situated. The Burowan terrace is situated on the southern foot of Sangetsu-kyō (bridge) at the bottom of the famous Taroko canyon near Batakan. The terrace is situated 400 m above sea level and the present river bed stands at about 200 m, thus, the relative height is 200 m. On the basis of relative height, it belongs to the highest terrace group in Taiwan. Thus, it definitely can be called a higher terrace. However, when we glance over the terrace surface, there is practically no residual weathered soil; it is composed wholly of those gravels constituting the flood plain near the present river bottom. Moreover, the terrace surface is divided into two horizons by a well-defined terrace slope 5 m high. When one climbs over the slope, it crumbles easily and does not show any difference in composition from the slope formed in the terrace near the present river bottom. The terrace gravel is composed of roughly uniform pieces of crystalline schist and sub-angular flat slate smaller than a human fist. Below the Burowan terrace there is a narrow terrace having a relative height of only 20 m. The gravel composing this terrace is limestone (crystalline) and the gravels are cemented with matrix so that the terrace looks somewhat old.

Thus, in the observations based on the depositional nature, there is an inconsistency in that the higher terrace has a much younger aspect in comparison with the lower terrace. In this case, my interpretation is that a landslide occurred some place in the lower part of the canyon below the Burowan terrace and the river was dammed and formed a lake. As the bottom accumulation proceeded, redissection commenced and the majority of the dry lake surface eroded away. Only a small part remains as the present Burowan terrace.

The formation of terraces due to damming of the streams by landslides are common phenomena, especially in places where rejuvenation of erosion is very active and deep canyons are formed. It is not difficult to conceive that such slides or dislocations very frequently occur on both the river banks as dissection advances. The best example of this is [lake] Sorei-tan or Seisui-tan which was formed by a landslide on the right bank in the upper stream of Seisui River, a tributary of the Dakusui River, as the result of a strong earthquake which occurred in December 1941. This dammed lake had an area of 6.6 sq. km, so that it was wider than the Jitsugetsu-tan (4.4 sq. km) the largest intermontane lake in the island. Such a lake was called a "seismogenetic lake" by HAYASAKA (1947), and when this natural lake formed by a landslide is stabilized, the water can be utilized for generation of electricity. Under the Japanese regime, a survey was made to determine whether it would stand permanently or not. In May 18, 1951, this natural dam was destroyed by an enormous increase of water brought by heavy and long rains. This catastrophe resulted in 150 deaths. Great property damage was inflicted by the inundation of paddy land in that area. It is thought that since the destruction of the dam a new lake shore terrace might have been formed. It was reported that a strong earthquake which occurred on October 22, 1951, in Karenko resulted in the formation of a seismogenetic lake as a result of a landslide on the Takkiri River. Detailed information as to the location and extent of damages has not been confirmed.

In the correlation of terrace surfaces, chief consideration must be given to the nature of the material composing the terrace planes, the relative height, and the degree of dissection. Of course on all gravel terraces and even rock terraces, the erosion surface of terrace is usually covered with a thin gravel bed. When a terrace is old, the gravel of the terrace surface is decomposed and the upper surface is usually covered by residual soil. By the degree of weathering of a terrace surface, it may be possible to judge the relative ages of the terraces. On both the higher and lower terraces which have been classified in Taiwan, the gravel in the lower terrace is identical with that of the flood plain because it has not been weathered and is not cemented with matrix or coated with limonite. The surface terrace gravel is only slightly covered by thin transported sand and mud. In higher terraces, on the other hand, the gravels are somewhat weathered and usually impregnated with limonite without having been consolidated. Of course, the surface is covered by lateritic soil but the boundary between the gravel bed and lateritic soil is clearly marked. It has been suggested by HILGARD (1911) that the lateritic soil is a subsoil formed through the permeation of colloidal clay by rain water, under the prevailing climatic conditions of high temperature and humidity; and that it becomes soil through the process of lateritization. The lateritic soil widely distributed along the terraces of Taiwan has a higher silica content than the laterite of tropical districts. The name lateritic soil was proposed by Kisaburō SHIBUYA (1922) in Taiwan, but Eitarō SEKI called it a red loam. The process of lateritization has a tendency to decrease the silica content but it is said that the loam-forming process has a tendency to gradually increase the silica content. There are two theories for the formation of lateritic soil of Taiwan; one is that the laterite forms through the loam-forming process, and the other is that the loam is formed during the lateritization process.

Both the higher and lower terraces cannot always be distinguished clearly, for when a series of terraces are arranged in a step-like form, there is a terrace which may be assignable to an intermediate type. This type of terrace is found in the middle of Unrin Pref., south of Chikuzan district (Nantō Pref.) where a group of terraces are formed around hills by the Dakusui River and its tributary on the south, the Seisui River. The top plain of these hills form an undulating dissected tableland. The surface of the terrace is covered with a thick reddish-brown surface soil, below which lies a lateritic subsoil. In the terraces 2 to 3 steps below, the top soil becomes thinner and at the same time the reddish tint fades. The more recent soil grades from reddish brown to yellowish brown; on the lower terraces, a dark-brownish soil is formed, and no trace of weathering of the gravel bed is visible.

An intermediate terrace is recognizable in the middle part between the higher and lower terraces.

It is relatively rare to see terraces arranged in 5 to 6 steps at one place. Even in such a case, it is possible to determine by the degree of weathering of the gravel bed whether the terrace is assignable to a higher or lower terrace, so that it probably is not necessary to make an intermediate division.

What comes into question here is lateritic soil which constitutes the surface soil of the higher terraces LT. It is impossible to regard the lateritic soil as a residual soil resulting from weathering of the top layer of the underlying gravel bed. In the gentle slope of lateritic soil which is topographically situated above the higher terraces, as will be stated later, the lower part of the lateritic soil bed often contains lateritized gravel due to weathering, leaving only the outlines of gravel grains. So, the boundary between the gravel bed and the lateritic soil bed is indistinct. In the higher terraces, however, the boundary is distinct, as already mentioned, which shows that the lateritic soil is not a product of weathering in the underlying gravel bed. It cannot be considered, however, that the lateritic soil was washed down from the lateritic soil slope in a higher altitude and was redeposited. It would be appropriate to attribute the sedimentation of lateritic soil to permeation and diffusion, as HILGARD maintains.

As mentioned before, when we regard river terraces as criteria in the correlation of topographic surfaces, we must consider the existence in Taiwan of two terrace surfaces, the higher and lower. For the sake of convenience in correlation, the former is designated tentatively as the LT surface and the latter the FT surface.

B. Gentle Slope Surface Covered with Lateritic Soil

As mentioned before, the upper portion of the higher terrace in Chikuzan is shown by the hilly land of a dissected tableland and flat surfaces are retained locally. In a broad sense, an undulating land surface is formed. We glance over the nature of rock formations: gravel beds cover the erosion surface of the Shinchiku series of the Tertiary system and the upper part of the gravel bed is converted into the lateritic soil. In the lower part of the lateritic soil bed the gravels still retain their form but their composition is totally changed into lateritic soil or to yellowish clay. The gravel is composed mostly of slate, sandstone, and siliceous sandstone, but because of the effect of weathering the nature of the gravel is not recongnizable. The gravel grains are almost wholly cemented and the cementing material has also been laterized. The boundary between the lateritic soil and gravel bed is not clear. As mentioned before, there is a point of marked difference between the lateritic soil slope surface and the higher terrace surface. In this place this gentle slope surface of lateritic soil is used tentatively as the former topographic surface and is called the "LH surface." This gently sloping LH surface is not only widely distributed in the tableland on the west consisting of the lateritic soil bed thickness of 5 m or so, but such surfaces are widely distributed from the upper portions of the river valleys to the mountain slopes throughout the island.

Notably, those situated on the mountain slope are now the aborigine villages for the mountain people of the "Takasago tribe." These villages are distributed in places with heights ranging from 1,000 to 1,500 above sea level in the north and central parts of the island.

In the southern part, however, these zones of gentle slope gradually decrease in altitude and height, and they attain a height from 300 m to 500 m. As these places are in a purely tropical climatic environment, the amount of rainfall is more than in the plains of the lowland areas, and foggy days are numerous so that the areas become a humid zone. Under this climatic condition, the areas became a focal point for pharmaceutical enterprises, including the quinine plantation of the Hoshi Pharmaceutical Company and the tropical medicinal plantations managed by such pharmaceutical companies as Takeda, Meito, and Shionogi.

In the northern and western parts the sloping surface of lateritic soil become gradually lower and grade into the tableland covered by the lateritic gravel bed mentioned before; at the same time the height is also lowered. The Rinkō tableland surface in the north attains a height of 200 meters. The original surface of the Tōen tableland links with Nyūko-zan (389 m), extends to the Taito tableland, Hakkei tableland, Shokkō tableland, and to the dissected Nantō tableland through the hilly areas of dissected tablelands including the Chikutō, Chikunan, and Byōritsu tablelands.

In the vicinity of Kagi, the tops of low hills composed of lateritic gravel beds and encroaching onto the Kanan plain can be correlated with these tablelands, but these low hilly areas are postulated as being due to the land tilting. Farther toward the south where the area approaches the south bank of the Sobun River by way of the Kanden River a remnant of the original gravel tableland is clearly visible in the vicinity of Kiriga where it attains 160 m in height. This tableland, called the Shinka dissected tableland, is correlated with the tableland situated in the vicinity of Kizan. Farther toward the south, the Shinka dissected tableland can be correlated with the dissected limestone tableland of Hozan about 100 m in altitude and it terminates in the limestone tableland near Kontei on the Kōshun peninsula and the Byōritsu tableland surface. To the north, it is also possible that gentle slopes on the sides of both the north and south summits of Mt. Daibu can be correlated topographically. On the top of the summits grouped on the east slope, a series of flat surface still remain. The best example of these flat-topped hills is that of "Chyokakurai" which stands about 700 m above sea level. This place is the site which has been utilized as a medicinal plant farm land as mentioned before. A quinine plantation of the Hoshi Pharmaceutical Company is located on the gently sloping surface above the Chippon hot spring to the north. This sloping surfaces are dissected consequent rivers, but these surfaces are developed in a narrow and long belt in the area extending from between 300 to 500 m in altitude. During the war a nursery of quinine trees extending for several km was developed on these surfaces.

In the Taito rift valley on the east side of the island, the gravel tableland of

Pinan in the southern part, the gravel tableland of Mizuho, in the middle, and the gravel tableland of Beiron-san near Karenkō in the northern part are all topographic surfaces which may be correlated. As remnants of gravel-covered tableland are found near Tamasato, Taishō, Tōjimpo, and the area between Shinkaien, and Raikōka, Hinode, it is probable that the faulting in this rift valley occurred before the accumulation of the tableland gravel. Hence, these gravel beds are alluvial fan deposits formed after the faulting or they may have accumulated after the dis-

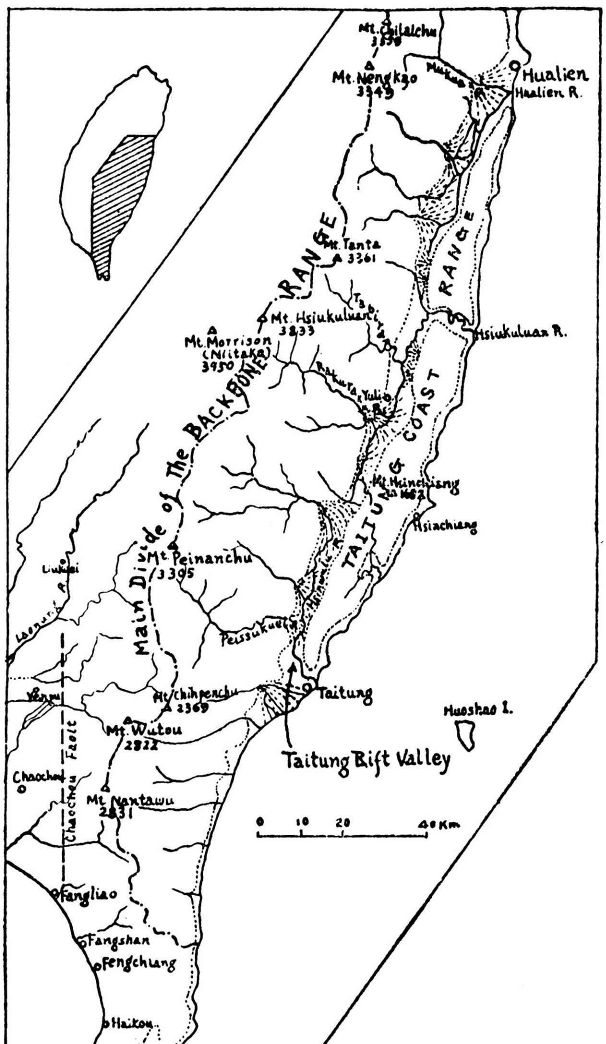

Fig. 7. Alluvial Fans in the Taitō Rift Valley.

section process was completed. The faulting was repeated and the alluvial fan-shaped land forms we now see were developed.

The physiographic development of the Taito rift valley is considerably complicated. It is probable that the graben structure was formed by the faulting in the beginning of the Pleistocene epoch, the fan-like accumulations were formed, and by subsequent dissection a subdued topography has developed on the gentle slopes of the lateritic soil. Following this episode, uplift at the end of the Pleistocene brought about deep dissection of the alluvial fans, and local remnants of the fans have been changed into the gravel-covered tablelands. On the other hand, it is considered that the faulting accompanying the land uplift caused the present land form resembling an alluvial fan (Fig. 7).

The Taito mountain range is a range of extreme dissection; it shows a topographic form recalling a skeleton mountain range composed of hard and compact rock such as limestone intercalated with the Tertiary system or agglomerates of basic andesite. The development on the mountain side of gentle slopes covered with lateritic soil is rare. However, on the west slope of the central area at Mt. Rokujukkoku, a flat surface of considerable width is covered with lateritic soil. Commonly, in the mountain systems of Taiwan, the latiritization process extends into a considerable depth and is weathered into the lateritic gravel bed, but in the Taitō mountain range such a feature is exceptional. These flat surfaces are lumbering locations and the exposures along the sides of the timber haulage roads expose the rock formations so that observation is facilitated.

Generally the lateritic gentle slope surface (LH), as is developed on the mountain side, can be interpreted as the penultimate form of the pre-subcycle of erosion and its form apparently similar to cirques due to ice erosion in the slope surface. Such shallow hollows are often recognizable in the topographic surface at the head of valley (Figs. 8 and 9). This kind of concave slope resembles a crate which is

Fig. 8. Higher Terraces (LT) and Gentle Slope Surfaces (LH) around the Upper Stream Region of the Tansui River Viewed from Kara Village to the Southwest (Ibao River Side).

Fig. 9. A Concave Slope (LH) of Yōrō Village in the Upstream Region of the Tansui River (Sakayachin River).

commonly used for the transportation of soil or a farm implement a sort of bamboo basket known as "punki" in Taiwan, so that in the term applied to the geographical name Funkiko, ko means a basin plain. A station name "Funkiko" of the Arisan Railroad Line is derived from "Punkiko." In any case it indicates the topographic feature.

According to Walther PENCK (1920) in his essay on the developmental processes of concave slope surfaces, such a concave form of sloping surface is developed in the interval between the pause and the subsidence. Such a landform, then, can be correlated with the convex slope of a surface which was formed during the period of uplift. I observed the topographic surface which has developed in the piedmont area of Hainanto in South China and compared it with that of Taiwan (TOMITA, 1944). This concave sloping surface covered by lateritic soil is considered to have been formed during the period turning from the pause to a period of subsidence.

The topography of the original surface of the gravel tableland, as is developed in a broad area on the western part, also may be correlated with the above-mentioned gently sloping surface covered by the lateritic soil. A shallow and wide valley shows a trellis drainage system peculiar to river valleys dissecting cliff margins. Thus, the original surface of the tableland must have been undulating, but it is distinct that a valley rejuvenated due to the recent uplift has cut into the wide and shallow valley of old age until a valley-in-valley topography developed, as is clearly manifested in the Rinkō tableland on the north. (TOMITA and WATANABE, 1931; TOMITA, 1932)

Fig. 10. Ledge (L) on the Left Side Spur and Gentle Slope Surfaces (LH-plane) around the Upper Stream Region of the Tansui River (Sakayachin River).

C. Ledges on the Mountain Spurs

A prominent development of an ingrown meander is found from the middle to the upper portion of the drainage course in each river valley of Taiwan, especially along the Tansui River, Taikō River, Dakusui River, Sobun River, Nanshisen River, Rōnō River and Dakkō River (the last three rivers are tributaries of the Shimotansui River). Here, extensive slip-off slope terraces are formed, however, in the upper stream valleys, the mountain spurs are linked with the shoulder-like plane (ledge), as remnants of slip-off slope terrace can be seen. This ledge was originally termed a slip-off slope terrace, but as the downward dissection advanced the terrace surface narrowed, and at the same time the relative height increased. The result is that the summit of practically all remnants stand as a horizontal line which can be termed ledge surface (Tomita, 1937A, 1938A) on the mountain spur (Fig. 10). Most of ledge surfaces can be correlated with the high terrace surface, but in the upstream area of the Taikō River they can be correlated with the lateritic soil slope surface (LH-plane). It is true, however, that another terrace surface stands higher, but the nature of the higher terrace makes determining its position difficult.

D. Ecktreppe Topography

In the upstream area of the Taikō River, on Heigan-san and in the vicinity of Saramao there are 4 to 5 step terrace-like flat surfaces. These are found in the interfluvial areas at the point of confluence of the Taikō River and its tributary the Nanko River, and between Gōkan River which drains from the south and joins the Nanko River. These terrace-like flat surfaces on spurs were named Eckflur by J. Sölch and the eckflur arranged step-like on a spur was called ecktreppe (Sölch, 1918). On this spur of interfluvial district, narrow and long planes run in step-like extending from the northeast between the Taikō River and

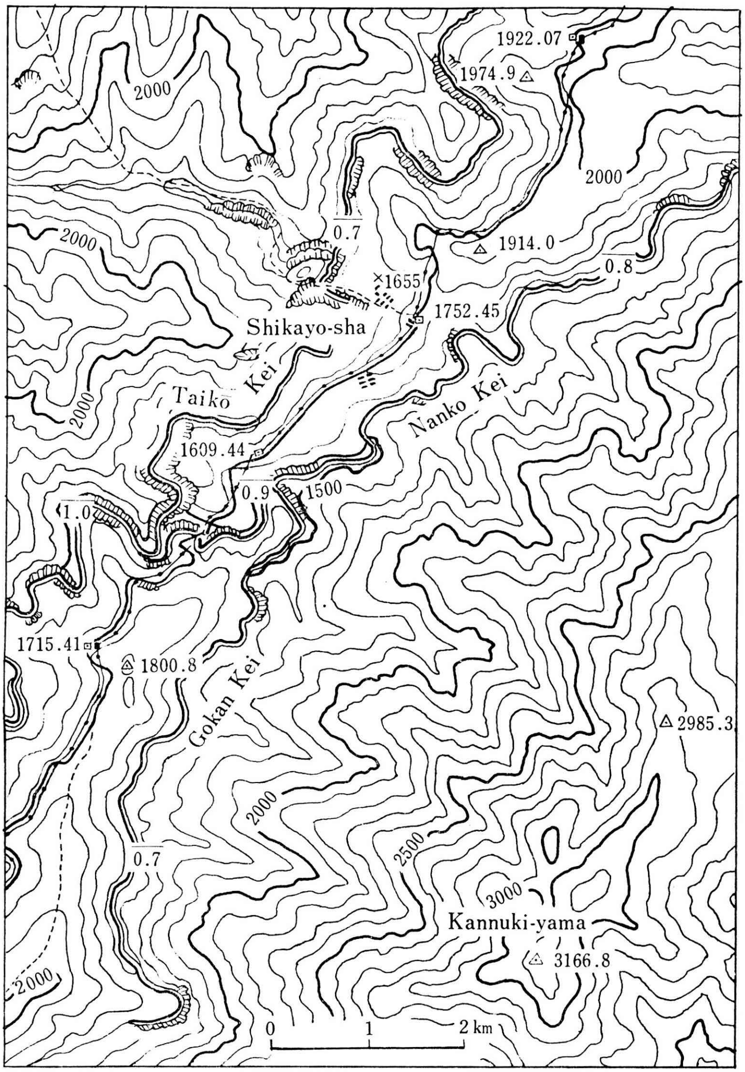

Fig. 11. Ecktreppe Topography along the Taikō River.

Nanko River called the Heigan-san spur, and one called the Taboku-oné or the Taboku spur extends from the southwest between the Taikō River and Gōkan River. On the Heigan-san spur there are five stepped flat surfaces at the following heights: 2,100–2,080, 2,000–1,900, 1,900–1,780, 1,780–1,600 and 1,580–1,540 m. These flat eckflure surfaces form an ecktreppe. On the Taboku spur there are four stairs as follows: 2,000–1,800, 1,780–1,760, 1,740–1,720 and 1,540–1,500 m (see Fig. 11). In each eckflur, the lateritic soil rests on the gravel bed. The gravel bed situated below the second stair has not been cemented so that they can be correlated with the surface of the higher terrace, but the first stair is considered to be correlated with the gentle slope covered by the lateritic soil. In the third stair of the Taboku Spur, the beds of sand and clay overlying the gravel bed indicate that the rivers of that time were sluggish.

Such ecktreppe is interpreted by J. Sölch (1918) as being formed due to the merger of river valleys. If that is the case, the process might have taken place in the

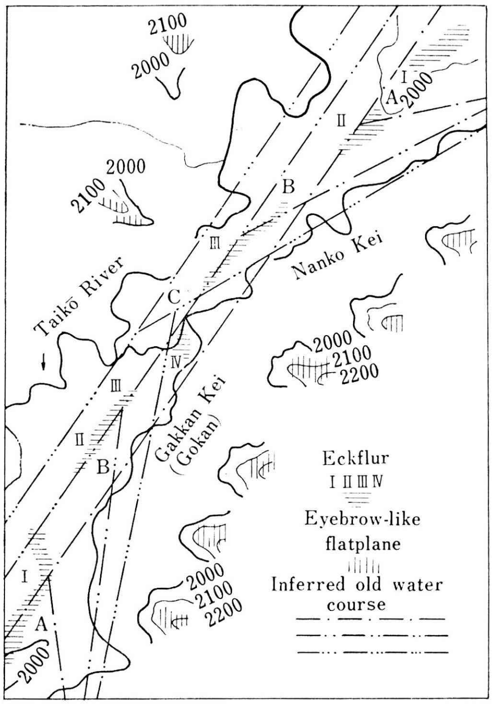

Fig. 12. Formation Process of the Ecktreppe of the Taikō River.

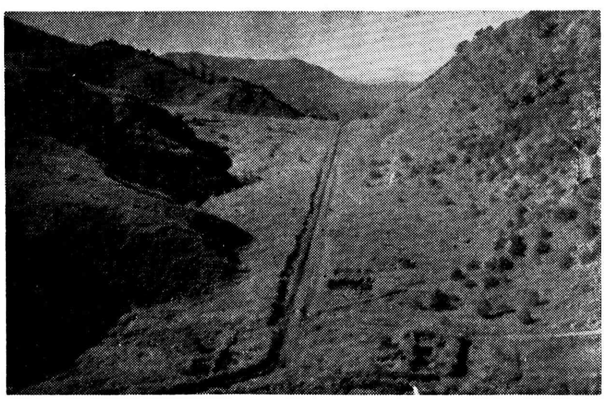

Fig. 13. Wind Gap of the Pianan Pass in the Taikō River Valley. Hills on Right Side are the Dissected River Terrace (LT-plane) Covered with River Gravel.

manner indicated in Fig. 12. It is considered to be reasonably explained by the mündungsmäander (confluent meander) proposed by I. MOSCHELES (1922). Examples of ecktreppe topography which has been formed through such a procedure

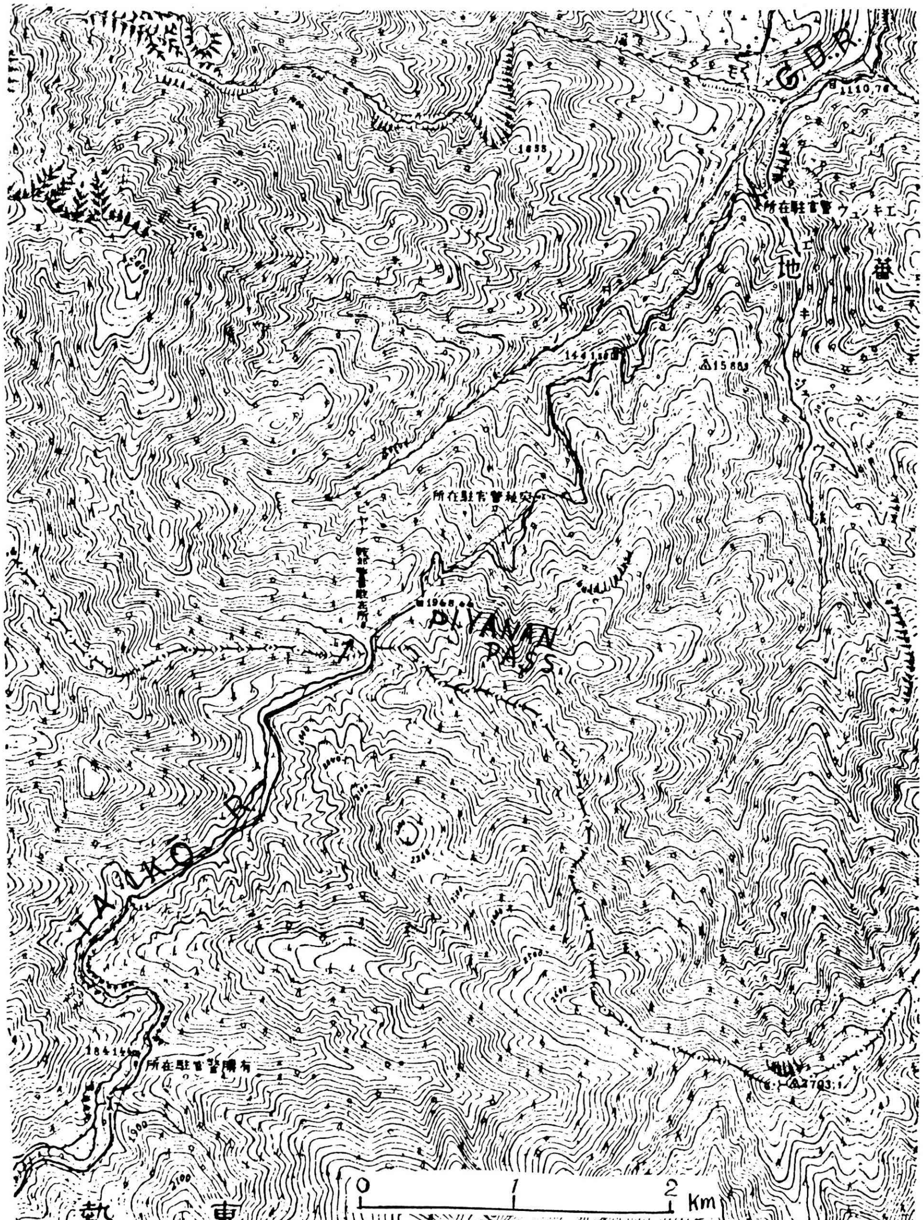

Fig. 14. Main Divide between the Taikō River (SW) and Girandakusui River (NE). Arrow in the Center of the Map Shows Wind Gap in Fig. 13.

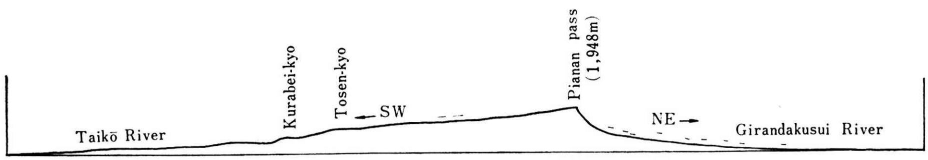

Fig. 15. Profile of the Taikō River and the Girandakusui River.

should be found in other river canyons in Taiwan, but so far as we are aware no such form has been found up to the present. At least, a type on such a large scale as that of the Taikō River may not be found on other rivers. The reason may be attributable to the fact that the river-valley topography developed on the Taikō River is different from other river valleys. That is, in the upstream canyon of the Taikō River, the valley remnant of the equilibrium channel of the pre-subcycle of erosion has prevailed for a much longer time than any other river. In addition, it shows a notable difference from the Girandakusui River which takes a NE direction from the divide (see Figs. 13, 14 and 15). A reasonable explanation is that in the middle part of the Taikō River there are two great canyons, Kurahei and Tosen-gorges which have sharp knick point so that down-cutting of the river bed has been prevented by these two turning points in spite of recent uplift.

Consequently the equilibrium channel in the upstream part of the Taikō River may represent an old topography. It is also verifiable on the basis of faunal distribution, as the habitat of the so-called "saramao" trout is exclusively confined to the equilibrium drainage channel after Wülm (4) (the name of this trout is derived from the aborigine village of the same name which is an important village situated near Heigan-san). In the present river bed, however, downcutting due to the recent uplift extends to just above the village of Saramao beyond the canyons of Kurahei and Tōsen-kyō, as is substantiated by the presence of a "umlaufberg" at Saramao where the old river bed is 40 to 50 m in relative height.

E. Denuded Planes in High Mountains

It has been known that flat or gently sloping surfaces are found in far higher places than the lateritic slope surface mentioned above. These flat surfaces are found locally on the divides of the high mountain range of Taiwan. Along the road crossing the backbone range from east to west, the gently sloping surfaces is visible near the divides where the road passes, and at the same time an old shallow river valley topography can be seen. The gently sloping surface is also visible between the backbone range and Nan-san south of Niitaka-yama (Yushan), and a relatively wide area of such surfaces is also recognizable where timbering is under way on Taihei-zan, Hassen-zan, and Ari-san. In all these areas, no lateritic soil is visible, but within the forest, a podzol is recognizable. On the northeast slope of Nankotai-san a wide plain surface 3,400–3,500 m is found that is assumed to be a remnant of glacial topography (Fig. 16). This area is considered to be one of the source areas of glaciation (Tanaka and Kano, 1934). Of course, some of these tableland sur-

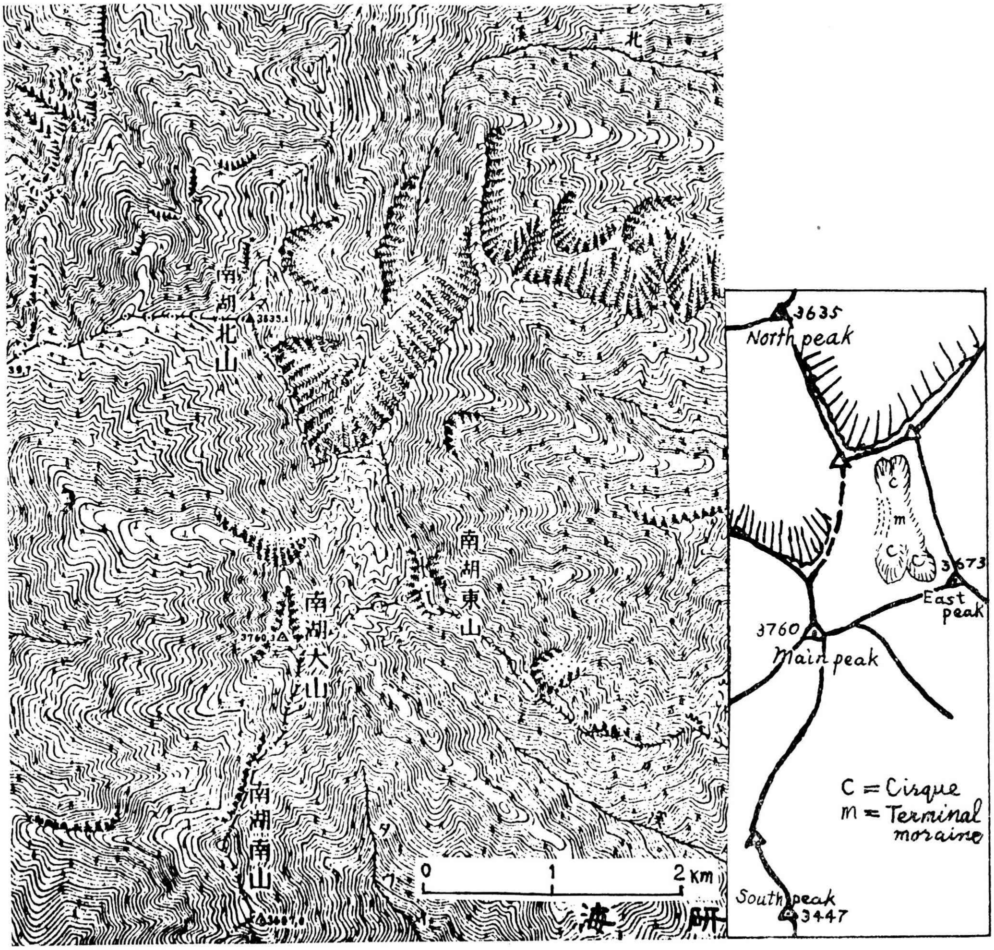

Fig. 16. Site of Cirque on Mt. Nankotaisan.

faces have been formed by differential erosion of hard rock formations, but usually it is thought that hard rock leads to the formation of undulating surfaces.

The absolute heights of high-mountain dissected tablelands are not uniform but they stand at a height of more than 2,000 m, and the gently sloping lateritic surface below is bounded by an erosional scarp so that it forms an independent topographic surface. Consequently this high-mountain dissected tableland, termed the HE surface, is considered to be the highest and oldest topographic surface of Taiwan.

A fan as a topographic form does not necessarily indicate a stage of equilibrium in river dissection of the alluvial topography. For example, one that formed at the base of a fault cliff is connected simply with the period of block movement. However, as many terraces are found in the areas where alluvial fans are developed, the fan surface is closely related to the alluvial terraces. As alluvial terraces can be classified into higher and lower terraces the fan surface can also be divided into higher and lower planes, according to their relative heights. The mode of weathering of fanglomerate on the fan surface is similar to that of terrace conglomerate. As the fan surface is rather gently sloping, like that of the terrace surface, some uncertainties may accompany topographic correlation, but it can be utilized as an accessory fact in determining the age of a topographic surface.

The fans of Taiwan are classified into four types according to the stage of development as follows: old, intermediate, young, and immature fans.

Old Fans

An old fan became a tableland by dissection after the land was uplifted; by further dissection it became a hilly land so that its original surface can be correlated with the gently sloping lateritic surface, that is, the LH plane. Although the topographic surface of the old fan is included in this chapter in which the broad outline of its distribution was described, it will be described again from the point of formational process.

An old fan topography can be found throughout the west piedmont zone in Taiwan in the northernmost part of it is the Tōen tableland (Fig. 1–2). As was described by Ichikawa (1929), a great fan area was formed at the base of the reverse or thrust-fault scarp of the Shinten fault which borders the western margin of the mountain area on the east. This old fan has been dissected by the Sekimon River the predecessor of the original Shinten and Tansui River. The aforementioned Rinkō tableland (Fig. 1–1), which stands west of the city of Taihoku, corresponds to the northern extension of this great old fan land. The Rinkō tableland was separated from the fault cliff due to subsidence of the Taihoku basin, and it as a remnant of the tableland can be found in that area. The fan surfaces in the central part of west Taiwan still retain the original surface which extends from the Tenshiko tableland (Fig. 1–3) through various tablelands including the Shimpo and Kokō tablelands (Fig. 1–4, 5). In the Tōen tableland district, according to Hanai (1931), an active fault scarp facing to W is running from ENE to WSW played a part in the formation of a series of fractures on the fan surfaces. The Kyūrin dissected tableland (Fig. 1–6) which borders the south edge of tbe Tōen tableland, and the Chikutō and the Shinchiku dissected tablelands (Fig. 1–7, 8) on its west all have a hilly aspect. Some remaining initial surfaces are composed of tableland gravels and still show some aspects of the great old tableland in spite of its subsequent dissection. The true nature of the topographic precursor of the Chikunan dissected tableland (Fig. 1–9) is difficult to determine because of the advanced stage of dissection.

Under close scrutiny, the Nanseikō tableland (Fig. 1–10), a part of the Byōritsu dissected tableland (Fig. 1–11) on the south reveals vast gravel tableland remnants of an original surface which shows the nature of an alluvial fan. Farther west, in the Hakushaton area and in the Tsūsho tableland (Fig. 1–12) south of this tableland, there are remnants of the gravel tableland surface. A part of this gravel tableland has become a terrace but most shows that it was deposited as alluvial fans. The Kōri tableland (Fig. 1–13) on the south, across the Taian River, is also considered a part of the same alluvial fan as the one which forms the Daito tableland (Fig. 1–14) on the south across the Taikō River. It is a great confluent fan area, but subsequently a part of the former fan surface was covered by intermediate and young fans. The latter (Daito tableland) was tilted gently toward the east, accompanied by subsequent depression of the Taichū basin, so that the fan surface also tilted toward the east.

The Hakkei hill (Fig. 1–15) which is situated south of the Daito tableland is also considered to have been deposited as an alluvial fan and it also is tilted toward the east. This tableland seems to link with the Heichōho tableland (Fig. 1–16) near the village of Takeyama across the Dakusui River. This tilting movement seems to have started at the eastern margin of the Taichū basin along a fault which shows displacement to the west, and the tilted surface shows downwarping.

The type locality of the Shokkō-zan gravel bed (HAYASAKA, 1931) which underlies the tableland gravel is situated in the area south of the Dakusui River between it the Seisui River. At this place the bed does not tilt as much as it does on the north, and on the eastern margin terraces are formed by the Seisui River. Here, the tableland gravel bed overlies the Shokkō-zan gravel beds. However, whether the tableland gravel has been formed by fan accumulation or not is impossible to judge on the basis of the present topography, but it can be inferred to form the south flank of the huge old alluvial fan formed together with the gravel tablelands developed on the north of the Dakusui River. On the south dissected tablelands such as Kokō (Fig. 1–17) and Koume (Fig. 1–18) run continuously to Takezaki (Fig. 1–19).

Farther southward the hills, as developed in Banro (Fig. 1–20), Shirakawa (Fig. 1–21), and Rokkō (Fig. 1–22), are similarly dissected tablelands, but all the traces of the original tableland surfaces have disappeared and a cliff-margin erosion pattern has been formed. The gravel bed remnants in the crest of the valley system are assumed to have existed as already mentioned. The existence of such gravel beds are affirmed by the fact that a remnant gravel bed is found at a height of 160 m in the Kiriga tableland (Fig. 1–23), a part of the Shinka tableland (Fig. 1–24) south of the Sōbun River, showing that it formerly was a gravel tableland. Further inference can be made that these were once alluvial fan deposits.

Turning to the eastern area of Taiwan, in the Taitō rift valley district there are gravel tablelands of old alluvial fan deposits besides the younger alluvial deposits already mentioned in Chapter B, namely in the north the Beiron tableland north of Karenkō, in middle the Mizuho tableland and in the south, the Pinan tableland (Fig. 1–25, 26 and 27).

The name intermediate alluvial fan designates the fan surface which has been dissected after uplift and which now remains as a tableland. The upper part of it can be correlated in topographically with the LT plane of the higher terrace surface.

When we observe the distribution of the old and intermediate alluvial fans, the old fans are typically developed north of the boundary formed by the Dakusui

River; of course, some doubtful old fans are also found in the southern part, but the typical forms are rather few compared with those of the northern part. On the contrary, fans of intermediate age are abundant in the southern districts. There is a remnant of an intermediate fan on the gentle slope at Daisuikutsu, Shikatani-shō, east of Takeyama near the south bank of the Dakusui River, even though it is suspected to have been built on solid rock. The surface is covered by a thin gravel bed which is covered by the lateritic soil. The elevation of the highest point attains 800 m, with a relative height of 420 m, and the length is 2.6 km. Between Kokō and Koume east of Toroku are found the Kantōseki, Sanchokutsu, Tairin and Chinsekiryō alluvial fans. All these places are located at an elevation ranging from 160 to 200 m and with a relative height ranging from 40–90 m. They have been dissected by consequent rivers but they still retain wide remnants of the fan surface.

On the right bank of the Hasshō River, east of the city of Kagi is a fan called the Banro alluvial fan (Fig. 17). It is a narrow, long remnant of a fan surface having a maximum height of 400 m, a relative height of 160 m, and a length of 8 km. South of Kagi to the Heitō plain intermediate alluvial fans are not developed, but the hills of the dissected tableland gradually lower westward and grade into the lowland plain. At the base of the aforementioned Chōshū fault scarps, on the northern half of the eastern margin of the Heitō plain, the development of an intermediate alluvial fan is prominent (Fig. 18). They extend from the bank of the Dakkō River to the mouth of the Rōnō River, on north to the Chingpuwei tableland, the Chialapu dissected fan and the Ailiao dissected fan consisting of the Santeimon and the Pinglungshan tableland.

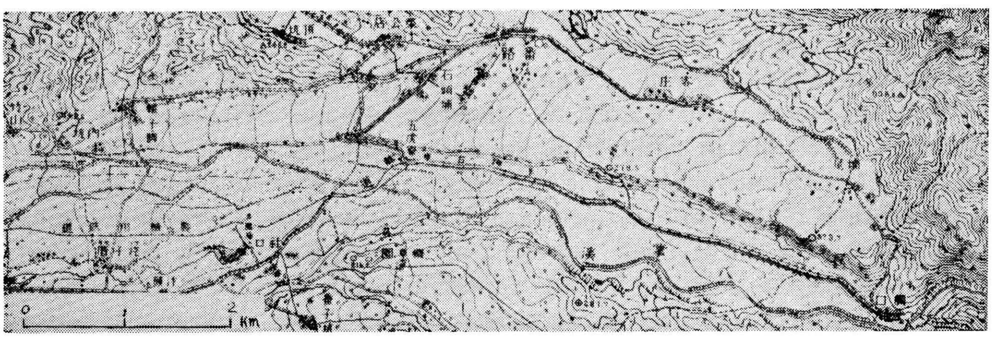

Fig. 17. The Banro Dissected Fan (Intermediate) along the North Side of the Hasshō River, East of Chia-l (Kagi) City.

Toward the south are gravel-covered hills which have been formed by river dissection of the old alluvial fans. Intermediate alluvial fans cannot be detected.

Many intermediate fans are found in the river valleys of Taiwan (Tomita, 1938). In most cases they are found in the longitudinal valleys and these longitudinal valleys are structural valleys which differ from the transverse valleys. Starting from the north, the Girandakusui River is shown clearly as an eroded

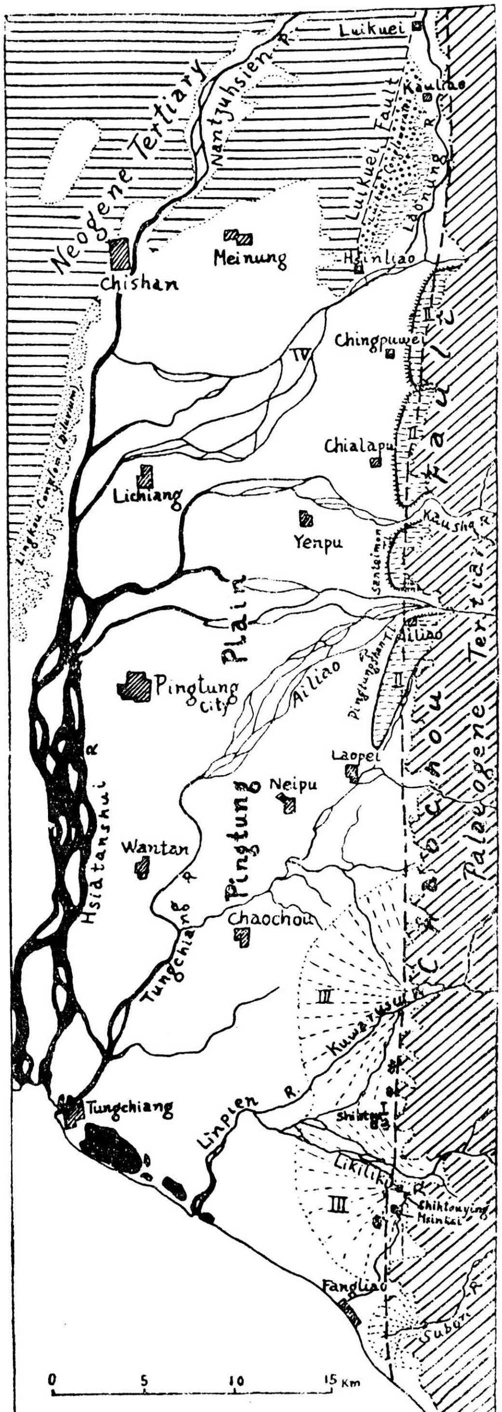

Fig. 18. The Pingtung Plain and the Chaochou Fault. II Shows Tableland Dissected Intermediate Fans.

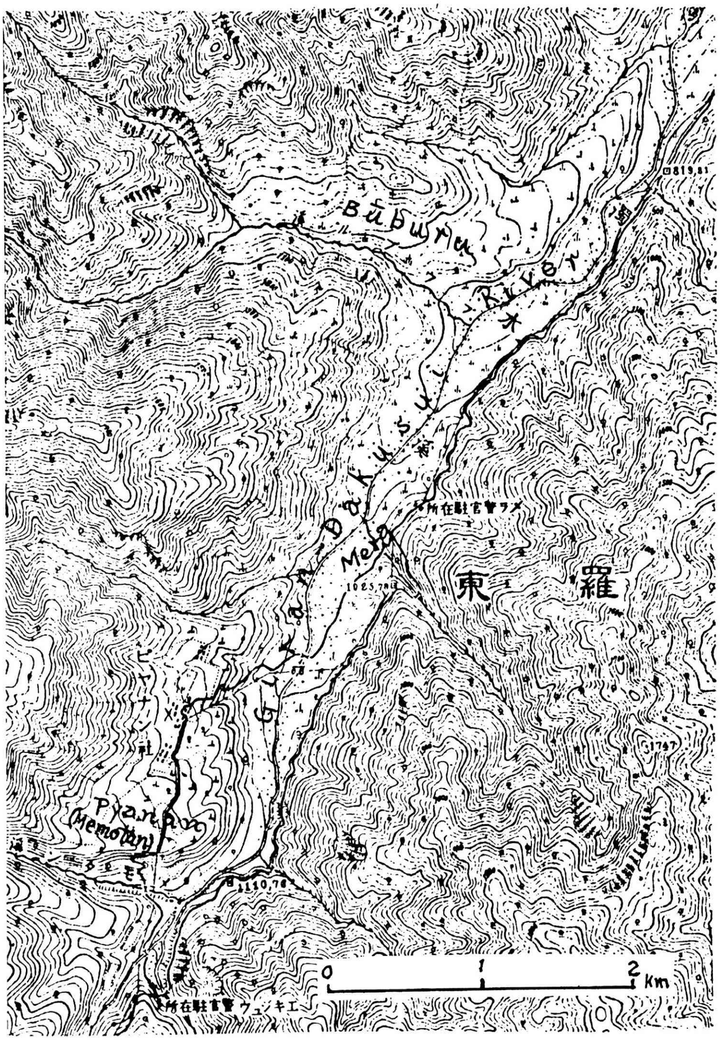

Fig. 19. Composite Fans in the Valley of the Giran-Dakusui River.

fault valley. In this river are four alluvial fans, namely: Pyanan (or Memotan), Mera and Būburu fans, in order, from the upper to the lower reaches (Fig. 19). Their relative heights as well as the heights above sea level gradually decrease and all alluvial fans except the Mera occur on the left side. The Būburu and Memotan fans are composite fans similar to a triple fan (Drew, 1873; Cotton, 1926). These fan surfaces are correlated with the LT plane, but a young fan surface in the lower part belongs to the FT plane.

The so-called Kayō fan terrace (Tomita, 1937C) is located on the right side in the headwaters of the Taikō River. This fan has been dissected to form a four-stepped terrace below the fan surface (Fig. 20). The fan surface and the first step

Fig. 20. The Kayō Fan, a Dissected Rock Fan in the Taiko River Valley.

are correlated with the LT plane, and the second, third, and fourth steps are correlated with the FT plane.

Along a longitudinal tributary valley at the middle part of the Dakusui River called the Chinyūran River, the Namakaban fan and Aripton fan are composed the largest confluent fan in Taiwan and the remnant of the fan surface is still widely retained indicating that it belongs to the LT plane (Fig. 21). The Bōkyō fan occurs adjacent to, and upstream from this fan. Tompo and Rakuraku fans are located farther upstream.

The Magatsun fan (Fig. 22) is situated on the left bank of the Nanshisen River,

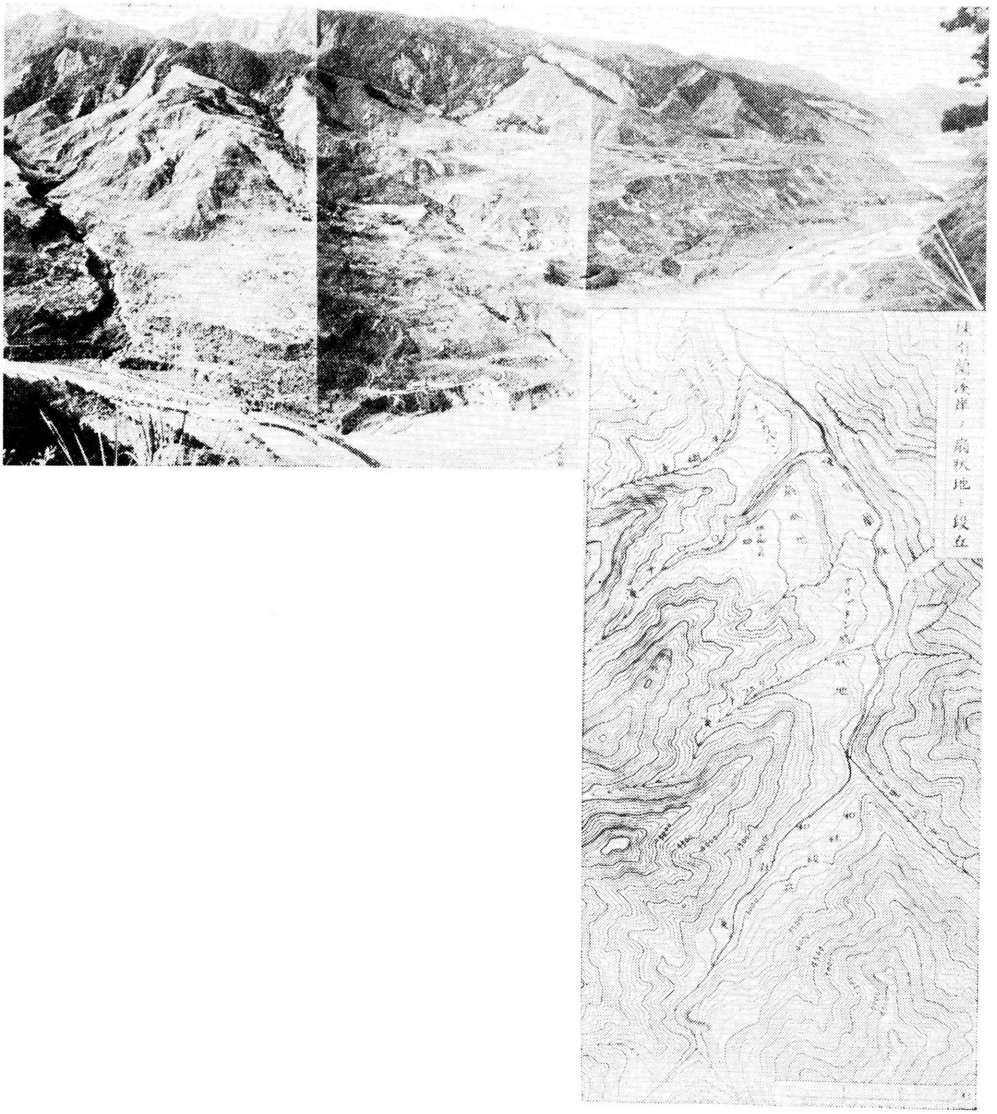

Fig. 21. The Namakaban Fan (North) and the Aripton Fan (South) along the Western Valleyside of the Chinyūran River in Central Taiwan.

a longitudinal valley in the upstream of the Shimotansui River in the south, and the shape of the fan is the most typical example of an uplifted fan. The surface of the fan is the LT plane, but the surface is used as a farm land and contains much humus so that the laterized soil has changed to a chocolate color. The fan on the right side of the upstream valley is narrower than the fan of the left side and the inclination is much steeper. The valley fan is different from the plain fan and it is clear that its development is restricted by the size of allowable ground.

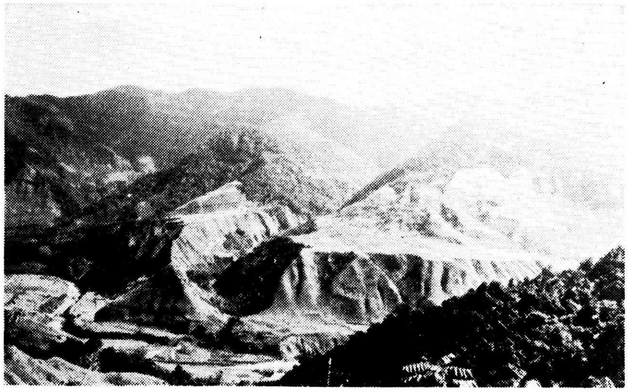

Fig. 22. The Magatsun Fan on the Left Bank of the Nanshisen River.

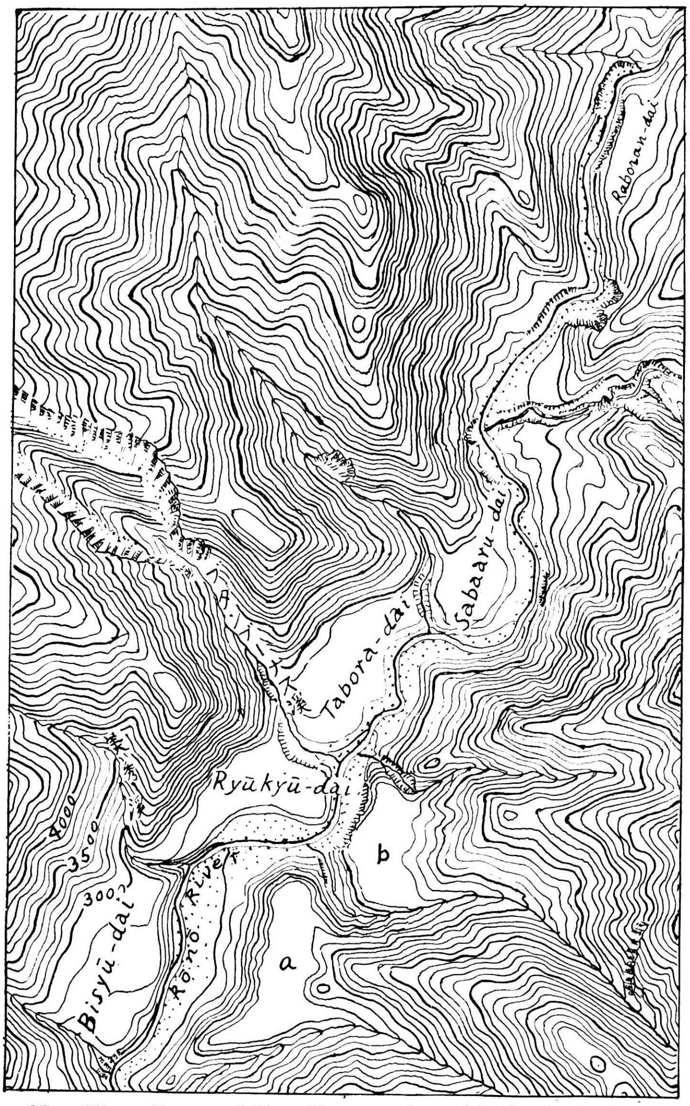

Fig. 23. Three Fans and Two Terraces (a and b) in the Valley of the Midstream Course in the Rōnō River.

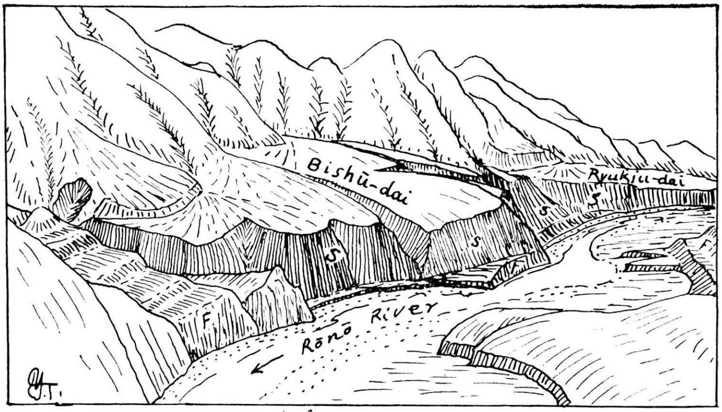

Fig. 24. A Sketch of Fans (Bishū-dai and Ryūkiū-dai) in the Midstream of the Rōnō River.
S sand and gravel F bed rocks

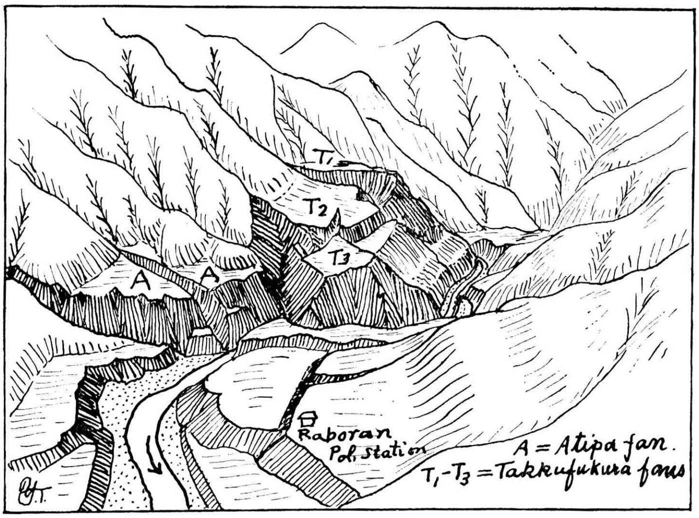

Fig. 25. Fans and Lower Terraces along the Upper Stream of the Rōnō River Reviewed to the North from the Top of Raboran Bluff about 4 km from the Sabar Fan in Fig. 24.

A tributary adjacent on the east to the Nanshisen River is the Rōnō River, a twin of the former river, and they both have longitudinal valleys. In this place six fans are developed mainly on the right bank of the Rōnō River. Beginning with the lowest they are: Yōshikyaku, Haisen, Bishū, Būnasu, Sabāru, and the Takkufukūra. Of these, Nos. 23, 24, and 25 form a confluent fan by the combination of a part of the fan sides. The young fan is to be correlated with the lower terrace, but according to my classification on the developmental procedure of alluvial fans (Tomita, 1937C), it corresponds to a graded fan (see Fig. 23).

Young Fans

A young fan has a surface that can be correlated with the FT plane of the lower terrace. According to my classification of fans (TOMITA, 1951) by means of degree of development, young fans correspond to the graded fans in equilibrium. A young fan is normal in form, and its development continues on the marginal part but is suspended at the apex where dissection has just started. Young fans are in a stage when the fan surface is the widest. Let us look at the areal distribution of the young fans. The Taihoku basin on the north Taiwan is a fault basin. Fans in intermediate and young stages of development are rare in its periphery. There is only the meager development of a young fan at the base of the Shinshō fault scarp. The reason for such a state is attributable to the depression which was followed by the formation of a temporary lake. Then the accumulated sediments became

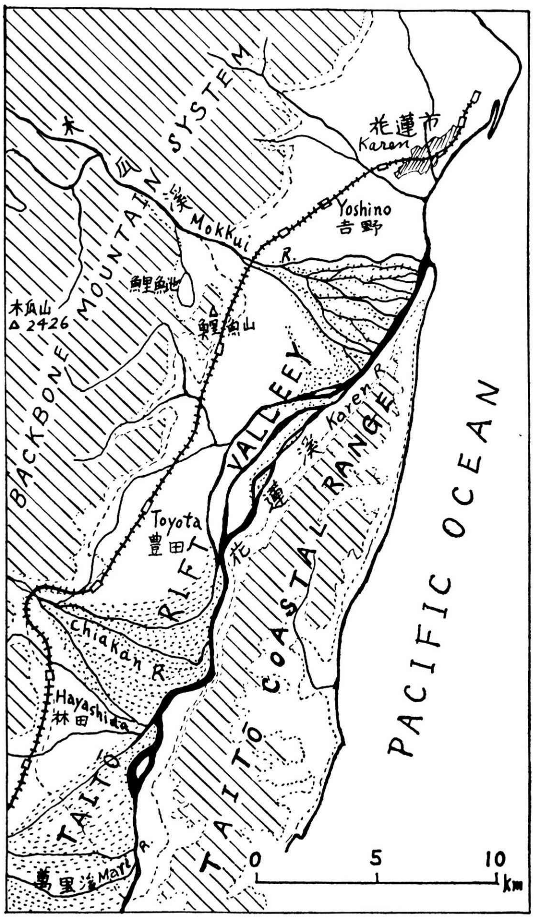

Fig. 26. The Immature (or Growing) Fans and the Site of Three Immigration Villages in the Northern Part of the Taito Right Valley.

dried so that it might have been formed under a deltaic environment rather than a fan.

In the central part of Taiwan in the southern part of the eastern margin of the Taichū basin some young fans are observed. The development of confluent fans is seen at the mouths of the Taikō River, Tōbenkō River and the Chikushikō River. In the southern part, a confluent fan is built east of the town of Toroku to form the Toroku fan district. East and south of the city of Kagi there are small young fans adjacent to the intermediate fans. On the southern margin of the eastern border of the Heitō (Pingtung) plain and along the southern half of the Chōshū (Chaoshou) fault scarp there is a development of typical young fans in the mouth of the Raisha River, the Chikatan River, and the Subon River (Fig. 18).

Immature Fans

In the Giran plain in the northern part of the eastern slope of Taiwan, young fans are found only at the base of the Shōkei fault scarp on the northwestern margin and on the southern margin, which is probably because the Giran plain is an aggraded plain. The most typical development of young fans in Taiwan is seen in the Taitō (Taitung) rift valley (Fig. 7). As the rift valley embraces a much wider plain than ordinary valleys, fans developing there are more like plain fans rather than valley fans, and they show the normal topographic features of plain fans. The fans (developed) on the Mokkui River, Chiyakan River, and Mari River are still in an early stage of development so are designated as so-called "immature fans." This immature (or growing) fan forms a confluent fan and the three government sponsored immigration villages of Yoshino, Toyota and Hayashida at the time of Japanese control, are located respectively on the adhering portion of the confluent fans (Fig. 26) to keep away from frequent flooding. The Ikegami fan, which is located at the mouth of the Rakuraku River on the west bank, south of the village of Tamasato on the south, and the Ōhara fan at the mouth of the Shinburo River on the south are graded fans in which dissective activity has just started. These fans seem somewhat older than the graded fan that is located at the mouth of the Pinan Ta River on the extreme south. The fans in the Taitō rift valley have been formed alternately on the east and west sides of the valley by the oscillatory crustal movement.

The differences in the young and old stages are closely related to the types of faults found in both sides of this rift valley. However, the problem will be discussed in the section on structural topography.

In the northern and southern extremities of this rift valley there are small graded fans at the mouths of small streams. Starting from the north on the west side of the rift valley are such fans as Okakai, Kararan, and Marankin and southward on the east side, south of Yamato are found the Basshi, the Reishisai, the Matarin, the Makutō, and the Taikaryō fans. Toward the south on the west side are the Izogan, Mariwan, Takopan, Kamuran, Kanaten, Rokuryo, Sun-nun-sun, Hatsushika, Taparakau and Shabakan fans. As these river canyons are small, the formational process ended in early stage of development.

III. Structural Topography and its Geomorphologic Process

A. Basin Topography

In Taiwan there are three representative basins, namely, the Taihoku, the Taichū, and the Hori, and all are fault basins formed by depression; they are not erosion basins. The Taihoku basin, as mentioned in the discussion on the fans in the Tōen tableland district in the previous chapter, was depressed between the Taihoku fault on the east, the Shinshō fault on the eastern margin of the Rinkō tableland on the west, and the Sankyaku fault, which has been formed by subsequent repeated crustal movements. This postulation was brought about in the studies on the geology of the Taihoku by Tan (1937, 1939). The geological survey by Makiyama (1930–34) and the opinion of Imamura (1944) on the basis of leveling data clearly confirmed the said postulation. No adequate survey has been made on the nature of the Taichū basin, but on its eastern margin there clearly is a fault, as mentioned before. This fault is linked with the Sansha fault farther north through the Taikō River and the Taian River, and toward the south it seems to join the fault east of Takeyama through Nantō. However, on the western margin of the basin there is no corresponding fault. As the tablelands of Kōri, Daito, Hakkei, and Heichō are all tilted toward the east, these planes can be called fault-angle basins formed by displacement on the east side.

Subsidence of the Taihoku and Taichū basins seems to have taken place subsequent to the formation of the LH plane and caused the LH plane to plunge into the basin. This postulation is based on the topographic surface. As seen in the Taihoku basin, this subsidence caused a change in the drainage channel of the original Tansui River which formerly flowed northwest near Sankyō-Ōka in the Tōen tableland, and made it flow into the basin, and the lower reaches came to end at the present Nankan River. The main stream started downcutting and resulted in the formation of the notable Taikei terrace group. As the upper terraces belong to the LT plane, the subsidence must have occurred after the formation of the LH plane and before the formation of the LT plane.

The Hori basin (Tomita, 1951B) is an intermontane basin in the central part of the island, where various kinds of basin groups are found. In linear arrangement from north to south are the Hori, the Gyochi, the Jitsugetsutan, the Tōsha, and Jūki basins. In the vicinity of these basins are a series of small basins, such as Sōnan, Rengechi, Sansakyaku-Mokaiketsu, Kita-Mokaiketsu, Byōran, Nishi Byōran, Yūsuikō, Higashi-Hokutan, and Kita-Tōsha. The Hori basin is the largest in areal extention as it covers 42 sq. km, but the initial surface of the basin has been already dissected, so when compared with other districts, it seems to have passed through a very complicated process of topographic change. The basin has been dissected by both rivers, the Hokkō-kei and the Nankō-kei, and can be divided into the higher (B and C in Fig. 27) and the lower (D and E in Fig. 27) basin planes built on the erosion surface. This erosion surface was formed after dissection, and the basin

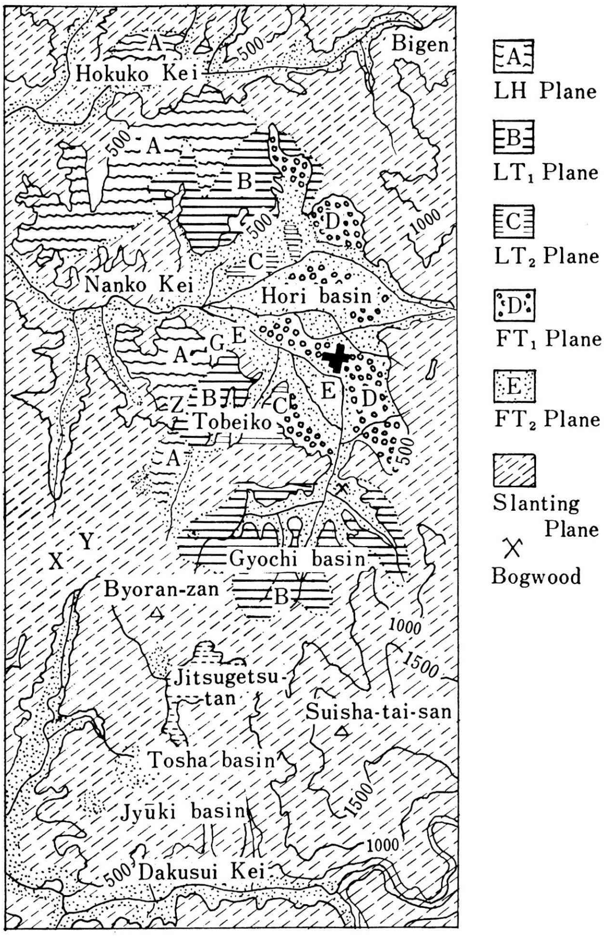

Fig. 27. Topographic Planes of the Hori (Puli) Basins.

plane retains the initial deposition plane. The former can be subdivided into two planes, and the latter can also be subdivided into two planes. The initial basin plane is not only distributed in the north and west-margins of the basin, but it is also retained on the spurs north of the Hokkō River.

The initial basin plane is also widely distributed in the area of Tōbeikō south of the Nankō River. All these surfaces are covered by lateritic soil on weathered gravel bed, thus indicating the LH plane.

From the above-mentioned areal distribution, the original form of the Hori basin can be imagined as being very large. It extends from the north bank of the Hokkō River on the north, and to the divide of Mt. Taiōhei (1,203 m) through the village of Kokusei on the northwest. From this point it extends to Mt. Shū-shūtai shan (1,396 m) along the fault valley which crosses the pass of Sankakurei (890 m) (X in Fig. 27). The southern margin of the Hori basin extends from

Mt. Oshōtō (Y in Fig. 27), east of the pass of Sankakurei to Mt. Byōran then farther east to the boundary with the Gyochi basin.

The first higher basin plane (B in Fig. 27) of post-dissection is also a lateritic soil covered-gravel tableland, and it is still present in the north of the Nankō River, at such places as Taigyūkō and Sekkan tableland, east of a line connecting Taiheichō with Suibi, and also on the east side of the line linking Gyūsōshoku (G in Fig. 27) and the Sōnan-basin, (Z in Fig. 27), south of the Nankō River.

The second higher basin plane (C in Fig. 27) is developed at Suiakutsu and Shikōkō to Wugyūran north of the Nankō River; south of the Sa-kei only a small tableland plane retains the initial surface on the northeast margin of Tōbeikō tableland? This higher basin plane can be correlated topographically with the LT plane.

The lower basin planes occupy the present Hori basin; they are erosion planes of the Nankō River composed of a dark brown transported surface soil. The D plane covers the majority of the basin, and the E plane forms a flood plain of both the Nankō River and the Bai River. Both the D and E planes (Fig. 27) are bounded by an erosion cliff 2 to 5 m high.

The geology of the basin can be easily observed from the uppermost part to the basement rock because all the rock formations are exposed. The basement rock consists of alternating sandstone and slate belonging to the Hakurei formation. The overlying bed consists of white clay with an intercalation of fine-grained sandstone beds, and is overlain by a gravel bed. This gravel bed can be divided into upper and lower zones. The gravels of the lower zone are smaller than those of the upper zone. The major portion of the gravel of the lower zone is composed of pieces the size of a man's fist frequently intercalated with lenticular beds of sand and clay; stratification is obscure. The upper zone is composed of large gravel the size of a human head and does not show any stratification. The lower zone is a common alluvial deposit but the upper zone seems to have accumulated fanglometratically under a torrential streams. The white clay bed with fine sand is lake-bottom deposit; this conclusion has been more or less confirmed. Lignite and peat beds are intercalated with the clay bed in the vicinity of the confluence of the Taigyukō, which drains from the east, and the Suiryūtōkō, which drains from the western margin of the basin to Suiryūtō on the north. On the south bank of Hokkō River, the clay bed strikes N 30° E, and dips NW 30°, and the above-mentioned peat bed dips 40°–60° east. This shows that crustal movement occurred after the completion of this lacustrine deposition.

The Gyochi basin borders the Hori basin on the south. It is a dissected basin, but the dissection is still in the initial stage, so that the basin plane has been dissected upstream only by long narrow dendritic river systems. The basin plane is 700 to 800 m above sea level and the lowest elevation of the Hori basin ranges from 200 m so that the Gyochi basin is higher by 500 m; it is 300 m above the highest part of the Hori basin, and is 100 m above the initial basin surface of the basin.

The geology within the basin surface is well exposed along the dissected river valleys so that observation is facilitated. It is a lacustrine formation composed of gravel, sand, and clay; the beds generally lie horizontally, but in the middle part an apparent dip of 20° E is observable. In the southern and eastern margins of the basin, the gravel bed of fan-like accumulation is thick. In the vicinity of Gaikadōkō near the outlet where the water is conducted from the basin of the dissected valleys two lignite beds are found within a clay bed which underlies alternating beds composed of gravel and sand. The lignite has been utilized as a native fuel. The thickness of these lignite beds ranges from 30 cm to 40 cm; occasionally they attain a maximum of 80 cm.They dip slightly toward the north, and thin out toward the southeast.

The surface soil of the initial basin plane is a lateritic soil but in places lateritization has not taken place. It certainly is assignable topographically to the LT plane; it probably became a lake during the post-LH plane depression, and as accumulation proceeded the dissection process of the Nankō River on the north changed the lake into a dry basin and subsequently dissection began on the basin surface. At the beginning of this dissection process, the difference in heights between the Gyochi and Hori basins was more than several hundred meters, so that it is reasonable to imagine that an enormous amount of sand and gravel was transported energetically to the Hori basin from the Gyochi basin.

In the vicinity of Sekkan, at the erosion scarp of a higher basin plane of the Hori basin north of Hori town, there is a lateritic soil bed 2 m thick upon which rests a gravel bed 5 m in thickness. This gravel bed is in turn covered by a surface of lateritic soil 2 m thick. From this sequence it can be interpreted that the gravel derived from the Gyochi basin was redeposited on the original lateritic soil bed of the Hori basin and that this gravel bed was subsequently coverted into lateritic soil.

The Jitsugetsutan lake basin adjoins the Gyochi basin on the north and its elevation above sea level is 750 m. This lake is used as a reservoir for a hydroelectric power plant. The water of the lake is augmented by an inlet at Bukai dam by a water tunnel on the headwaters of the Dakusui River so that both the water level and depth are not constant, however, the depth when the water is full probably attains a maximum of 30 m. The following limnological description of this lake is found in a report by HARADA (HARADA, 1933; 1942). The natural water level of the lake is 726.8 m and the maximum depth is 4.6 m. The natural drainage outlet is situated in the Suishasuibi River at Suisha on the west bank of the lake. The discharged water enters the Suiri River then joins the Dakusui River by passing through Gojō. At a distance of 1 km from the lake shore the width of the river becomes about 50 m so that a dam was constructed at the shore of the lake. However, if the lake bottom is exposed and abandoned in the natural state erosion will incise the lake shore in a short time and the water will be drained and the lake eventually will become dry, just in the same manner as in the Gyochi basin in the past. On the lake shore of Jitsugetsutan a thick lateritic soil rests on the Hori slate. It is probable that this lake basin was formed by the depression of the LH plane.

As to other small basins, some of them distinctly show faulting accompanying with shattering zones in their basin floors, but some others are supposed to be erosion basins produced by valley-head erosion on the LH plane. In either case, most of the basins present a typical basin topography as seen in small craters of volcano.

HAYASAKA (1930) made a preliminary report on the formational process of these basins and contended that depression occurred along the group of strike faults that run longitudinally throughout the island. Upwarping occurred at the same time and Jitsugetsutan, which was located on the top of upwarping remained as a lake to the present.

B. Fault Topography

As to the fault topography, the first features to be discussed is the fault valleys. Among the principal valleys in Taiwan, most longitudinal valleys can be said to be fault valleys. That the formation of some river bottoms has been influenced by such a disturbance is clearly manifested. Sometimes the mountain ridges on both sides of the river valley show dips that are gentle, but upon approaching the river valley gradually increase, and frequently, almost vertical dips can be observed in the valley floor. The reason for such a phenomenon is due to the interbedding of hard and soft rocks. In the horizontal beds the erosional process does not progress much, whereas in the vertical beds the downward erosion of the river bottom along the weaker beds have progressed greatly. It is probable that in some cases the drainage course has been determined by a strike fault, however, on close observation of the vertical formations along the river bottom, it also can be interpreted as an overturned high-angle fault. The basic structure of Taiwan is probably an imbricate structure which is attributable to overthrusting, as suggested to me by Bailey WILLS when he came to Taiwan. During the periods of physiographic development of the HE and LH planes, subdued topography was developed throughout the island.

Thus, the fault valleys observable at present have been dissected and further modified through subsequent erosional rejuvenation due to the land uplift, so differential erosion is well manifested. Some rivers seem to have gone through the fault-line valley process at least locally.

The most typical fault valley in Taiwan is the Taitō rift valley. FUNAKOSHI (1933) considers that the faulting movement on both sides of the rift valley is an earth wave* movement, on the basis of asymmetric distribution of fans. I agree with FUNAKOSHI, because I myself observed that the height of marine erosion caves on the Pacific coast at the east end of the Taitō mountain range varies from 5 to 30 m.

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* E. N. Earth wave ("Chiha" in Japanese) is a recent term advocated by G. IMAMURA, well-known Japanese geographer. It is, on the whole, similar to a kind of warping or active folding. IMAMURA used ocean waves as a means of comparison. IMAMURA, Gakurō, 1932, *Earth wave*: *Iwanami Lecture Series, Geography* (in Japanese).

The Taitō coastal range shows an échelon structure belonging to a left tilted m-type échelong structure, proposed by TOKUDA (1926–27). It is assignable to the Luzon arc rather than the Taiwan—Luzon arc. In Taiwan this arc is linked with the Ryukyu arc (Ketting) on the north (TOMITA, 1952).

As for fault cliffs, there is the Chōshū (Chaochou) fault cliff at the eastern margin of the Heitō (Pingtung) plain, as already mentioned (Fig. 18). The fans on the base of this cliff can be classified into old, intermediate, young, and growing (immatured) fans. These fans were formed alternately in the northern half and the southern half in the eastern meargin of the Heitō plain just as they were formed in both sides of a hinge fault. But, it is also probable that these fans exhibit a part of earth wave or active folding.

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A Summary of Geological Observations in Taiwan from 1895 to 1948

Ichiro HAYASAKA

I. Preface

I have been requested by the editors of *Geology and Mineral Resources of the Far East* to summarize as briefly as possible, contributions to the field of geology in Taiwan until about the period of the rehabilitation of Japanese after the war. A number of geologists and geological engineers had worked in Taiwan from about 1895 until about 1945, when almost all the staffs of Government offices including University faculties, and those engaged in business sailed back home. However, a few Japanese professors remained in Taiwan to cooperate in various ways with the new faculty members of the National University. I and my wife remained, and I worked in the Department of Geology of the Faculty of Science until the latter part of 1949, working with the teaching faculty members, post-graduates and students, a few former students alumnai of mine, several graduates of Taihoku Imperial University, beside some newly appointed professors. Moreover, it happened that a few old friends were on the administrative staff of Taiwan National University.

The more than four and a half years as an honorary member of the National University was really a pleasant and fortunate aspect of my life. I was even able to do some scientific work either with the cooperation colleagues or by myself.

Our home life during our sojourn, of more than twenty years, was happy, but the last few years were especially impressive. We are thankful for the memorable association of friends and many others.

As mentioned at the outset, the editors wish to describe the extent of Japanese contributions toward geological enterprises in Taiwan. It seems more plausible, however, to describe how Japanese geologists and geological engineers laid foundation stones for modern earth science.

The edifice has been under construction for some time; we have to pay attention to it with great expectance.

What I have summed up may not include anything novel, however, I do not apologize to anyone because all these things have been put into an old wine skin.

II. General Geology and Topography

A. Introduction

It may be said that a Japanese scheme for systematic research on the geology of Taiwan came for the first time only around 1895–96. Until then records show that only a few European mining engineers had rather casually visited mineral localities here and there. Geological activities by Japanese in Taiwan were unexpectedly handicapped, however, because of the unaccustomed natural conditions, physiographical, climatological, and so forth, on the one hand, and of unstable civil conditions on the other.[1] Notwithstanding, many geologists devoted varying periods of time to exploring various parts of the island from time to time, chiefly in accordance with the research plan for East Asia of the Imperial Geological Survey,[2] the Tokyo Geographical Society and Tokyo Imperial University. In 1925 there was a Mining Section at the Bureau of Industry of the Government General of Taiwan with a geologist and a mining engineer forming the faculty. Then, in 1928, the Taihoku Imperial University was established, and included an Institute of Geology in the Faculty of Science and Agriculture (a few years later it was divided into the faculties of Science and Agriculture). Meanwhile the Mining Section was expanded somewhat and the number of geologists and mineralogists was increased from time to time to finally form the Geological Survey of Taiwan. Thus, this group and the University Geology Institute approached to each other in order to collaborate in every possible way on the geological sciences and techniques in Taiwan.

However, the famed 1:50,000 scale topographical maps of Japan published those days by the General Staff did not include all of those of Taiwan, particularly of mountain terrain, as they were delayed in preparation. As a result, the field work was carried out first in the hilly zones and flat lying plains regions, where coal and oil fields had been found buried; the exploitation of some metallic veins also seemed urgent. For this reason the field work was not carried out in regular order.[3]

Geologists during this period were engaged in various fields of the science. They worked hard during the war years though they had little luck in preparing reports or papers some of which contained significant data, or, much less luck in publishing them. Neither could most of them take materials with them when they were repatriated after the war. A number of unfinished manuscripts, photographs, charts, etc. were given up for lost. For this General Outline, many of those who were engaged for some time in geological work in Taiwan were asked by the Committee for written accounts of their respective observations and experiences, however, due to preoccupation with possible personal affairs and other activities not as many contributions as expected were received.

For my part, I stayed in Taiwan for four and a half years after the War as a professor of the National Taiwan University. I was able, more or less, to avail myself of information collected at random and edit a rather non-professional essay entitled "An Outline of the Geology and Geography of Taiwan" (1943).[4] This was written at the request of a certain Chinese professor who came from mainland China after the War. Up to this time *Taiwan Tigaku Kizi* (Geological News of Taiwan) was published occasionally by the former University Geological Institute. I had access to a few other publications issued by associates. Most of the material for this General Outline compiled in Tokyo a few years after my return home in 1949 was taken from these sources. Although this material was far from being satifactory for the purpose mentioned it was supplemented with my personal experiences in Taiwan. Reports on the areas of mineral resources have not been covered and will be done by others who are more knowledgeable about the subject.

As the history of geological exploration in Taiwan by the Japanese is not as so long as that of the Chinese mainland, and at the same time as the size of the area concerned was rather limited, not to speak of limits in planning, the results of studies are neither conspicuous, nor much to boast about. When geologists started their activities earnest around 1915, geology from the scientific had also of begun to seriously consider careful observations of the faces of nature. Therefore, if we record everything, there will be a vast amount of material including hitherto unfamiliar phenomena, because of unfamiliarity with territorial conditions. With regard to exogenetic processes we had to pay heed especially to weathering, river erosion and transportation, sedimentation, landslips, and thermal springs (ground water).[5] Concerning endogenetic processes, seismic activities are important in Taiwan, there having been severe and often destructive earthquakes every four or five years.[64] In the field of paleontology, beside numerous molluscan fossils of different ages, there are unexpectedly frequent mammalian remains chiefly from Pleistocene formations; foraminifers, brachiopods, and echinoderms are of significance, especially for biogeography, and as materials for studying the problems of "actuo-paleontology" and also the "actuo-geology."

A comment on III is necessary here. III is based largely on an article by HAYASAKA, LIN and YEN entitled "An outline and some problems of the Stratigraphy of Taiwan."[6] Some changes were in contents, however, to take into consideration papers by the late K. TAN on the Eocene and Paleogene faunas,[7] a note by YEN on the younger Paleozoic fossils[8] and a report by LIN on a Jurassic faunule discovered deep beneath the coal- and oil-bearing Neogene formation by LIN.[9] These papers and the theories derived from them have provided remarkable additions to our knowledge of stratigraphy, historical geology, structural and economic geology of Taiwan.

B. PHYSICAL GEOGRAPHY

A conspicuous continental shelf embraces the southeastern part of the east coast of China. On its margin the mountainous island Taiwan rises abruptly above the level of the sea. The Formosa strait or channel which is barely 100 m deep is located between the continent and the island. The Pescadores islands are located and consist of more than 70 large and small islets and rocks, that are considered as dissected remnants of an extended basalt mesa. The real continental margin of this part of eastern Asia coincides with the eastern border of the island of Taiwan which very abruptly descends to the abyss of the western Pacific.

Excluding the Pescadores and several other dependent islands like Ka-sho-to; Ko-to-sho and smaller islets, the main island of Taiwan has a somewhat fusiform outline in plan with the longitudinal axis extending roughly north-south. Strictly speaking, however, this longitudinal axis forms an arc with its convexity facing westward: the northernmost part trends almost north-northeast to east and the southern major part extends almost due south on slightly by south-east.

As has been recognized by geographers and geologists, the insular festoon of eastern Asia is composed of several arcuate islands like the Kuriles, north-east and south-west Japan, and the Ryukyu arcs. All of these arcs face the Pacific with their convex sides. This was pointed out a long time ago, for instance, by V. RICHTHOFEN,[10] as a characteristics feature of the geomorphology of eastern Asia. The northern extremity of Taiwan turns toward the east, and points to the western end of the Ryukyu island arc. The geological relation between these two arcs must be an interesting but very perplexing problem. As is well known, V. RICHTHOFEN also propounded a theory long ago, but the modern theories in structural and morphological geology may not conform to it.

Be that as it may, the maritime mountain range of southern China, the Hsien-Hsha-Ling, appears to assume an arcuate trend with its concavity facing eastward: it is as if a concentric curve is drawn by Taiwan, though it may be merely coincidental.

Another point probably worthy of note regarding the physical geography of Taiwan is its very simple shoreline. This may have been due, as a whole, to the very recent relative upheaval of the island. Yet, it is discernible that the very steep, precipitous cliff along the eastern coast is naturally much simpler than those on the western, marshy shore with a broad watt in front. The total length of the shoreline of the main island measures only about 1,144 km, while the total area occupies 35,970 sq. km: in other words, the average length of shoreline per sq. km is 0.032 km. On the other hand the Pescadores Islands have the total area of about 79 sq. km. at low tide, with the average length of shoreline per sq. km. being as large as 1.45 km.

C. SALIENT TOPOGRAPHICAL FEATURES

The topographical feature which seems most significant is the fact that a lofty mountain system runs almost lengthwise through this small island; it is the Taiwan Mountain System which is also important in the consideration of the geology.

The Taiwan Mountain System consists of several ranges, long and short, almost parallel to each other. All these collectively form a high plateau-like topography comprizing more than a dozen high peaks over 3,000 m. Of the parallel ranges the one which may be called cardinal rises immediately south of the triangular plain of Giran and Rato, with an almost circular cove, called Suo in the southeast corner of the plain; it is a part of Taihoku Prefecture. It extends south-westward for some distance, and quite abruptly increases in altitude to culminate in the Nanko-taizan (3,535 m). Here, the range turns south-south-west, and begins to show a tendency toward realization of the commanding position of the Axial or the Backbone Range; the latter, with some slight, irregular bends, extends southward, finally reaching close to the southern end of the island. Among the prominent peaks that follow toward south are the Chuo-Senzan (3,412 m), the Anto-Gunzan (3,087 m), the Kan-zan (3,667 m), the Sho-Kuan-zan (3,254 m), the Pinan-Shuzan (3,305 m) and the Daibu-san (3,262 m).

An apparently subsidiary range extends north-northeast from the Nanko-Tai-Zan, and ends in the promontory of Samtiao Point in NE. Generally speaking, deep gorges are carved between these ranges: their upper courses take almost the trend of the ranges, turning to a more or less westerly direction in the middle course, and finally, almost due west, down to the Japan Sea.

Due to this topography there are different landscapes that represent the very young history of the formation of the island.

Some singular features of mountain passes, intermountain basins, large and small, river terraces and the like, are formed.

Another subsidiary range extending southwestward carries the peaks of Tsugitaka-yama or Setsuzan (3,931 m), etc. This short range is called the Tsugitaka Range. Between the Axial Range and the Tsugitaka Range, almost at the latitude of Nanko-Daizan, in the former, and the Tsugitaka Peak of the latter there is a high mountain pass, popularly known as the Pianan Saddle, dividing the very steep, and deep gorges of the Daikokei, running about south-south-east, and the Dai-Dakusui-kei, flowing almost north-northeast, and terminating in the delta of the Giran and the Rato rivers formed by sediments carried down by these rivers. Thus, the courses of these two rivers are nearly on a straight line; this most likely suggests the existence of a sort of crustal disruption zone possibly on a grand scale. The southern slope of the Saddle, that is, of the Daiko valley presents an unusual topographical feature resembling a shallow lake basin filled with sediments of clays, and gravel and the like; these lake deposits have been dissected by the headstream waters of the Daiko-kei, exposing the profiles of the sediments. The northern Dakusui-kei gorge, is roughly about 40 km from the mouth to the Pianan Saddle. South of the Pianan Saddle, about 20 km southward, the Daikokei gorge turns westward and across the midland zone, middle part of the island flows down into the sea as stated above. The behavior of the courses of the rivers on the western slope of the Axial Range is in general similar to that of the Daikokei. Most of the river valleys extend lengthwise in their upper courses, parallel with the length of the island, turning southwest or due west in their mid-lower, or lower courses.

Mountain passes somewhat similar to the Pianan Saddle are not unfamiliar in Taiwan. The Tahtaka Saddle (2,250 m), and the Hattsu-kan (2,800 m), east of Arisan, are examples; the former is situated between Niitaka (3,950 m) and the

Arisan ranges, and the latter is in the west of the Niitaka. The valleys to the north and south of both passes run almost west-east, each coinciding with the geological structures observed in these region.

The loftiest peak Niitaka-yama, i.e. Yu-shan, consisting in reality of several peaks of varying heights arranged more or less in a north-south direction. This group is situated to the west of the Axial or Backbone Range beyond the Hattsukan mountain pass. Its southern extention rather abruptly lowers down to the plains of Heito and Takao.

A distant view the Niitaka range gives the physiography of a plateau, conforming to the general appearance of the whole island in a silhouette, so to say, this seems to be significant in consideration of the geology and geohistory of Taiwan.

The Arisan range is located to the west of the Niitaka-yama beyond the Tahtaka Saddle and extends in a north-south direction. The range is only 1,000 to 2,000 m high as a whole, the Arisan itself forming its loftiest peak.

Thus far an outline of the topographical features of the mountainous region has been presented. Some distance to the west beyond the Arisan is a zone of hilly lands several hundred meters in average height, more or less sposmodically developed in a roughly north-south direction. To the north this is traced in part on the north-west slope of Tsugitaka-yama. While the mountainous region is built up, chiefly of the Paleogene slaty sediments, this hilly zone is occupied by the Neogene and the younger formations as far as is known on the surface. Further westwards is a flat lowland of Diluvial and Aluvial deposits. The slaty Paleogene formations yield relatively numerous fossils though not many of them are excellently preserved; there are molluscs, echinoids and the so-called higher foraminifers among the invertebrates, and some fragmentary remains of terrestrial plant leaves. The Neogene formations are much more richly fossiliferous, especially in certain localities. Beside the Invertebrates, as for instance, foraminifers, molluscs, echinoids, bryozoans, brachiopods and a few insects, several vertebrate jaws, teeth and bones of mammals and a few reptils also have been discovered in several localities. These fossils have been studied by several paleontologists, most of whom have published their works; among these fossils a major part belongs to the Pleistocene.

Taking all these fossils into consideration, as well as the observations on the sediments, it is evident that all the Cenozoic sediments and the fossils therein indicate a shallow sea environment during the Tertiary and Quaternary ages; the present-day physical environment is very similar and looks as if represents the last phase of the Geosynclinal stage.

The last zone of West Taiwan is occupied by the Alluvial plain which continues to the flat Wattenmeer or the shoal sea. This muddy flat in the middle of Taiwan is several kilometers wide, and there are examples of several paddy rice fields made in the historical ages from such shoal flats, around Tainan and northward. This is considered to have been due, at least in part, to the constant uprising of the island as a whole, which might have been active even during fairly recent historical period.

Turning to the eastern side of the island, the very steep and ruggedly precipitous cliff hanging down into the deep, blue Pacific are immediately noticeable. The Axial Range, as seen in plan, divides the island into two unequal halves, the eastern half being about half as wide as the western. Consequently, there are longer rivers with much more water in western Taiwan than in eastern Taiwan. The great rivers of western Taiwan, most of which carve deep gorges, accompany graceful river terraces in the upper and middle courses, and spred into wide agricultural grounds of the coast in the middle or lower course. The valleys on the steep slope of the Axial Range on the eastern side are naturally much shorter, and the water, mostly flowing deep in the bottom of the gorges is characterized by magnificent incised meanders.

The development and distribution of the Alluvial plains are commanded by the topographical characteristics sketched above. The most extensively of such plains is the Heito-Takao; the western coastal part continues northward with the Tainan coastal plain. Farther northward, beyond Tainan, there are a few, less conspicuous but not discontinuous coastal plains of West Taiwan.

Inside this stretch of the West Taiwan shore plains is a series of narrow and low hills of Neogene and Pleistocene deposits, arranged roughly longitudinally. Within or inside this low series of hills are several basins equally arranged in an almost north-south directions. The most conspicuous among them is the Taichu plains. The Taihoku basin in the north is of structural origin surrounded by faults, and it is evident that it was once filled with water, as is evidenced by remains of certain fresh-water shells and debris of terrestrial plants.

In eastern Taiwan, the plains are still more limited in expanse. In the north the Dakusui-kei delta plain where the Giran and Rato are found local towns are conspicuous.

From the south-eastern corner of the Giran-Rato delta, that is from about the small, almost circular cove of Suo, the coast extending south-southeast traverses the trend of the Axial Range forming very steep, hanging cliffs until it reaches the coastal plain of Karenko. Beside a few, small deltaic estuary plains along these hanging cliffs, a plain appears around the town of Karenko which is a metropolis of eastern Taiwan. As a matter of fact, the so-called Karenko coastal plain is somewhat more complicated than it first appears to be, both in extension and also in formation. It may be said that it was composed of several deltaic deposits combined, the northernmost being the one formed at the mouth of the Takkiri-kei. The plain is very narrow until we get to the Karenko, where it gets wider because the debris seem to have been brought forth from at least more than one source. A part came from the eastern slope of the Backbone Range, the other was transported from a wide valley occupying the broad depressed zone of the Backbone Range and from what is called the Taito Coastal Range; it is the so-called Taito Longitudinal Valley, about 130 km long, and about 10 kg wide. At about a little less than a third of the length from north of this longitudinal valley a low but apparent watershed is located. The waters of the three relatively rich rivers from the Axial Range flow down into the longitudinal valley, and reach its eastern valley wall, to turn to north toward Karenko. It is another source of supply of the deltaic deposits of Karenko Plain. Thus, it is possible that the formation of the plains around Karenko may have been complicated. The southern two-thirds of the longitudinal valley is similar pattern to the northern one-third, and another low watershed comparable with the first is located about 60 km south of it. The river waters of this section of the longitudinal valley drain into the Pacific through the Shukoran traversing the Taito Coastal Range, cut by the conspicuous loops of the incised meanders. This and those of the eastern slope of the Axial Range suggest a rather sudden upward movement of the island of the most recent date, because the Neogene formation is contained in it. In the rest of the Longitudinal Valley the waters flow southward, to Taito, and also close to the eastern coast of the Taito Coastal Range. The bottom of the Longitudinal Valley is by no means flat, but of different types of deposits are found here and there, these sediments being of different thicknesses, forming river terraces here and there.

The maximum altitude of the Taito Coastal Range is 1,682 m, and the maximum width is not quite 20 km. It is composed of Tertiary sediments accompanying some andesites, agglomerates and tuffs, as well as occasional exposures of serpentinite.

The western side of the Taito Longitudinal Valley, namely, the steep western slope of the Axial Range has been assumed to be a dislocation of a grand scale. The topographical features seem to favour this idea. The famous steep cliff between Suo and Karenko runs in a straight line against the western cliff of the Taito Longitudinal Valley.[11] Its eastern wall also is regarded by geologist as a dislocation. Thus, the Taito Longitudinal Valley is most likely a depression formed by faults, if not a graben.

In consequence of the asymmetry of topography, the water system also is asymmetrical in various ways. The rivers in eastern Taiwan have their sources everywhere in the backbone range. At certain top stream regions, the water flows in the flattish and comparatively shallow extensive basins formed high up on the mountain range: from there the collected waters flow down along cardinal streams through a valley or valleys. A typical example is the plateau surface northwest of Karenko. In certain cases, small marshes or swamps supply drinking water to mountaineers.[12]

In Taiwan lakes are not common. The most famous is the Jitsu-Getsu-Tan (Sun-Moon-Lake after the Western style of appelation), which is located in the hills about 190 m high. It is a rather shallow lake occupying almost the center of the whole island, and the bottom is 720 m above sea level. In this region a zone of dislocation seems to longitudinally run throughout, and a longitudinal series of basins of different sizes, filled with water, were produced, possibly at more or less different altitude. Among these lake basins the Jitsu-Getsu-Tan might have been the highest in position, or, the region as a whole might have been up-warted with the Jitsu-Getsu-Tan at the center, so that they were drained off, the remoter from the center the faster, the Jitsu-Getsu-Tan alone remaining with water now.[13]

The Jitsu-Getsu-Tan has been made use of by the Taiwan Electric Company as an electric power reservoir for many years, and has been deepened and enlarged to a great extent. Its original area was 4.4 sq. km.

A seismogenetic lake much larger than Jitsu-Getsu-Tan was formed in December of 1941 by damming up the Seisui-kei with the debris shaken off by severe earthquakes from the steep walls of the river. The Seisuikei, which is a tributary flowing down chiefly through sandstone formations, to the master river Dakusuikei, of which the major part of the course runs through a terrain of black slate. The dammed-up lake was reported to be barely 6.6 km in extension, and almost 55 m in maximum depth. In reality this was much larger than the Jitsu-Getsu-Tan, but in a few years the seismo-genetic dam collapsed naturally, inflicting some damage to the farmlands below.

Taiwan's next important lake is man-made. In this case the river Kandenkei which is richly supplied by numerous tributaries in the lower Pliocene terrain northeast of Tainan City, was dammed up in its lower reaches. This lake was very seriously planned and brought into realization because of the problem of irrigation for agriculture land in these areas which had been considered by the Government for many years. Its total water surface is barely 9 sq. km.

Beside the lakes in the alpine regions, there are a number of small ponds and marshes that are well considered to have genetic connections with glacial or freezing phenomena during a late geological age, possibly at about the late Pleistocene. It is assumed that this period was one when the whole island rose hundreds or perhaps a thousand meters following the subsidence of the island, on the basis of the submarine canyon south of Takao, as well as the step terraces surrounding the Daiton-zan, an isolated volcanic dome originally a submarine volcano, situated along the shore north of Taihoku. The numerous river terraces on the sides of rivers were traced, and it was discovered by Y. Tomita[14] that there are roughly corresponding steps in all the valleys. This also may involve some sequence with the phenomena referred to above.

In the southwestern plains region, we find lagoons formed along shore. The careful observations will show various evidence important for the study of Recent geological history. Especially, in and around Anping and Tainan regions some such finding may throw some light on the connections also with the historical consequences.

III. Stratigraphy and Geological History

A. A Historical Sketch of the Stratigraphy and Geology of Taiwan observed since THE END OF THE NINETEENTH CENTURY

Since about the turn of the century, geologists had been engaged in stratigraphical research in particular areas of Taiwan, according to specific purposes. However, for the compiling of a general geology or stratigraphy the material remained far from satisfactory although Y. ISHII[15] had prepared a Reconnaissance Geological and Mineral Resources Map as early as 1897 which, however, did not appear to be of much practical value. The Map of Topography, Geology and Mineral Resources of Taiwan, 1:300,000, compiled by Y. DEGUCHI[16] in collaboration with two mining engineers, was published by the Government General of Taiwan in 1912. It was the result of personal efforts and experiences over a period of several years. This map and the explanatory text actually laid the foundation for further research.

Between 1898 and 1917 several geologists and mining engineers, besides ISHII and DEGUCHI, worked for the Government. As a matter of fact, DEGUCHI himself studied the geology of the Daiton[17] volcano north of Taihoku (1912), and his paper on the geology of the Hoko (Pescadores) Islands appeared in the same year. Shorter accounts on the same Island were published by Y. SAITO[18] as early as 1897. DEGUCHI also visited the Taito Coastal Range together with G. HOSOYA, a mining engineer, and presented a report to the Governor General. Some reports on the coal and oil fields as well as on certain metal mines, mostly in the northern part, were also presented.

In the meantime, Y. ICHIKAWA completed geological exploitation works in Taiwan. He and H. TAKAHASHI, a mining expert, were teamed for several years after. He was fortunate because a lot of accumulated information and material were available for reference.

With the new information a new edition of the 1:300,000 Geological Map with accompanying text entitled "Explanatory Statements of the Geology and Mineral Resources of Taiwan (Formosa)[19] was compiled by ICHIKAWA and TAKAHASHI. For some years this publication remained a very useful guide for everyone concerned with the geological sciences of Taiwan.

It is noteworthy that in the explanatory text, the geological formations were divided into Tertiary and Pre-Tertiary. For the present the Tertiary will not be touched.

Some comments on Pre-Tertiary will be made. Besides a group of igneous rocks, five other groups are distinguished: 1. Gneiss group; 2. Crystalline limestone; 3. Crystalline schists; 4. Lower Slate formation; 5. Upper Slate formation. The first three groups are not clearly distinguished, but rather different kinds of rocks are often found intricately blended so that ICHIKAWA and TAKAHASHI were not able to discover any fossils in them. The Lower and the Upper Slate formations appeared in general continuous, but were unconformable in certain places. The Lower Slate formation is often found gradually changed into chlorite and graphite schists in the east. The Lower Slate Formation consisted of alternating beds of slate, graywacke and phyllite, and widely occupied the Axial Range area. It is here that M. YOKOYAMA[20] once recognized *Macrodon* ?, *Cucullaea* ?, *Myophoria* ?, and *Schizodus* ? in the neighborhood of Niitaka-yama, and assumed that they could possibly point to upper Paleozoic and Triassic in age. The Upper Slate Formation continues to the west of the Lower Slate Formation, and consists of black slate and graywacke below and black slate and sandstone above. The Tertiary formations extend westward.

A (Scale 1:50,000)

Sheet No.	Name	Date	Author
9.	Taihoku	1930	Y. ICHIKAWA
17.	Chikutō	〃	〃
13.	Tōen	〃	〃
18.	Ritōzan	1931	Z. OOE
5.	Daitōzan	1932	OOE & M. OGASAWARA
4.	Tansui	〃	〃
14.	Shinten	〃	Y. ICHIKAWA
11.	Kyūkō	〃	T. MAKIYAMA
7.	Oosono	〃	〃
8.	Kannonzan	1933	〃
12.	Chūreki	1934	〃
16.	Shinchiku	〃	〃
21.	Hakushaton	〃	〃
15.	Tōi	〃	Y. ICHIKAWA
35.	Tōsei	1935	K. TORII
27.	Taikō	1936	M. OGASAWARA
20.	Ratō	〃	M. USAMI
20.	Giran	〃	〃
12.	Hōkasho	1937	T. KIMURA & R. MATSUMOTO

B (Scale 1:100,000)

Sheet No.	Name	Date	Author
2.	Dainanō	1933	M. OGASAWARA
4.	Kenkai	1936	〃
9.	Toyohama	1939	M. USAMI
6.	Karenkō	〃	〃
13.	Taitō	〃	Z. OOE
16.	Daibusan	1940	M. USAMI

In 1927, the Imperial Japanese Navy published the "Report of the Geological Reconnaissance of the Oilfields of Taiwan," by Y. OOINOUE et. al. The field work covered all the known and promising areas,[21] as a matter of course, outside the alpine regions. Generalized geological maps were of 1:200,000 scale.

It was only in 1930 that the Geological Survey of Taiwan published the first of their Geological Sheets.[22] The Survey belonged to the Mining Section of the Bureau of Productive Industries of Taiwan. Naturally the plan was to produce sheets covering the whole island, but it was unfortunately abandoned in 1940 after a total of 25 had been published. Nineteen of the 25, including the northwestern part, are in a 1:50,000 scale; the other six of the eastern mountainous region are in a 1:100,000 scale.

The Geological Sheets of Taiwan published by the Government General of Taiwan[22] are listed below.

Almost simultaneously the organization of the Geological Survey was improved to some extent in order to press forward with the exploitation of petroleum reserves, and a few geologists were invited for this purpose. During the period from 1931 to 1938 a number of geological reports, especially elaborate in stratigraphical and structural features were published under a dozen titles, each with the name of an oil field or two, but often including the records of other nearby oil fields. The oil fields are listed below according to the order of their locations.[23]

Reports on the Oilfields of Taiwan by the Bureau of Productive Industries of Taiwan

Oilfield and Location	Date	Geologists
Byōritsu & Chikutō, Shichiku Prefecture	1932	K. TORII
Kagi, Tainan Prefecture	1931	H. ROKKAKU
Shika, 〃	1932	K. TORII
Tamai, 〃	1934	H. ROKKAKU
		T. MAKIYAMA
Kizan, Southwestern part, Takao Prefecture		K. YOSHIDA
Kizan, 〃	1933	K. TORII
Kōshun 〃	1934	ROKKAKU & MAKIYAMA
Koume, Tainan Prefecture	1935	YOSHIDA
Senzanko, Taihoku Prefecture	〃	TORII
Sanshikyaku, 〃	1938	K. TAN
Seisuiko, 〃	〃	H. HISAZUMI
Kokusei, Taichu Prefecture	〃	Z. OOE

In the meantime, members of the Taihoku Imperial University began their search. Their activities covered almost the whole island and included several dependent islets. In the domain of minerals and rocks the late Prof. T. ICHIMURA[24] took the lead, with the assistance and cooperation of a few senior and postgraduate students. Along this line of research, however, ICHIKAWA[25] and HATTORI *et* *al*[26] contributed to some extent. As to the paleontological works quite a lot had been carried out by members of the Tohoku Imperial University,[27] Sendai, such as S. NOMURA (Molluscs), S. HANZAWA (Foraminifera), and H. YABE (corals). Besides, M. YOKOYAMA also had already published several papers describing the Tertiary molluscs collected chiefly by geologists who had engaged in field works in different oilfields.

Fossil molluscs were studied also by members of the Taihoku Imperial University, including K. TAN, C. C. RIN, and K. ISHIZAKI. Regarding the Tertiary molluscs, the scheme had been to collect as many species and as many individuals, not only of the fossil shells but also of the Recent forms, so as to be able to make clear the real faunal relations between the fossil and actual forms in this part of the world. In other words, so-called "actuo-paleontological" data was sought with respect to molluscs so abundant in this region. For this purpose S. KANEKO and T. KURODA provided excellent service, by successfully collecting numerous specimens, and publishing excellent catalogues and papers.

Among the most noteworthy publications of this period was "A List of Japanese Neogene, Pleistocene and Recent Foraminifera, excluding Orbitoididae, Re-

Table 1. A General Stratigraphical Scheme of Taiwan by HAYASAKA, LIN and YEN (1947).

		North	South	Eastern coastal range
Holocene		River and Shore terraces lake deposits, etc.	River and Shore terraces Raised reefs	River and Shore terraces
Holocene		Older terraces and fans	Older terraces and reef Limestone terraces	Older terraces
Pleistocene		Faulting——Titling——Erosion		
Pleistocene		Tableland Gravel	Older Reef Limestone	Older Reef Limestone
Pleistocene		Folding, Thrusting, Upheaval, Diaton Volcanic activity, Erosion		
Neogene		Tōkazan Group { Syokkōzan Conglomerate, Tsūsyō Sandstone		Pinanzan Conglomerate
Neogene		Byōritsu Group { Takuran Sandstone and Shale, Kinsui Shale		Sandstone and shale
Neogene		Kaizan Group { Upper Kaizan beds, Middle Kaizan beds, Lower Kaizan beds		Sandstone and shale Agglomerate and tuffite
Palaeogene	Basic & Acidic Intrusions	Regional Metamorphism		?
Palaeogene	Basic & Acidic Intrusions	Slate Formation——?——Metamorphic Complex		Basic Intrusives

corded up to 1938" by K. ISHIZAKI.[28] This was the result of his strenuous efforts to build a base on which he expected to develop his field of study. The list was published in the *Taiwan Tigaku Kizi*, vols. X and XI (1939 and 40), 182 pp. including 21 pages of Index.

The late K. ISHIZAKI left many papers, however, on the Cenozoic smaller foraminifers from Taiwan; one of the important works was "An Index to Formosan Stratigraphy", 1942.[29] The promiscuity of the stratigraphical terms used in the geology of Taiwan had troubled geologist for a long time. Therefore this convenient Index was warmly received. The validity of this list is expected to last for a long, and be enlarged and revised as time passes. ISHIZAKI picked up over 160 names from 45 articles published by about 20 authors. This list was published in Nos. 220–226 (January to July, 1942) of the Transactions of the Natural History Society of Formosa, vol. XXXII.

Beside these rather routine type of research, various works, often of particular significance, were taken up by geologists either of the Geological Survey or of the University faculty. Graduation theses by University students were also available. All of this helped to increase our knowledge greatly during these years. However, as is suggested by the compilation of the Index, it is difficult to classify, and wear some to recapitulate the correlation. Thus, for convenience's sake, a brief correlation table was compiled in a somewhat generalized form with slight improvements by HAYASAKA, LIN and YEN, in 1947. As I stayed in Taiwan several years after the war I had the privilege of joining in this project, working together with them and other colleagues. The Table given below is brief, but is slightly more than a mere order of succession of formations. We endeavored also to involve more manifest geological events recognized up to that period.

B. THE METAMORPHIC COMPLEX

The correlation table (Table 1) mentioned above is based on previously-mentioned paper "An Outline and some Problems of the Stratigraphy of Taiwan," which was for some years an expedient reference. The explanations given by basal Metamorphic Complex and Slate Formation, as well as other formations, will be recapitulated in the essence.

The Metamorphosed Complex[30] is composed of a group of crystalline rocks occupying the eastern wing of the Backbone or Axial Range; rocks distinguished are paragneiss, sericite-graphite schist, chlorite schist, graphite schist, phyllite, conglomerate, etc. among the sedimentaries. Of the rocks of igneous origin, granite, granite-gneiss, hornblende-mica-quartz schist, and amphibolite are known to occur as injections into the schistose rocks, being metamorphosed together. The dykes of pegmatite, quartz and lamprophyres penetrating them are characteristically free from schistosity.

To the west this Metamorphic Complex becomes gradually weaker in metamorphic alteration. Approaching the crest line of the Taiwan Range the chlorite and graphite schists are found in thin alternation in many places in association with crystalline limestone on the one hand, and black clay slate on the other. Farther west the black clay slates gradually become dominant. In the mountain range to the west of Karenko some Eocene foraminifers, such as *Camerina, Discocyclina* and the like were discovered in the limestone bed in the transitional zone of the Metamorphic and the Slate Formations.[31] Similar Eocene foraminifers were found in the thin limestone in the black slate farther west, as well as in the north and south of the Axial Range in several places. For some time K. TAN indulged in collecting such foraminifers as well as, with almost equal frequency, molluscan shells. Fossil occurrences like these seem to have suggested to some people that the two groups of formations referred to might be intimately related to each other.

In the Metamorphic Complex the Xenoliths of quartzite conglomerate are found occasionally, T. ICHIMURA[32] who examined them microscopically was of opinion that the grade of metamorphism of the conglomerate is different from and stronger than the matrix. His assumption is that there was a period of metamorphic process before the formation of the Metamorphic Complex itself, and also that the quartzite conglomerate block might have originated somewhere beyond the Formosa Strait, on the continent.

In the meantime, T. P. YEN, now of the Geological Survey of China and two of his associates happened to discover some fragmentary specimens of fusulinid foraminifers during field works in the Metamorphic Complex region. The fossils were preserved in the Crystalline limestones, and were collected in the exposures north of Hualien, at three localities, namely, Tungai, Nantzu, and Kussu. Although the fossils in thin slides are only scarcely recognizable by trained eyes, this discovery was really a memorable event in the history of the geology of Taiwan. In fact something like the features of such fossils were alluded to by T. ICHIMURA[33] and K. TAN[34] a few years ago; they recognized some questionable fragments of a coral-like enclosure which were hardly possible to identify from the exposures of the same crystalline limestone in the same region.

Following a paper written in 1951, YEN wrote another paper in 1953,[35] in which not only the localities of fossils were increased and the distribution of the fossils extended but also the paleontological examination of the fossils had been recorded. The fossils were examined by Prof. M. L. THOMPSON of the University of Wisconsin who said that the fusulinids are *Schwagerina* ? sp., *Neoschwagerina* ? sp., and *Parafusulina* ? sp. Besides, in the opinion of Prof. TIN YING H. MA of the National Taiwan University, a tabulate coral was found by YEN in the same metamorphosed limestone: it is a species allied to *Waagenophyllum*, an important genus in the Permian of the Indo-Pacific region.

In 1960, another article by YEN appeared on the Metamorphic Complex, entitled "A Stratigraphical Study of the Tananao Schist in North Taiwan."[36] In this study the author endeavored to further scrutinize the stratigraphy of the Metamorphic Complex based on the knowledge of their petrography and petrology, supported by the petrofabric and the geology of the region. He descriminated the Tananao Group and the Tananao Schist: the former is the original Paleozoic sediments, while the latter is the metamorphic product of the former. The Tananao Schist is tentatively classified as follows, numbered from top to bottom:

4) Yuli formation (ca. 2,000 m): Triassic (?) to Up. Permian:
Coarse-grained sandstones dominant, accompanying shale beds, basic tuff beds and serpentinites.

3) Tailuko formation:
a. Tungaw facies (ca. 2,100 m): sandstones, shales, basic lavas and tuffs, limestones (with fusuline fossils)
b. Tachinshui facies (1,200–1,800 m): mainly limestones with some of tuffs and cherts (with *Waagenophylum*, and larger forms of fusulinids above).

2) Kanagan formation (ca. 800 m): arkose of coarse-grained sandstones, and partly sandstones, shales, and limestones, metamorphosed to parag-neiss, locally original sediments.

1) Sanchui formation:
a. Gong facies (500–700 m): sandstones, shales, basic tuffs and limestones dominating. Permian and/or Carboniferous
b. Raushi facies (500–800 m): Limestone dominant, a little of basic cherts and tuffs.

Each of the stratigraphical units are minutely described and compared with the stratigraphical sequence of the Yoshinogawa group of Shikoku, Japan, by Prof. J. Kojima of Hiroshima University, Japan. Yen points out that in the rock sequences, lithic characters and grades of metamorphism in the Tananao Schist and the Yoshinogawa Group are very akin to each other, except for the very rich development of the limestone in the former; that is, the former is quite like the Sanbagawa Group of Japan.

In a paper "A Geologic Consideration on the Taitung Valley, Eastern Taiwan" (1967),[37)] Yen explains the geological structure on the basis of own research, and recorded the discovery of a thrust fault around in the southern part Chulu area, and an unconformity and/or a fault at Fuli, both in the Valley almost buried under the thick Quaternary sediments that fills the Valley.

What is of particular interest here is, the Yuli formation forming the western side of the Valley, that is, the eastern slope of the Axial Range. It forms the upper division of the Tananao Schist as referred to above. In the southern part of the Valley, especially between the north of Luyen and the neighborhood, the eastern slope of the Axial Range is occupied by a slate or phyllite formation, which is questionably assessed at Paleogene by Yen.

The Yuli formation is assumed to range from the Permian to the Triassic. Possibly the last mentioned bed of slate or phyllite may be conjectured to represent the Triassic part of the Yuli formation. Were this inferential conception allowed, could it not be expected that this phyllite part forms a lower horizon of the Slate Formation upon which the succeeding Mesozoic formations follow?

Turning back to the Tananao Schist, the very thick limestone of its middle part yielding fusulinids and a few other fossils of the Permian age is reminiscent of similar thick limestone formations in Japan which contain hosts of fossils, representing different zonal assemblages ranging from Carboniferous to Permian. Although the Tananao fauna is not very lucid so far, there is no reason to give up the hope for future discoveries both in the mode of preservation and in the kind of fossil organisms, as well as of different fossiliferous horizons of the Paleozoic. This limestone and possibly also the less conspicuous ones in the other parts of the rock complex look promising in this concern. That the whole complex represents not only the Permian, but also the Carboniferous, I hope and expect, may be realized by finding proper fossils in the future.

I wrote to Dr. YEN asking for recent information on the stratigraphy, especially of the Metamorphic Complex and the Slate Formation of Taiwan. He kindly explained the situation.[38] He explained the gist not only of the Tananao Schist, but also of the Slate Formation, and the succeeding formations as well. The following is the substance of this communication.

The Tananao Schist is developed in the upstream regions of the Tananao and Tachosui rivers and their tributaries in the northern part of the eastern Taiwan. The zone of this rock group extends for southward to the northwestern vicinity of the city of Taitung. The area of this rock group, as a whole, forms a synclinorium of a conspicuous scale, accompanied within by the folds of minor scales, variable in size and of different periods of formation. The fossil evidence is only of the Permian age recognized at the present.

According to the dominant features of the constituting rocks the whole Tananao Schist can be grossly characterized part by part. YEN defines it in the following way.

Upper Part:	sandstones and shales
Middle Part:	limestones, tuffs, sandstones-shales, fusulinids and corals in limestones
Lower Part:	arkoses, sandstones

Of these rocks, limestones and tuffs are dominant on the eastern, that is, the Pacific side of the Axial Range, while on the west side the facies are chiefly of sandstones, shales, tuffs and occasional limestone.

The metamorphism of the rocks represents the degree indicative of the chlorite and biotite zones: the injections into the rocks show the stages of the epidote-amphibolite or hornblende-hornfels facies and in part the stage of glaucophane schist. The age of the metamorphism is conjectured to be between middle and late Mesozoic: the late Cretaceous pegmatitic injection accompanied: the injection of the migmatitic parts of the Gneiss may be of the early Tertiary age, probably being about 50 Million years old.

As YEN's communication touched also the Slate Formation, I will passingly refer to it in advance of explaining our former knowledge of the same Formation summarized in Table 1.

The Slate Formation covers the Tananao Schist unconformably. In the Axial

Range it froms (Mesozoic?)–Eocene–Miocene. Westward, in Hsuehshan range the Oligocene is recognized between Eocene and Miocene, thus, latter two are generally regarded unconformable. The structure as a whole is a low angle geosyncline of a grand scale devoid of complicated structures. Owing to the test borings it is certain that the Eocene or the older beds lie unconformably in west Taiwan under the middle Miocene beds; this relation resembles that revealed in the Axial Range region.

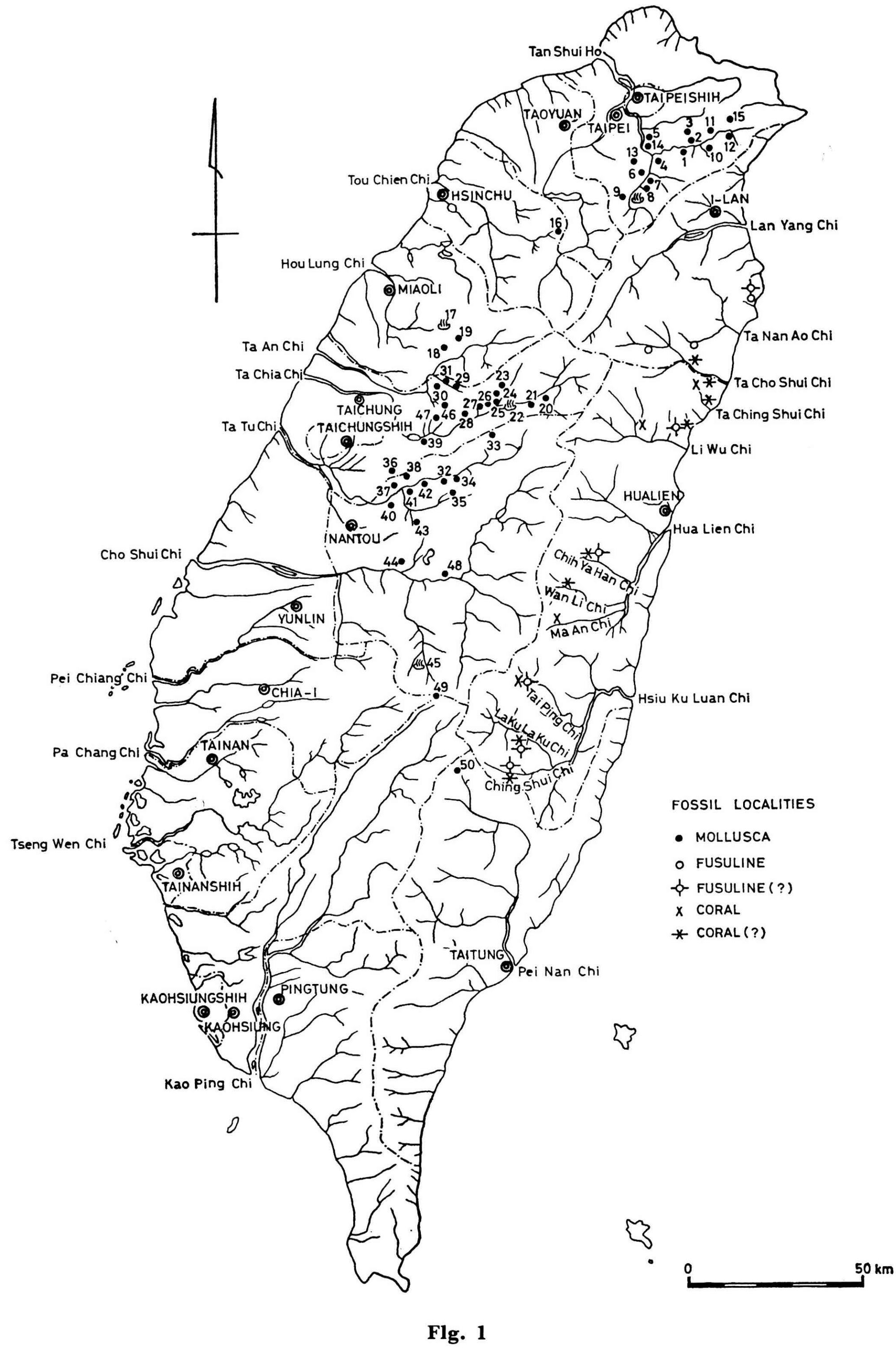
C. The Slate Formation

The western flank of the Taiwan Mountains or the Axial Range is composed chiefly of an apparently very thick sequence of hard, black slates. This sequence comprises, at different places, beds of sandstones ordinarily in meager volumes; besides, intercalated thin beds of conglomerate and limestone also are found. The stratigraphical relations with the Metamorphic Complex has been explained elsewhere. The Slate Formation as a whole has been used to be divided into two parts; the Lower or the Suo Series, and the Upper or the Urai Series. Beside the generalized divisions, several indefinite local names have been proposed for rather local isolated exposures where some fossils are actually obtained but devoid of reliable evidence for correlation among them. Actually, the Slate Formation is, just like in the case of the Metamorphic Complex as a whole, quite severely disturbed, strongly crumpled, traversed by complicate fissures, faults, etc., and the recognition of the order of bedding rendered extremely intricate. Often different blocks of the same formation are apt to be called by different names. At certain places, however, in the Slate Formation which, as a whole, has been said to be deficient in fossils, some organic remains have been yielded. The following is a list preliminarily recorded by the late Prof. K. Tan, in 1942.[39]

Upper Slate Formation:
- *Cyclammina* spp.
- *Assilina formosensis* Hanzawa
- *A. niitakaensis* Tan
- *Heterostegina* sp.
- *Lepidocyclina* (S. S.) *formosensis* Hanzawa
- *Operculina* sp.
- *Discocyclina* spp.

Lower Slate Formation:
- *Camerina* spp.
- *Amphistegina*? sp.
- *Discocyclina* (s. s.) spp.
- *Orbulina universa* d'Orbigny

Beside these foraminifers several marine shells were described by M. Yokoyama, Tan and others. They are *Crassatellites nipponensis* Yokoyama and *Pholadomya margaritacea* (Sowerby); both are Eocene in age. There are some others that are


Tan Shui Ho
TAIPEISHIH
TAOYUAN
TAIPEI
Tou Chien Chi
HSINCHU
I-LAN
Lan Yang Chi
Hou Lung Chi
MIAOLI
Ta An Chi
Ta Nan Ao Chi
Ta Chia Chi
Ta Cho Shui Chi
TAICHUNG
Ta Ching Shui Chi
Ta Tu Chi
TAICHUNGSHIH
Li Wu Chi
HUALIEN
Hua Lien Chi
NANTOU
Cho Shui Chi
Chih Ya Han Chi
Wan Li Chi
Ma An Chi
YUNLIN
Pei Chiang Chi
CHIA-I
Hsiu Ku Luan Chi
Tai Ping Chi
La Ku La Ku Chi
Pa Chang Chi
TAINAN
Ching Shui Chi
Tseng Wen Chi
TAINANSHIH
FOSSIL LOCALITIES
MOLLUSCA
FUSULINE
FUSULINE (?)
CORAL
CORAL (?)
TAITUNG
Pei Nan Chi
PINGTUNG
KAOHSIUNGSHIH
KAOHSIUNG
Kao Ping Chi
0
50 km

Flg. 1

rather widely distributed in the Cenozoic, namely, *Corbicula*, *Pecten*, *Cyprea* and the like.

In a personal communication, YEN mentioned also the current status of the Slate Formation concisely. The Slate Formation is of a vast thickness and ranges in age from the Mesozoic (?) to Neogene. The Oligocene formation is lacking except in the northern part around Hsueh-shan, the Eocene and the Miocene formations being unconformable in general. The Slate Formation forms a low angle synclinorium as a whole of an enormous scale, though not so complicated in structure as has generally been considered. The Formation can be traced along almost the whole length of the Axial Range, and extending down the western slope for some distance. It is generally fossiliferous, often proliferous in certain horizons. (The occurrence of some Eocene fossils in certain horizons of what was regarded the Slate Formation suggested that the Metamorphic Complex also might belong to the Tertiary.)

The late Prof. K. TAN was successful in collecting numerous Eocene and Paleogene fossils from various localities in Taiwan. He studied them paleontologically in universities in Taipei and Akita (Japan), and around 1950 prepared a report, which is quite comprehensive.

Comparing the maps of the fossil localities of TAN and YEN, there is a palpable boundary between the two areas, the one on the western slope of the Axial Range, and the other on the eastern. The former area is where TAN collected Eocene and Paleogene molluscs in as many as 50 localities, while the latter includes fewer localities of the younger Paleozoic fossils. The terraine of the former is chiefly of Slate Formation, while the latter, of the Tananao Schist land. Neither of the areas seem to transgress the frontier, however (See Fig. 1).

In 1961, some unusual information regarding the historical geology and the paleontology of Taiwan was made known. It was the discovery of an ammonite and some other fossils of the Jurassic age in the central plains region of Taiwan. According to Prof. C. C. LIN[40)] of the National Taiwan University, these fossils were struck by one of the test bore holes for oil carried out by the Chinese Petroleum Company at a well near the town of Peichiang (or Peikang), northwest of

Fig. 1. Distribution of Localities of the Permian and the Paleogene Fossils in Taiwan. Dr. K. TAN, about 1950, drafted a chart showing the distribution of his Paleogene and Eocene molluscs (and foraminifers). Dr. T. P. YEN, subsequently, in 1953, prepared another similar chart on which he plotted all the known localities of his Permian fossils —the fusulinids, unaware of TAN's work. I was interested to compare these two charts,* interested with regard to the problems of stratigraphy, sedimentology and structural geology. In order to make the comparative study of the charts more easy, I asked Mr. Y. SAITO of the National Science Museum for help. He made a single chart uniting the two, and on it he plotted all the localities of TAN and YEN. This shows that the Paleozoic and Paleogene "domains" are almost distinctly divided but one—No. 50, one of the Paleogene molluscan localities. May not this be more or less significant for further contemplation for disclosing the problems of the stratigraphical, structural, etc. relations of the Tananao and the Slate Formations? (I.H.)

* K. TAN (in the press): The Paleogene Stratigraphy and Paleontology of Taiwan, p. 22, fig. 4.
T. P. YEN, See Note 35 (1953), p. 24, fig. 1.

the city Chai, Tainan Prefecture. The depth of the well was 1,692.8 m from the surface, so that the horizon of the fossil bed may not be more than a few meters higher than the depth below sea level. The quite well-preserved ammonite was tentatively identified as *Holcophylloceras* aff. *mediterraneum* (NEUMAYR) by LIN; the associate fossils were fragmentary specimens of Belemnites, and Brachiopods, together with a few fragments of terrestrial plants. These fossils were buried in a "hard, compact, fine-grained, carbonaceous sandstone" (LIN). The ammonite was briefly described and illustrated by LIN in *the Proc. 9th Pacific Science Congress*, vol. 12. Fragments of another kind of ammonite was reported to have occurred at a different level of the test well.

It was ascertained by this discovery that the West Taiwan Tertiary formations embodied oil and coal concealed beneath not only the Paleogene and Neogene formations but also a bed with some Jurassic fossils, and possibly a more comprehensive parts of the Mesozoic formation, as it seems to have been presupposed by some geologists in Taiwan the early days. As early as in 1910 Y. DEGUCHI,[41] assumed the existence of the Paleozoic and the Mesozoic formations in Taiwan. K. MURAYAMA,[42] a member of the OOINOUE party exploring the oil resources, happened to pick up a piece of sandy shale with an obscure remain that looked like an ammonite impression. It was found in the upstream region of the Ninaichi, near Hengchun, Kaohsing Prefecture. The sandy shale belonged to the Lower Arishan formation. Provided that the fossil is really an ammonite the rock cannot but be of the Mesozoic age.

In regard to these occurrences, DEGUCHI's expression of his supposition on the possibility of the existence of the Paleozoic and the Mesozoic, "the late Paleozoic—early Mesozoic" and "the Cretaceous—the Tertiary," is noticeable. This is in recognition of the more recent advancements in science in Taiwan.

In reality, the knowledge of the Mesozoic of Taiwan has been much advanced by the geologists in Taiwan. An article by YEN, SCHENG, KENG and YANG, "Some Problems on the Mesozoic Formation of Taiwan" (1956)[43] may be regarded as representative.

Much more information on the Mesozoic of Taiwan is expected as well as information on the relations with the Mesozoic and the Paleozoic.

Here, before summarizing the Neogene Formations of Taiwan, the stratigraphy and the historical geology by the close of the Paleogene may be reviewed according to recent data and information mentioned above. For further detailed studies, contributions by researchers in Taiwan along these line also are awaited.

1) The Tananao Schist may involve the Carboniferous formation, or, at least its part or parts, although this is not obvious at present.
2) The Jurassic formation may be a part of the Mesozoic formation, which may include the whole sequence of the Jurassic and the Cretaceous upwards; a part of the upper Cretaceous is said to be indicated by such fossils as *Elephantaria* sp. and *Astrocoenia* sp. Downwards, the fossiliferous horizons of

the Jurassic may have preceding horizons, possibly representing the upper part of the Slate Formation, together with the older Triassic part.

3) The structural relations of the Pre-Tertiary and the Paleozoic formations, and those of the Paleogene and the Neogene formations are important and at the same time interesting as problems. Perhaps a number of borings reveal information on such problems.

In light of this information Table 1 should be amended. In the column "Paleogene" instead of Paleogene, Paleozoic and Mesozoic, with their subdivisions, should appear.

In this note the so called Metamorphic Complex and partly the Eocene or the Paleogene formation have been taken up for discussion, on one hand, and the Jurassic as the representative of the Mesozoic on the other. Scrutiny may further reveal data to throw some light on the restoration of deficient Ages and Systems.

The general stratigraphical sequences must have been compiled officially, though it was not yet made available for me. The following were at my disposal:

CHANG, Li-Sho (1953): a. Geohistory of Taiwan; b. Stratigraphy of Taiwan. "The Geology of Taiwan" The Economy Research Section of the Taiwan Bank.

LIN, C. C. (1964): Geographical and Topographical Documentary Literature (Chinese). Documentary Literature of Nantouhsien, 12.

As I have no information on current progress, explanations concerning the Cenozoic, especially the Neogene formations, can be found following in the main summaries of HAYASAKA, LIN and YEN, 1948.

D. THE BASIC AND ACIDIC INTRUSIONS

The cardinal members of the basic intrusives are amphibolites, schistose and otherwise, gabbro, diabase and serpentine: these have been referred to in the foregoing pages. These rocks are the products of metamorphism together with the Paleogene (so assumed at least for the time being) sedimentaries. Besides, there are, in association with the Metamorphic Complex, lamprophyre dykes, augite minette, biotite minette, augite spessarite, biotite spessarite in association with the Metamorphic Complex, without showing the schistosity as recognized in the latter. Consequently, the last phase of the magmatic injection process is considered to have lasted until after the dynamic metamorphism came to an end. The gabbro, peridotite and serpentine found around Taito in the Taito Coastal Range are older than the Neogene formation developed in the region. Moreover, the xenolithic capture of peridotite by gabbro is known in this area.

To the acidic intrusives of the same region belong granite, granite-gneiss and hornblende-amphibolite. Non-schistose rocks like pegmatite, quartz porphyry and quartz veins seem to correspond in phase to the lamprophyres mentioned above.

In the central regions of Taiwan, along the highways across the Axial Range, layers of diabase tuffite and volcanic agglomerate as well as porphyrites associated with the Slate Formation are sometimes met with. Similar cases are rarer northward, the occurrence of tuffaceous zones being known at a few places in the proximity of Taihoku as well as in the hill region east of Taito.

E. Regional or Dynamic Metamorphism

Considering the time or period of the metamorphism which produced the metamorphic rocks referred to above, it is so far certain that (1) none of those injection rocks ever affected the Neogene sediments and (2) those latter do not show the symptom of regional or dynamic metamorphism. On the other hand, the Oligocene fossils have been discovered quite limited outside Kotosho islet; the lower division of the Neogene formation had not been discovered in the middle part of Taiwan; and the development of the latter appears to be quite unsteady in the southern Taiwan.[44] These facts taken together indicate that the dynamic or regional metamorphic processes that seem to have taken place have to be assumed to be the phenomena which took place after the Eocene period and before the Miocene. Geographically considered, and judging from the trend of distribution of the metamorphic rocks, the process of metamorphism appears to have been most severe where the general north-north-east—south-south-west trend of the axis of Taiwan turns all of a sudden toward the east: the energy is considered to have been mitigated on proceeding southward.

F. The Kaizan Group

The Kaizan Group is just as was defined by Yabe and Hanzawa (1930),[45] and includes the Upper Arisan formation of Ooinoue.[46] In other words, the coal-bearing and petroliferous formations of the northern part of Taiwan are embraced in it. It corresponds to what was named the Shukkoko formation by authors in Shinchiku Prefecture.

The formation is schematically divided into three rhythmical subdivisions as follows:

c)	Upper Kaizan beds ca. 800m	Upper marine beds Upper coal-bearing beds
b)	Middle Kaizan beds ca. 1,300–15,000m	Middle marine beds Middle coal-bearing beds
a)	Lower Kaizan beds ca. 1,000m	Lower marine beds Lower coal-bearing beds

a) The lower coal-bearing beds are a succession of a coarse-grained quartz sandstone and overlying beds of sandstone and shale in alternation, the shale intercalating seams of coal.

The lower marine beds are specified by certain foraminifers of Miocene age, such as *Lepidocyclina taiwanensis, Nephrolepidina verbeeki Miogypsina mammillata, M. inflata*, besides *Cellepora formosensis*. These species collectively indicate the Burdigarian in age. There are several other forms of fossils known including *Cyclo-clypeus communis, Lithothamnium* cf. *ramosissimum, Pecten (Amusiopecten) yabei, Echinodiscus formosus,* and *Schizaster taiwanicus.*

The lower Kaizan beds, however, are not found distributed around the Shukkoko oil field itself.

b) The middle coal-bearing beds including three seams of coal yielded incomplete specimens of *Ficus, Cinnamomum* and a few other plant remains. The accompanying middle marine beds yielded some fossils at certain places. The more important among them hitherto collected are: *Operculinella bartschi ornata, O. b. multiseptata, Operculinella venosa, Amphistegina communis,* and some smaller foraminifera like *Textularia, Biloculina, Globigerina,* etc. Beside these foraminifers *Pholadomya, Clypeaster, Astryclypeus integer* and the like were discovered.

The middle Kaizan division is very well exposed in the neighbourhood of the anticlinal axis of the Shukkoko oil field, where the successions of the formation are well recognized: an alternation of sandstone and shale at base, sandstone, shale and another alternating beds of sandstone and shale at the top.

c) The upper division is best developed in Shinchiku Prefecture. Here the coal-bearing series is characterized by the development of a coarse-grained white quartz sandstone, associated with thin beds of shale and sandy beds. In this upper division there are three principal seams of coal, which, as a whole, are not of an excellent quality: and the thickness also is rather variable, and neither is the extension constant. The overlying marine bed is a medium-sized calcareous sandstone, which is sometimes glauconitic in nature. In this marine bed is somewhat fossiliferous, containing abundant specimens of *Operculina venosa* and occasional molluscs among which *Pecton (Amusiopecten) yabei* may be worthy of note as an index.

In eastern Taiwan, in the Taitung Coastal Range, a series of shales and sandstones is considered to correspond to the lower Kaizan beds, chiefly by reason of the paleontological correlation: the occurrence in certain calcareous beds at certain places of *Miogypsinoides, Amphistegina* and some others have been discovered.

In the mountainous region around Arisan in the middle central part of Taiwan, the geology is mainly of a series of sandstone and shale, mostly in alternation, and in part cross-bedded. The total thickness is assumed to be about 800 m. Fossils are rare except for some molluscan shells found in the upper part of the sequence.

G. The Byoritsu Group

This group of formations is quite well developed in the Shinchiku Prefecture and southward from there. But, farther north, around Taihoku, this group is incompletely found sporadically. The lower division of this Group is dominantly shaly, and the upper part is mainly the alternating beds of sandstone and shale. The former was named the Kinsui Shale, and the latter the Takuran sandstane and shale, respectively. It is limited below by the Daiho beds or the Kantozan beds by Lin, and above by the base of his lower Tokazan beds. The Kinsui Shale is about

1,000 m thick in Shinchiku Prefecture, but is barely 500–600 m in Taihoku Prefecture in the north. This Shale formation tends to increase in thickness southward from Shinchiku Prefecture. At the same time it gets somewhat richer in sandstone beds, as is seen in the Kwanshirei and the Mokusaku beds, in Tainan Prefecture; the total thickness around here increases up to about 2,000 m. The Kinsui Shale is rather poor in fossil content: however, molluscs and the so-called smaller foraminifers are common; so also with some echinoids, namely, *Clementia nonscripta, Amusium* cf. *pleuronectes, Rapana bulbosa, Tonna costatum, Xenophora* cf. *solidiformis, Operculina venosa, Streblus schroeteriana, Clypeaster* cf. *japonica, Galena granulifera*, etc.[47]

The Takuran Sandstone and Shale formation tend to form the structural topography of the so-called "homoclinal ridges" in certain regions. The Unsui and Koteiko formations of southern Taiwan correspond to this. This formation is only about 500 m in thickness in the northern part of Shinchiku Prefecture, but their thickness is also augmented in the south, attaining about 1,800 m in the Taichu Prefecture, and culminating to nearly 2,500 m in Tainan. In Tainan Prefecture, where some local names are proposed for certain local beds, as for instance, the Unsui beds, or Koteiko beds just referred to. In this district this bed is characterized in intercalating a few thin Oyster beds with swarms of the gigantic valves. This may possibly have some bearing on the consideration of ecology and sedimentology of this formation.

As to the occurrence of fossils of this formation, there are a number of foraminifers that are of the same species as those from the Kinsui shale, and besides, there are many more remains of molluscan shells: the more common forms being as follows: *Pecten laqueatus, Ostrea gigas, Arca inflata, Anadara granosa, Architechtonica perspectiva, Fusinus nodosoplicatus, Oliva mustellina, Turritella filiola, T. terebra*, etc. The bluish gray sandy shale of the Takuran Sandstone and Shale seem to react to the process of weathering in an unusual manner; it is presumed that this is the cause for the so-called "badland" topography in the southern part of Taiwan. Besides, a similar phenomenon is known to take place in a certain part of Taito Prefecture in southeast Taiwan, but the details about the Byoritsu Group in the Taito Coastal Range are not yet known.

H. The Tokazan Group

This is a group newly proposed by Hayasaka, Lin and Yen[48] to include the upper part of the Byoritsu beds and the overlying Shokkozan beds of the former usage. The lower part of the Tokazan Group is dominantly sand, and coincides with what had been called by some people the Tsusho Sandstone, and the upper division, the Shokkozan Conglomerate.

The Tsusho Sandstone consists in sandstone that is yellowish gray to gray in colour, intercalating beds of mudstone and gravel, and often containing pieces of carbonized drift wood of considerable size, here and there. This formation had been often called the lower Tokazan formation in Taichu Prefecture, and Kityo beds and so on in southern regions. In the Koshun region, that is the southernmost district of Taiwan, the richly fossiliferous Shiko beds and possibly also, the underlying *Globigerina* Sand minutely studied by the late K. ISHIZAKI[49] geologically correspond to this. In the northern regions especially, this formation yields very abundant molluscs and some other kinds of fossils at various places. The beach of Hakushaton close to the village of Tsusho in Shinchiku Prefecture, for instance, may be mentioned as the typical locality; almost all of the numberless fossils formerly labelled to have occurred at Hakushaton have now to be recorded as being from Tsusho, and most of them are not to be called the fossils of the Byoritsu formation. The fossil collected were far more than 200 species. According to S. NOMURA,[50] the species inclusive of varieties he listed in a monograph (1935, 1938) amount in reality to over 400, including 13 Scaphopoda, 73 Pelecypods, and 275 gastropods. If analyzed stratigraphically, the great majority of them represent the Recent to the Pliocene forms. Among them, however, those limited to Pliocene are 31 Pelecypods, 69 Gastropods and 1 *Dentalium*. These 101 species correspond almost all to those introduced as new from the so-called Byoritsu formation by NOMURA and YOKOYAMA. The old known Pliocene cosmopolitan species are only three among pelecypods, namely, *Arca (Arca) sedanensis* MARTIN, *Pecton (Vola) javanus* MARTIN, and *Cardium (Fragum) alfuricum* (FISCHER). Of the 69 gastropods *Clavatula serana* FISCHER is Miocene (?)-Pliocene, *Astenostoma epitonica* (FISCHER) and *Clavus tjibaliumgensis* (MARTIN) are Pliocene. All the others are, as stated above, known from the Pliocene to the Recent, and almost all of them are possibly living in the actual sea around the archipelagoes of Japan and the Philippines, as well as Malaysia. Comparing them as the whole with the present day fauna of Taiwan in general, it seems that there is some disagreement.

The Pliocene marine shell fauna represented by the fauna of Tsusho where compared with the present marine molluscan fauna, species by species, do not seem to show such a difference in the climate about the close of the Pliocene to provoke any perceptible ecological influence to the shore shell fauna.

The following is the list of some of the more significant molluscan species.

Anadara granosa (LIN.)
A. tricenicosta (NYST)
Trisidos kiyonoi (MAKIYAMA)
Cucullaea granulosa (JONAS)
Pinna attenuata REEVE
Chlamys (Chlamys) squamata (GMELIN)
C. (Decatopecten) plica (LIN.)
Pecten (Vola) naganumanus YOKOYAMA
P. (Amusium) pleuronectes (LIN.)
Placuna placenta (LIN.)
Anomia lischkei DAUTZ. & FISH.
Ostrea denselamellosa LISCHKE
O. gigas THUNBERG

Crassatellites loebecki (KOBELT)
Dosinia (Phacosoma) gruneri (PHIL.)
D. angulosa (PHIL.)
Chione (Clausinella) foliacea (PHIL.)
Anomalocardia impressa (ANTON)
Paphia (Paratapes) undulata (BORN)
Aloides erythrodon (LAM.)
Dentalium (Dentalium) hexagonum GOULD
Umbonium (Suchium) moniliferum (LAM.)
Turritella filiola YOKOYAMA
Architectonica perspectiva (LIN.)
A. maxima (PHIL.)
Cerithidea (Cerithideopsilla) ungulata (GM.)
Batillaria zonalis (BRUG.)
Xenophora (Tugurium) exuta (REEVE)
Strombus taiwanicus NOMURA
Natica (Notocochlis) rufilabris REEVE
Phalium japonicum REEVE
Bursa (Gyrineum) rana (LIN.)
Murex ternispina (LAM.)
Nassarius (Alectrion) canaliculatus (LAM.)
N. (Niota) gemmulatus (LAM.)
Oliva mustellina (LAM.)
Mitra (Cancilla) flammea QUOY et GAIM.
M. (Scabricola) yokoyamai NOMURA
Turricula byoritsuensis NOMURA
Turris (Turris) oxytropis (SOWERBY)

Beside such an abundance of mulluscan fossils, this formation has yielded several echinoids[51)] such as *Echinarachnius (Scaphechinus) mirabilis* (A. AG.), *Astriclypeus manni* (VERRILL), *Breyinia* spp. and some other genera, often beautifully preserved. In the same formation developed around Shiko, to the south in Takao Prefecture, three species of *Pictothyris* (Brachiopoda)[52)] were collected, together with almost equally prolific shells.

In Taiwan, various mammalian[53)] fossils, mostly fragmented, have been unearthed from time to time, in the Prefectures of Shinchiku, Taichu and Tainan. In most of the fossil localities, the mode of their preservation is not consistent. At Sachin, in Tainan Prefecture, where such mammalian bones have been most frequently collected, they were found washed out on the bottom of the stream, with fragments of shells and also of pieces of carbonized drift wood. The mammalian remains known to include something like *Cervus (Sika) taiwanus*, *C. (Deperetia) kazusensis*, *Bison geron*, *Rhinoceros* sp. nov (?), *Stegodon sinensis*, *S. insignis*, *S. orientalis*, *Elephas indicus buski*, *E.* cf. *trogontheri*, etc.: a fragment of a scull of Crocodilia was once reported to have been discovered from Satin.

After careful exploration, it was ascertained that these mammal or rather vertebrate remains were originally embedded in the Kicho beds, in Tainan Prefecture, that is a bed which stratigraphically almost corresponds to the Tsusho Sandstone bed.[54)]

A few words on the Shokkozan Conglomerate bed which overlies the Tsusho Sandstone. It is a thick conglomerate bed, gray in colour, and is intercalated with sandstone beds sporadically. The Shokkozan bed was formerly regarded as the upper part of the Tokazan group, and is very conspicuously developed in the Prefectures of Shinchiku and Taichu, attaining the thickness of from several hundred meters up to over a thousand meters. Because of the particular, loose and brittle nature of the rock, and being tinted deep ochre, it is severely eroded to induce the so-called earth-pillar pattern. Such a rough exposure of the ochre-coloured conglomerate cliff reflecting the evening sun glows magnificently, hence it has been called the Kaenzan—"flaming hill" for a long time. In all of Taiwan there are several places where similar geology and topography present the "flaming hills" of similar landscapes. The most graceful, however, is the one in Taichu Prefecture, about 15 km southeast of the city of Taichu. In the sandy part at the basal horizon of this Shokkozan Conglomerate a few fresh-water or brackish-water shells, like *Corbula, Unio, Potamides fluviatilis* and the like are buried. This may possibly throw light on discerning the condition of the sedimentation of the formation.

Concerning the Shokkozan Conglomerate, details have been observed and much has been discussed. From most of what has been studied, it is almost unanimously believed that it represents the lower part of the Pleistocene formation.

As regards the stratigraphical relation between the Tokazan and the Byoritsu beds, they are decidedly conformable to each other as far as is known in western Taiwan, and it is assumed that the same sequential relation may prevail all over the island.

In the meantime, the Shokkozan Conglomerate bed, that is the upper Tokazan bed, wherever developed, is overlain by younger sediments with clino-unconformity. The explanation for this is that after the deposits of the Shokkozan Conglomerate were laid down the land was raised with accompanying folds and thrusts. The volcanic activities which erupted the Daiton Volcanic Group were to follow.

I. Upheaval, Folding, Thrusting, Volcanic Activity and Erosion; Glaciation

It is said that in the Taito Coastal Range, the Shokkozan Conglomerate unconformably lies on the eroded surface of the Byoritsu Group, and the succession as a whole is reversed by a tectonic disturbance. If it is really the case, there must have been a crustal movement of some sort before the deposition of the Shokkozan Conglomerate. This cannot but be considered exceptional in the recent historical geology of Taiwan, however. In western Taiwan where the Neogene formations are very widely spread and well developed, the Shokkozan conglomerate always concordantly succeeds the Tsusho Sandstone, and the latter and the Byoritsu Group are also conformable. The Conglomerate, on the contrary, is always clino-unconformably overlain by younger formations. The period or phase of the crustal movement following the Shokkozan Conglomerate is characterized by the dominance of folding and thrusting. The present-day Axial Range region of the island seems to have been highly raised along with the folding of the crust. This movement of the upheaval had been at work for some time, but it seems to have culminated in this period. The actual configuration of the island of Taiwan is believed to have been decided by this crustal reformation. The geographical conditions were almost the same as they are now, and the sedimentation of rocks took place in flood plains, basins, and shore zones, forming terraces, fans, taluses and the like everywhere. Along the shore, especially in the southern part, coral reefs developed vigorously, and they remain as raised reef limestones at present.

As is shown by certain marine charts around Taiwan, there are a few drownd valleys, signifying the recent subsidence of the dissected land of Taiwan. The most evident is the one which is the submarine extention of the Shimo-Tansui-kei, south-east of Takao harbor. In 1927, on the occasion of the 5th Pacific Science Congress in Java, YABE and TAYAMA read a paper concerning it.[55)a] Unaware of it HAYASAKA prepared a paper regarding the same, the main points being similar.

"In the later Pliocene period the island of Taiwan was about 1,000 m higher than it is now. During the course of the subsequent drowning, which was less conspicuous northwards, coral reefs were formed in the south, ... while gravel was deposited in the north where progradation was particularly vigorous. The general cooling, and the lowering of the sea level, of the Pleistocene age, caused the deadth of coral animals. It was immediately followed by an uplift of land, in the course of which the rise of the water level resulted by the melting of the polar ice gave a chance to the formation of the younger coral reefs. ...." The land uplift still continued and consequent valleys were in the making.

"Glaciation might have taken place in Taiwan when it was 1,000 m higher, but the topographic characteristics are not likely to be preserved under such a climatic condition like this, and especially where the mountain ridge is composed of very fissile slates and sand-stons" in the main.[55)b]

The volcanic activities were also powerful in the northern part of the island and in the dependent islets. It is important to note that the Daiton Volcanic Group north of Taihoku seems to have started as a submarine eruption, because the volcanoes as a whole are fringed all around with remnants of several succeeding series of marine terraces.[7)]

In the northernmost region of the island where volcanic energies manifested themselves in vigorous activities, two areas are distinguished. The Daiton volcanic mountains form the main area where there are various kinds of andesite lavas together with some pyroclastic rocks. There we see lavas of pyroxene andesite, two-pyroxene andesite, hornblende-two-pyroxene andesite, two-pyroxene-hornblende andesite and hornblende-andesite, with which andesite conglomerates and tuffites occur in association. These rocks are distributed in Kannonzan, Sho-Kannonzan, Daitonzan, Shichiseizan, Shabozan, Kiirunzan, and several others. The other area includes the mining fields from around Zuiho and eastward. Here biotite-hornblende-dacite is found, and chiefly in the forms of necks and sills, as are observed in Kiirunzan, Butanzan, the main mines of Kinkaseki, Sozan and Keimorei.[24),1)]

This was really a very active period of volcanic energy in the geohistory of Taiwan. But it does not mean that there had not been any other phases of the manifestation of magmatic energy before, and possibly also after this period. During the latter part of the Miocene period, that is, in association with the upper Kaizan beds, there were basaltic activities as are represented by the dykes and sills of olivine-basalt, olivine-dolerite, and thoreiite (teschenite) found in the area extending over the south-western part of Taihoku Prefecture (Sankyo district) and the north-eastern part of Shinchiku Prefecture (Kappanzan, Mabutoku, etc.).

The basaltic activities seem to have started somewhat earlier, and we see lavas, tuffites, and agglomerates of olivine-basalt, dolerite and teschenite that are in association with the lower Kaizan beds; they are observed at such places as Kiirung, Nanko-Daiko, Kokan, Shinten, Sanshikyaku, Seisuiko and Dairyo-Kinkaseki, all quite closely near Taihoku.

So far are the volcanic activities and volcanic rocks of the main island of Taiwan. Concerning those of the dependent islets hitherto on record may be summarized as follows:

North of Taiwan:

Agincourt Island—basaltic flow and andesitic or basaltic agglomerate
Crag Island—basaltic andesite flow
Pinnacle Island—basaltic andesite flow
Kiirun-to—dacite dyke

East of Taiwan:

Kizanto—andesite flow and andesitic agglomerate
Kashoto—the same
Botel Tobago Island—andesite and andesitic agglomerate, and exposures of serpentine at places
Little Botel Tobago—andesite and andesitic agglomerate

West of Taiwan:

Pescadores Islands—basalt flows (with quartz porphyry dykes in Huahsii)
Lambay Island—raised coral limestone

South of Taiwan:

Vele Rete Rock—unknown

Keeping pace with the uprising of the axial region of the island, a denudation of a great scale took place to result in an extensive erosion surface on which the Tableland Gravel was laid down. There are pebbles of andesitic lavas in gravel developed around the Daiton volcanoes. The great altitude reached by the island was high enough to provide natural conditions competent enough to cause the glaciation high up on the ridges and peaks. I had maintained this idea for some years, on account of various geological and geographical observations, until at last the geographers KANO[56] and TANAKA[57] discovered topographical and other favourable evidences a few years later. The uprising of the island was also the cause of the deposition of the Tableland Gravel formation which will be explained below.

J. The Tableland Gravel and the Older Reef Limestone

Over the surfaces of the series of tablelands lined up almost north-south, with that of Jurinko, immediately west of Taihoku as the northernmost member, followed by those of Shinchiku Prefecture (Toen, Chureki, Heichin), and Taichu Prefecture (Daito, Hakkei), a particular, somewhat unusual sedimentary formation is developed everywhere. It appears like a kind of terrace deposit. It is characterized by two unequal heaped-up layers; an ochre coloured sandy-clayey bed above, and a rather loosely consolidated conglomeratic or gravel bed, the two being clearly distinguished in appearance from each other. Besides, these tableland formations are slightly tilted but all with plain surfaces. The boulders and pebbles are mainly of hard sandstone, but in the northern region those of andesites are not uncommon; the boulders are often as large as a human head. The ochre soil above owes its colour to the cementing material which is strongly tinted with iron hydroxide, and is in appearance resembles what is called the "laterite."

Similar formations are found to develop also in the southern and southeastern districts, in which cases they are more isolated in distribution. Thus, it is conjectured that this formation might have been originally much more widely developed in this region, of which parts, however, have locally survived the degrading geological agencies that followed.

As this formation—the ochre solid and underlying gravel bed inclusive—was named the Tableland Gravel because it covers different older formations with clear unconformities everywhere. This surface of unconformity is presumedly the most extensive one in the Cenozoic sequence of Taiwan. Because of the very noticeable, loose gravel bed with its unusual occurrence was the name of the formation—the Tableland Gravel—proposed.

Concerning with formation YABE and HANZAWA[58] once propounded a theory that it is the Alluvial deposits accumulated at the foot of steep slopes of the high mountain ranges. However, after more recent, careful and detailed observations at numerous exposures, we discovered a very conspicuous fact to refute this; that the upper soil of the ochre colour and the lower gravel are everywhere very clearly distinguished in bedding, is an important phenomenon. Such an occurrence is a phenomenon expected only from an inundation of a grand scale. This latter idea seems to be supported by Y. TOMITA[59] who assumes his "lateritic slope" originally occupied a very extensive area, and the tilted blocks observed are the remnants of those "lateritic slopes."

What is called here the Older Reef Limestone is a formation including the "Ryukyu Limestone" so designated by some geologists in Japan and in Taiwan for some time. This so-called Ryukyu Limestone was designed to include an important formation which needs be distinguished from the definition often carelessly alluded to. Here is an example. On the top of the hill west of the old historical town of Koshun, there is a thick bed of *Globigerina* Sand.[60] This was included in the Ryukyu Limestone of YABE, HANZAWA and some others. It is very clear that this *Globigerina* Sand and the type of the Ryukyu limestone—say, that of Takao area, are different from each other either lithically or paleontologically; the mode of genesis cannot be the same. At Byobito, a promontory, south of Koshun, the coral limestone bed is divided into two, or possibly three, by intercalating beds of sandy shale with molluscs and brachiopods (especially known as of northern habitat in Japan) had to be investigated before the correlation was to be assigned.[61] Besides, there are many places along the seashore in the southern part of Takao fringed with living coral reefs, where number of low terraces, about twenty or thirty meters high, with abundant blocks and debris of reef corals are accumulated. In these blocks the structures are clearly preserved, but the stocks are more or less broken, and their postures are quite at random, as well as weathered to white, and the surface is more or less worn out: they do not form a rock either.

To make clear these different types of reef limestones and foraminifer limestone, the name "Old Reef Limestone" was proposed more recently. The "Ryukyu Limestone" may still remain intact especially in Okinawa, but in point of the geological antiquity, geologists should be somewhat careful not to mix up the different materials.

It is in order to avoid confusion that we proposed to take up the Older Reef Limestone:[62] by appending "Old," and the other, younger coral reef beds should be distinguished from the "Ryukyu" Limestone. The latter is assumed to correspond in the stage to the Tableland Gravel, because it overlies, in west Taiwan, the tilted blocks of the Tokazan Group.

Concerning the stratigraphical relations between the Tableland Gravel and the Old Reef Limestone, there had been some people who were inclined to regard that the former was deposited over the latter. In reality there are a few places where beds of gravel are found lying over the Old Reef Limestone, but these gravel beds cannot be identified with the latter. The form of the pebbles of the gravel are of different types, first of all: the thinner, loose and less massive. Consequently, it should be assumed, at least for the time being, the Tableland Gravel and the Older Reef Limestone might have been deposited almost simultaneously at certain different sedimentary environments.

All these younger formations are considered to have been deposited during the late Pleistocene period. Following this a period of crustal unrest is considered to have ensued, arousing dislocations, tiltings, necessarily accompanying the processes of erosion which is unavoidable. Thus, the period of the last phase of Pleistocene should have been closed.

K. Folding, Tilting, and Erosion: Earthquakes

After the deposition of the Tableland Gravel and the Older Reef Limestone, there ensued a period of crustal unrest in which faulting and tilting predominated, as has been summarized before. These tilted blocks are, without exception, inclined eastward. Further, many of the dislocations cut through these formations not only lengthwise, but crosswise as well. The crustal equilibrium does not seem to have been restored until now, and there are young fluviatile terraces traversed by faults. The destructive earthquakes that occur frequently in western Taiwan are considered due chiefly to the same cause, as was pointed out sometime ago by Hayasaka.

In regard to the topographical and structural features, the Tableland Gravel seems to find its equivalents in such remote regions as the Philippines, southern China, including Hainan island as far as was witnessed by us.[63] It appears quite likely that the Tableland Gravel may be a formation deposited on a vast area in the southeastern Asia including those mentioned and possibly elsewhere also. Such a land was separated into remote and unequal regions by the crustal revolutions which took place subsequently. The continent and the continental island like Hainan have been comparatively stable since, while the marginal islands of Taiwan and the Philippines have been further shattered and splitted into blocks, many of which were tilted. The patterns of the severe earthquakes, as far as I have experienced personally during the years of my life in Taiwan, should have some close relations with the crustal behavior or behaviors of the island.[64]

L. The Older Terraces, Fans, and Newer Raised Reef Limestones

The Tableland Gravel, as stated above, is very noticeable in Taiwan on account of the ochre-colored soil. Sometimes the secondarily deposited exposures are often deceptive, however. The Tableland Gravel often looks from afar as terraces and fans. The distinction between them and the genuine Tableland Gravel is rather easy, however. In the secondary, ochre-colored gravel bed, for instance, the cementing material consists of grains of variable kinds of sand and clay that are tinted; the sandstone gets perceptively paler toward the upper part; the tablelands do not present tilting, and the topography is different from the characteristic features popular in this region.

The terraces and the fans formed of the "secondary lateritic" deposits are commonly observed in the west-middle region of Taiwan quite often, especially in the basin regions of Hori and the Sun-Moon Lake basins.

In the southern coastal regions in the extreme south of Takao Prefecture, there are a few coastal terraces carrying the fragments of the reef-building corals, on the surface, as mentioned elsewhere. The best places to observe them are the regions in the neighborhood of Garanbi, the southernmost promontory, and Kaiko several km north. Along the shore of this region these younger raised Reefs or the coastal terraces are about 10–20 m above the living reefs, as observed above.

M. THE RIVER AND THE SHORE TERRACES, LUCUSTRINE DEPOSITS, AND RAISED REEFS

These are the records of the most recent formations. The raised coral reefs of this category are well formed along the shores of the southwestern and southern regions. Besides, even in the northeastern part of Taiwan they are often found as dissected fragments or remnants.

Lacustrine deposits indicate former water basins formed on the Older Terraces like those in the neighborhood of the Hori basin, as explained in I. In the northern Prefecture, Shinchiku and in the southern Taiwan, Older Fans often bear similar deposits. At Tamio, a village north of the city of Kagi, Tainan Prefecture, the surface of the Tableland Gravel was observed to be covered by a few meters of hard, white Clay Pan[65] of the freshwater origin. A similar case was reported to occur at a certain place in Shinchiku Prefecture, but I have not had a chance to visit there.

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12) KANO, T. and YOSHIMURA, S. (1934), On the High Mountain Ponds in the Vicinity of Mount Tsugitaka, Formosa. *Limnological Journal*, Tokyo, IV.

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32) ICHIMURA, T. See Note 24, Ichimura (1942).

33) & 34) See Note 8.

35) YEN, T. P. (1953), On the Occurrence of the Late Paleozoic Fossils in the Metamorphic Complex of Taiwan. *Bull. Geol. Surv. Taiwan*, 4.

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41) DEGUCHI, Y. See Note 1h, Fukutome et al. (1911).

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45) YABE and HANZAWA (1930), See Note 27, YABE and NANZAWA (1930).

46) OINOUE et al. (1928), See Note 21.

47) Here and previously, reference to the occurrences and localities of fossils from various parts of Taiwan, especially of the Neogene have been made. The Paleogene forms have been connected with some frequency, but Neogene forms are far more abundant and are often found in profusion in some places. Except for the marine molluscs and foraminifers, the yield of most of them has not been enough to encourage monographic description: echinoderms may probably be counted one such group.

S. NOMURA's Catalogues (1935 and 1938) are voluminous and well-illustrated descriptions of Tertiary and Quaternary molluscs of Taiwan. YABE and HANZAWA wrote several papers about the foraminifers. A number of people can be counted among the foraminifer students of whom the name of the Late Dr. ISHIZAKI is noteworthy. He was a very energetic student, and wrote several important papers. His most memorable "List of Japanese Neogene, Pleistocene and Recent Foraminifera, excluding Orbitoidedae, recorded up to 1939" is one of his best known works.

Works on the foraminifera were expanded by CHANG, Li-Sho of the Geological Survey and young HUANG, Tun-Yu of the Chinese Petroleum Company at Miaoli; both greatly contributed to the stratigraphy, especially of oil field geology. Prof. LIN, C. C. of the Taiwan University is actively leading the study of fossil mollusca.

This present account is concerned with the paleontology, and also with geology of Taiwan.

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59) TOMITA, Y. (1941), An Outline of the Physiographical Development of Taiwan. *Geography*, IX. This is a brief outline of this author's great work presented to the Taihoku Imp. University to fulfill the requirement for the degree of Sc. Dr. He prepared a new and more detailed edition of the outline for this book. To this author we are greatly indebted for his work on the Physiography and Geomorphology of Taiwan. See also Note 14, TOMITA (1937A,B; 1938A,B; 1954).

60) ISHIZAKI, K. (1964), See Additional Papers 7. Also Note 29.

61) HAYASAKA, I. (1940), See Additional Papers F7.

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65) HAYASAKA, I. (1938), The Geological Meaning of the Clay Pan in Tainan Prefecture. *Taiwan Tigakukizi, IX,*

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2. ISHIZAKI, K. (1939), On the Foraminifera of the so-called Upper Marine Fossil Beds in the Vicinity of Kwansai, Sintiku Prefecture, Taiwan. *Taiwan Tigaku Kizi*, X.
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4. ——, (1940), On *Streblus schroeterianus* (PARKER and JONES) and Allied Species. *Taiwan Tigaku Kizi*, XI.
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On the Geotectonic Development of Taiwan (Formosa)

Teiichi Kobayashi

In a series of the Ryukyu and northern festoon arcs in the northwestern side of the Pacific basin, virgation is undeveloped, while it is typically represented in another series comprising the Philippines and southern islands. Thus the two series indicate a remarkable contrast in the geologic structure of eastern Asia. As noted in my "Sakawa Cycle" (Kobayashi, 1941), Taiwan (Formosa), 25,570 sq. km., attracts special attention as their link. As I had the good fortune to be able to see the general picture of Taiwan's geology on the return trip from the VIII Pacific Science Congress held in the Philippines in 1953, I took a pleasure of discussing the tectonic development of the island.

I wish to express my most cordial thanks to Prof. Ting Ying H. Ma of the National University of Taiwan, Messrs. L. S. Chang (formerly Reikyoku Choh), T. P. Yen (Soha Gan) and T. L. Hsu of the geological survey of Taiwan for their guidance during my excursions, and to the survey and other Chinese government offices, as well as mining and other companies for the facilities provided during my visit.

Although some geological observations have been reported since the middle of last century, in the beginning they were fragmentary and Taiwan long remained as a terra incognita. Taiwan's geology was, however, immensely clarified in the half century from 1895 to 1945. During this period the geological sheet-maps of the northern part (scale 1:50,000 and in part 1:1,000,000) and the geological survey of the Neogene oil fields were completed. In addition, many valuable contributions were made, both in the basic and applied aspects. Knowledge of Taiwan was further advanced in the last quarter of a century by the works of many Chinese geologists besides several foreign geologists (B. Elishwitz, W. Hashimoto, A. Heim, T. Kimura, K. Konishi, T. Oinomikado, A. Schreiber, L. Stach), notably in the fields of metamorphic and volcanic rocks (Yen), Tertiary biostratigraphy (Chang, Huang), Quarternary geology (Ma, Lin), submarine geology (Emery), geotectonics (Big, Ho) and petroleum prospecting (Meng). Among recent discoveries more important for stratigraphy are Permian and Cretaceous fossils in the metamorphosed complex (Yen), Mesozoic fossils in bore cores from drillings in the western coastal plain (Lin, Matsumoto et al.) and an Oligocene fauna in the central range (Chang).

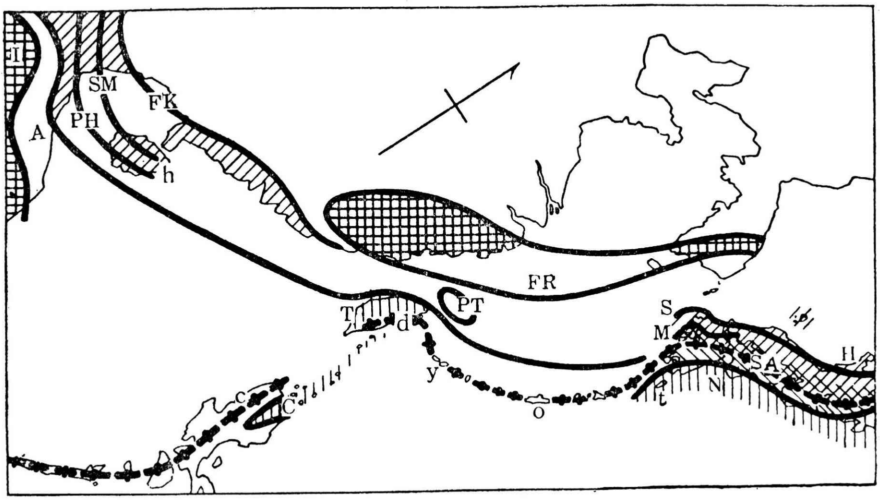


Fig. 1. Tectonic Position of Taiwan in Eastern Asia.

FR. Fukien-Reinan (Yongnam) massif
FK. Fansipan-Kuantung metamorphosed axis
SM. Song Ma arc with R. Noire nappe
PH. P'ou Huat arc
A. Annam zone
I. Indoshinian massif
PT. Pre-Taiwan dome
H. Hida gneiss zone of Akiyoshi folded mountains
S. Sangun principal metamorphic zone of Akiyoshi folded mountains
M. Motoyama auxilliary metamorphic zone of Akiyoshi folded mountains
SA. Axis of Sakawa folded mountains
T. Taiwan folded zone
C. Cagayan synclinorium
N. Nakamura folded mountains
t. Tanegashima
o. Okinawa-jima
y. Yaeyama insular group
d. Dainano metamorphic zone
c. Cordillera Central
h. Hainan island

Little, however, had been mentioned of the tectonic development of the island and its relation to the neighbouring areas before my synthetic paper (KOBAYASHI, 1956). The geological sketch is drawn here in further detail on the basis of new facts gathered since then. This synthesis is of course based on the mass of data accumulated during this time. The interpretation and coordination of these facts in the history of the development and the tectonic lineament of Taiwan in the geology of eastern Asia is based on my own judgement. In my opinion the metamorphosed Permian and older rocks belong to the axial zone of the Cretaceous Sakawa folded mountains. The Taiwan subgeosyncline was brought forth on the continental side of this axis. The Triassic Akiyoshi folded mountains further beyond were its foreland (see Fig. 1).

Neither angular discordance nor orogenic sediment is found in the Tertiary sequence except for the Koshun conglomerate (s. l.) in South Taiwan and the Pinanshan conglomerate in East Taiwan. Thus I was not convinced of the Oligocene or middle Tertiary orogeny or related metamorphism as emphasized by

Hayasaka et al. (1947), Yuan (1953) and some other geologists. It is my opinion that the middle Tertiary event or the so-called Puli movement described by Chang (1960) was not complicate foldings and thrustings but the westerly shifting of the sinking axis, caused by the upheaval of the embryonic geanticline of the Urai-Tananao zone and some related undulations. The shifting commenced with the so-called Puli movement described by Chang (1960). Biq (1956) distinguished the Neogene sequence of the West Taiwan zone into lower and middle Miocene suite and upper Miocene and Pliocene suite by subsequent shifting. Because there is no sharp boundary between the metamorphosed Palaeogene and nonmetamorphosed Neogene, metamorphism commenced probably in the middle Tertiary and is thought to have continued by the Plio-Pleistocene Penglai paroxysmal phase of the Taiwan orogeny.

The gentle foldings or warpings were repeated in the geosyncline. The mountain structure constructed at length by the orogeny consists of the Tananao (Dainano), Urai and West Taiwan zones in addition to the Hualienhsi (Kwarenkei) rift valley and Tatung (Daito) coastal range. The former three zones which are separated from one another by tectonic lines, indicate the western wing of the Taiwan anticlinorium. On the two sides of the Tatung coastal range there are still greater rupture lines with which its eastern wing was destroyed (see Fig. 2).

Like the south bend of the Japanese arc in Kyushu, the Ryukyu arc is abruptly bent toward North Taiwan. At this back bending the Taiwan geosyncline was strongly compressed resulting in thrustings that were repeated against the foreland and a typical imbrication was produced. There the Kiirun (Chilung) imbricated subzone and the Toen (Taoyuan) undulated subzone can clearly be distinguished in the west Taiwan zone. Subsequently, Taiwan was detached from the Ryukyu islands and performed geanticlinal upheaval by itself, causing dislocations among the tectonic zones. Because the geanticline was asymmetrical, the backbone range runs close to the eastern coast, Yüshan, 3,950 m high in the Urai zone being the highest.

The Penghutao isles to the west of Taiwan are ruins of a Pleistocene basaltic mesa in the Akiyoshi terrain. The eastern chain of dependent isles lies on the same submarine ridge on which Batan, Babuyan and other isles of the Philippines are located and which is a northern projectile from the Tertiary synclinorium of the Cagayan valley in Luzon. It is separated from the Tatung coastal range by a deep submarine trench.

Recently, I demonstrated that the Triassic Akiyoshi folded mountains on the inner side of Japan extend into Tonkin, North Viet-Nam through Hainan island (Kobayashi, 1951). Prior to this I concluded that the Cretaceous Sakawa folded mountains in the median part of Japan are traceable to the axial zone of the Ryukyu islands (Kobayashi, 1941). Permian fusulinids were first reported by Hanzawa (1935) from a limestone in the Motobu peninsula of Okinawa-jima. In the main part of the island the Palaeozoic formation is represented mainly by shale and sandstone, and is partly metamorphosed into chlorite schist and graphite

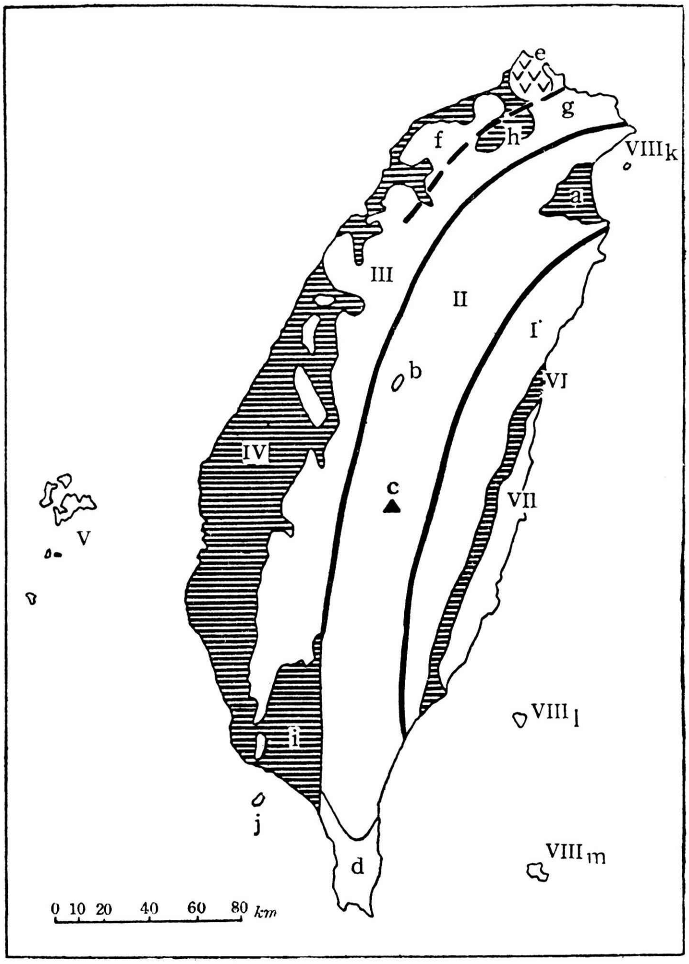


Fig. 2. Teconotic Division of Taiwan.

I. Dainano (Tananao) zone
II. Urai (Wulai) zone
  a. Ilan (Giran) plain
  b. Puli (Hori) basin
  c. Yüshan (Mt. Niitaka)
  d. Southernmost Neogene
III. West Taiwan zone
  e. Taitun (Daiton) volcanic group
  f. Taoyuan (Toen) undulated subzone
  g. Chilung (Kiirun) imbricated subzone
  h. Taipei (Taihoku) basin
  i. Pingtung (Heito) plain
  j. Liukiuyu (Ryukyusho)
IV. Western coastal plain
V. Penghutao (Boko island)
VI. Hualienkang (Kwarenkei) rift valley
VII. Taitung (Daito) coastal range
VIII. Eastern dependent islands
  k. Kueishantao (Kizanto)
  l. Lutao (Kwashoto)
  m. Lanhsu (Kotosho)

schist. In addition, however, there are limestone lenses, Radiolarian chert layers and conglomerate beds containing exotic granitic rocks like the Permian Usuginu conglomerate in North Honshu, Japan. The Palaeozoic formation is intruded by diabase or granite in Tokunoshima and Ishigaki-jima. Recently, ISHIBASHI (1969) discovered Carnic ammonites and *Halobiae* of the *styriaca* (KOBAYASHI and ISHIBASHI, 1970) and other groups in the Triassic Nakijin formation of the peninsula which is composed of pelagic sediments rich in limestone and basaltic lava. KONISHI (1963) on the other hand found calcareous algae, corals and stromatoporoids in the polymictic conglomerate of Attsu in the Kayo formation. These fossils are allied to the Torinosu biota of the Shimanto terrain in West Japan whose age ranges from late Jurassic to early Cretaceous. In the Ishigaki and Kohama isles in the Yaeyama group there are phyllites and crystalline schists which indicate the axial core of the Sakawa folded mountains.

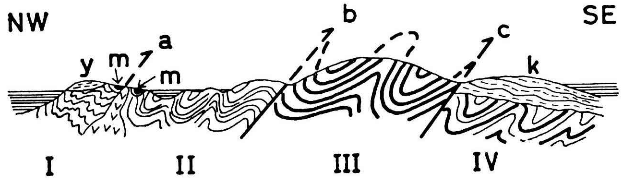


Fig. 3. Systematic Cross Section of the Ryukyu Islands (After KONISHI, 1963, simplified).

a. Omoto tectonic line
b. Hedo thrust
c. Tengan fault
I. Ishigaki belt (Palaeozoic Tumuru metamorphosed formation)
II. Motobu belt (Palaeozoic Fusaki, Yonami and Motobu formations, metamorphosed in part)
III. Kunigami belt (Mesozoic Nago and Kayo formations)
IV. Shimajiri belt (Palaeogene Kunigami formation)
m. Eocene Miyara formation
y. Miocene Nasoko and Yaeyama formations
k. Neogene Shimajiri and Kukinaga formations

Ryukyu islands	West Japan
Ishigaki belt	Sambagawa (or Nagatoro) terrain
Omoto tectonic line	Mikabu line
Motobu belt	Chichibu terrain
Hedo thrust	Butsuzo line
Kunigami belt	Shimanto terrain
Tengan fault	Nobeoka-Shiozan line
Shimajiri-Kumage belt	Nakamura (or south Shimanto) terrain

In Tanegashima in the north there is the strongly folded Palaeogene Kumage shale and sandstone formation, on which lies the Neogene Kukinaga sandstone and conglomerate formation containing *Vicarya callosa*. Therefore the Kumage, combined with the folded pre-Miocene Nakamura group in South Kyushu, Shikoku and the areas further to the east represents the middle Tertiary Nakamura folded mountains. KONISHI (1965) classified the pre-Miocene complex of the Ryukyu arc into four belts with three tectonic lines and showed their parallelism with the structure of West Japan from the continental to the other side as shown in the preceding tabel.

Combined with the discovery of Permian fossils it became evident that the metamorphosed Tananao formation indicates the extension of the Ryukyu axis, i.e., the Sakawa axis. There are three distinct belts in the Tananao metamorphosed zone, namely, (1) a belt of sericite-chlorite schist and chlorite schist, (2) a thick crystalline limestone belt and (3) a belt of chlorite schist and graphite schist enumerated from the east. In the third belt there are, in addition, quartz schist, quartzite and limestone lenses in the last of which YEN discovered Permian schwagerinids and *Waagenophyllum* which were determined, respectively, by THOMPSON and MA. These metamorphic rocks are intruded by diabase and gabbro in some places and partly altered into gneiss by injection of granitic magma. Like the metamorphic group in the Sakawa axis of Japan, Kieslager of Besshi type is imbedded in the Tananao group.

The schists and granitic rocks are discordantly overlain by the basal conglomerate of the Pihou formation. Its Upper Cretaceous age is determined by MA's study on hexacorals which were discovered by YEN in a thin limestone lens. This formation is overlain unconformably by the Suo (Suao) formation with a conglomerate at its base, which is composed mostly of black phyllitic clayslate and quartzose sandstone, and the calcareous layers above it yield Eocene foraminifera. YEN proposed the Nanao and Taiping movement, respectively, for the deformation before and after the Pihou sedimentation.

While the Neogene is extensive in the west Taiwan zone, the Urai zone is mostly occupied by Palaeogene formations. Clayslate and shale are leading components of the latter which can be divided into three parts with Yonryo sandstone in the middle. Eocene fossils have long been known to occur at some places. According to CHANG (1954) the Yuhangian foraminifers from the upper or Suichoryu division are Oligocene.

In North Taiwan four coal measures are intercalated in the formations from upper Oligocene to Miocene. They are inserted within neritic sediments, suggesting four minor cycles of sedimentation due to pulses of embryonic folding. There were some volcanic eruptions within the Tertiary geosyncline which were fairly strong in North Taiwan in the Miocene, as indicated by basalt flows, tuffs and agglomerates of Kokan (Kungkuan) on the lower coal measures (see Fig. 4).

The occurrence of the lowest coal measures of Aoti are restricted to the most northeastern part, while the lower coal measures are more extensive in North Taiwan. The middle coal measures are traceable as far south as Sinchu and Chunan and only the upper ones are distributed farther south to Alishan. Reciprocally to such a southern advance of coal measures, limestone lenses show a tendency to retreat. More precisely, Miocene *Lepidocyclina-Miogypsina* limestone occurs in

The Stratigraphic Sequence of Taiwan

Alluvium Holocene	Raised beach sand, raised coral reef	
	Lower terrace deposits, Peipin formation	
Diluvium Pleistocene	Lower coral reef limestone, Taoyuan (Toen) formation	
	Middle coral reef limestone, Higher river terrace deposits, Tainan formation	
	Lateritic gravel beds	
	Higher coral reef limestone, Tananwan formation	
	Kaenzan (Huoyenshan) conglomerate facies	Tokasan (Toukeshan) formation
	Kozan (Hsiangshan) sandstone facies	
Pliocene	Takuran (Chuolan) formation, 200 m	Miaoli (Byoritsu) group
	Kinsui (Chinshuei) shale, 450 m	
Upper Miocene	Tawo (Taika) siltstone, 750 m	Sankyo (Sanhsia) group
	Shihliufeng (Jurokufun) shale, 100 m	
	Kantosan (Taiho) sandstone, 450 m	
	Wuti (Nansho) upper coal measure, 1000 m	
Burdigarian	Nanko (Nankang) formation, 600 m	
	Sogo (Tsouhe) formation, 300 m	
Aquitanian	Shihti (Shikyakutei) middle coal measures, 450 m	
	Tairyo (Taliao) formation, 400 m	
	Kokan (Kungkuan) tuff, 150 m	
	Mokusan (Mushan) lower coal measures, 500 m	
	Wuchihshan (Seitan) formation, 1000 m	
Oligocene	Coal measures of Aoti, 600 m	
	Suichoryu (Shueichangliu) formation, 2000 m	
Eocene	Yonryo (Szuleng) sandstone, 500 m	
	Nishimura (Hsitsun) formation, 1000 m	
Cretaceous-Palaeozoic	Pihou formation	Buried Cretaceous of Peikang
	Dainano (Tananao) metamorphosed complex	

Average thickness is shown in meter.
Straight line: conformity.
Wavy line: unconformity.
Broken line: stratigraphic relation indeterminable.

North Taiwan (Taipei and Sinchu) and Pliocene *Gypsina* limestone in Central and South Taiwan (Tainan and Kaohsiung).

Alternations between shale and sandstone are conspicuously well developed in the Neogene formation. Because staurolite, garnet, purple zircon, monazite and several other heavy minerals in the sediments are exotic for Taiwan, the Fukien massif was suggested by ICHIMURA (1940) for their provenance. It may be, however, better elucidated if a pre-Taiwan dome is assumed in the foreland or in the Akiyoshi axial zone which must have been exposed before the sediments of the Yangtze and other rivers levelled the basement relief of the China Sea. This is because high grade minerals like staurolite are known to exist in the Hida gneiss group in Japan which belongs to the Akiyoshi metamorphic rocks. Furthermore, in this kind of folded mountains it is a tendency for the foreland to become warped by embryonic folding, as, for example, in the Ozark dome in front of the Ouachita mountains, and the Nashville, Cincinnati and Adirondack domes in front of the three arcs of the Appalachian mountains. The supposed dome must have been located to the northern part of Taiwan because a similar mineral assemblage is found also in the Miocene coal measures in the Yaeyama group.

Glauconitic sandstone is distributed in various Tertiary horizons and becomes more common upward, but is totally absent in the Suichoryu and older formations. It is an authigenic product agitated by a shallow sea. Together with foraminiferous or coralline limestones and false-bedded sandstone it suggests a shallow sea for the Neogene geosyncline. The Kinsui (Chinshuei) shale extensive in the lower part of the Pliocene merges with the Takuran (Chuolan) alternation in which sandstone exceeds shale. It becomes thicker in the south near Tainan where the thickness of the alternation measures 2,500 m. The retreat of the sea toward the south is shown by the distribution of *Ostrea* banks.

Thus there is no orogenic sediment in the above-mentioned Tertiary sequence, although some conglomeratic sandstone containing small pebbles are found in the Neogene formation. As is discussed later, the Koshun conglomerate (s. l.) in the southernmost part of the Urai zone is an exception. No clear-cut clinounconformity has as yet been found in the Tertiary sequence of Taiwan.

The Plio-Pleistocene Tokasan (Toukeshan) formation which is dated by a mammalian fauna, is a typical synorogenic sediment. It is generally conformable with the Pliocene, though local or minor erosion-unconformity is seen in rare instances. It consists of Kozan (Hsiangshan) sandstone facies and Kaenzan (Huoyenshan) conglomerate (Shokkozan conglomerate) facies where the former is mostly higher and the latter lower, but the two easily merge laterally or interfinger with each other.

The Kozan facies is chiefly composed of fine muddy silt or sand beside intercalations of clay and gravels; it often contains limonite and false-bedding is common. A copious neritic fauna comprising echinoids and molluscan shells is known in North Taiwan.

Though sandstone wedges and lenses are common in the other facies, con-

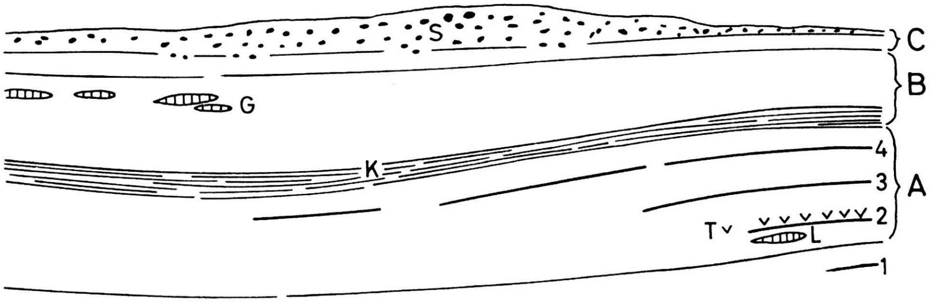


Fig. 4. Diagramatic meridional section showing the lateral change of facies and thickness of the geosynclinal sediments in the west Taiwan zone from the north (right) to the south (left).

C. Plio-Pleistocene
B. Pliocene
A. Miocene
S. Kaenzan conglomeratic facies
K. Kinsui shale
T. Kokan tuff
G. *Gypsina* limestone
L. *Lepidocyclina* limestone
4. Upper coal measures
3. Middle coal measures
2. Lower coal measures
1. Lowest coal measures

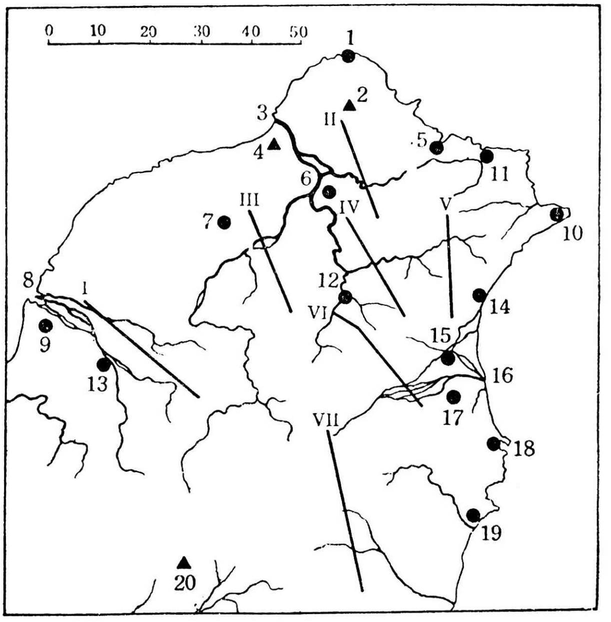
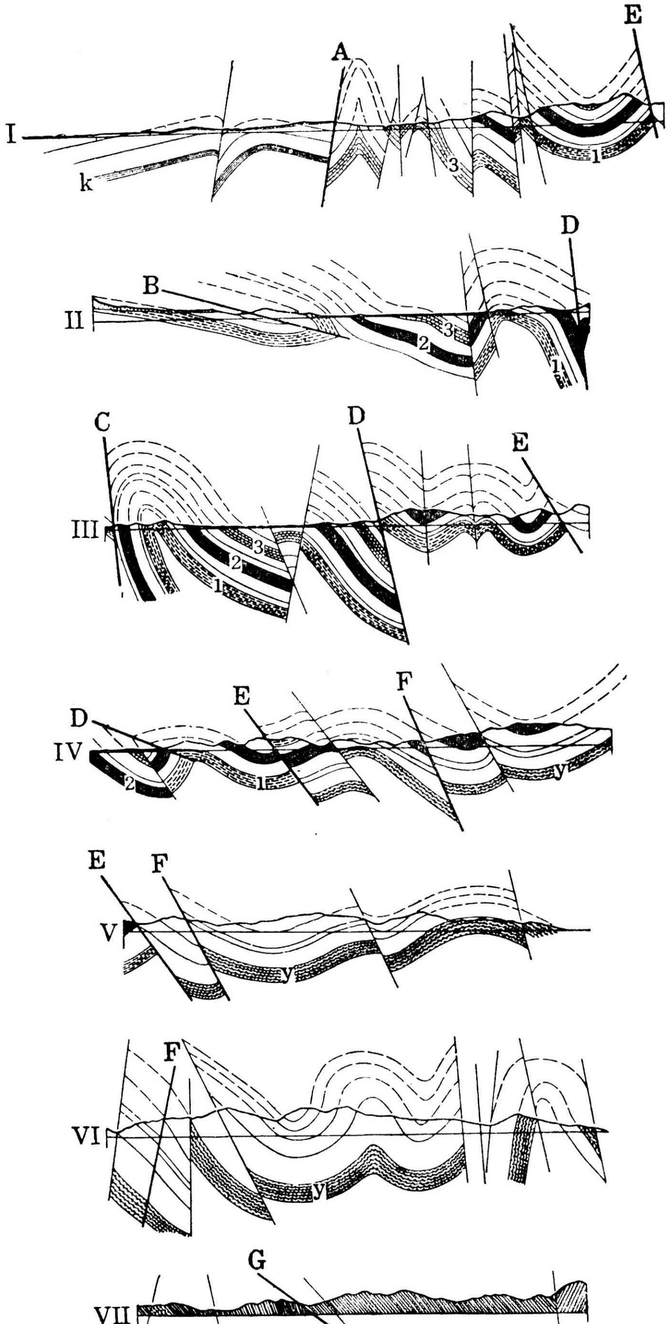


Fig. 5. Index map of the profiles through North Taiwan.

1. Fukueicho (Fukikaku)
2. Tatunshan (Daitonsan)
3. Tanshueiho (Tansuigawa)
4. Kuanyinshan (Kannonsan)
5. Chilung (Kiirun)
6. Taipei (Taihoku)
7. Taoyuan (Toen)
8. Fengshanchi (Hozankei)
9. Hsinchu (Shinchiku)
10. Santiaochio (Sanshokaku)
11. Juifang (Zuiho)
12. Wulai (Urai)
13. Chutung (Chikuto)
14. Touwei (Toi)
15. Ilan (Giran)
16. Choshueichi (Dakusuikei)
17. Lutang (Lato)
18. Suao (Suo)
19. Tananao (Dainano)
20. Tzukaoshan (Mt. Tsugitaka)



I–V. From the sheet maps of Chikuto, Taihoku, Toen, Shinten and Toi by Y. Ichikawa (1930–34).
VI. From Giran sheet map by M. Usami 1936
VII. From Dainano sheet map by M. Ogasawara, 1933; scale different from the precedings
A. Chikuto (Chutung) fault
B. Kankyaku (Chienchiao) fault
C. Shinoso (Hsinchuang) fault
D. Shinten (Hsintien) fault
E. Kushaku (Chuche) fault
F. Kinkwaryo (Chinhualiao) fault
G. Sanseizan (Sanhsingshan) fault
k. Kinsui shale
3. Upper coal measures
2. Middle coal measures
1. Lower coal measures
y. Yonryo sandstone
u in VII. Urai zone
d in VII. Dainano zone

Fig. 6. Profiles through North Taiwan.

glomerate is its principal member. Hence the name, Kaenzan conglomerate. Occasionally drift wood, and *Unio, Corbicula* and other shells are contained therein. Large boulders attain a maximum diameter of over 1 meter, but most of the gravel range in size from a man's fist to a man's head and are well rounded. Its thickness exceeds 1,000 m near Taichun in Central Taiwan, but is only 20 m minimum in North Taiwan.

It is reasonable to consider that the Kaenzan conglomerate is the sediments of deltas and alluvial fans on the west side of the backbone range at the time of its upheaval, because it is thick in Central Taiwan where the range was highest and because its material was mostly derived from the Urai zone. Because the Tokazan formation is folded to some extent, it is certain that the crustal disturbance was violent until the end of the Kaenzan age. Lin (1963) distinguished 7 ages in the Quaternary period of Taiwan and 7 phases in his Tungning orogenic cycle of the period, but, I think, these phases of movements would be metaorogenic episodes complicated by eustatic changes except for the Penglai phase which was paroxysmal for the Taiwan orogeny.

As shown in a series of profiles through North Taiwan, the geologic structure from the Tananao zone to the west Taiwan zone is a grand anticlinorium with the Sakawa metamorphic rocks at its core. The metamorphism becomes lessened distally (see Figs. 5 and 6).

Much cannot as yet be mentioned of the structure of the Tananao zone, but it is known that an overturned anticline near the western margin thrusts itself upon the Urai zone along the Sanseizan (Sanhsingshan) tectonic line. In the Urai zone, about 30 km in breadth, foldings and thrustings are repeated, the folded axes or thrust planes being inclined to the southeast in different degrees. The most important key bed is the Yonryo sandstone which shows the general tendency for the folds to be more compressed on the eastern side where the folded axis or thrust plane is subvertical. On the west side on the contrary the folding is more gentle, but the thrusts are more low angled.

The Kushaku (Chuche) thrust draws the boundary between the Urai and west Taiwan zones, but the degree of its displacement is not much different from the others in the Urai zone. In the Kiirun (Chilung) subzone, however, the Miocene is extensive and strongly compressed in form of imbrication; in the Toen (Tungyuan) subzone on the other hand the Pliocene extensive and gently folded. Their boundary is sharply demarcated by a low angle thrust on the north side of the Taipei basin and a few Klippen are found in its northeastern extension. The gentle undulation of the Toen subzone suggests its being the frontal part of the foreland.

Near Chutung, however, the boundary fault is normal and its downthrow on the northwest side. Because the embryonic folding in the Kiirun subzone was composed of brachyanticlines and brachysynclines arranged somewhat alternately in checker pattern, their end products are arcuate thrusts in a similar pattern. Their planes are inclined in different degrees between the median and lateral parts of each arc; the breadth of the thrusting sheets is changeable. The imbrication is cut by strike faults as well as diagonal or rectangular ones. The latter is mostly reverse but the former normal. These fault systems suggest that the folding and thrusting of the geosynclinal sediments gradually developed into a compressive block movement of the already imbricated terrain in which the basement blocks probably played a role. Later, however, a tension movement took place and the triangular Taipei basin was produced.

The two subzones are distinctly separated by a boundary thrust in North Taiwan where the West Taiwan zone is sharply bent, but in Central and South Taiwan the two subzones are inseparable because the imbricated subzone merges with the zone of open folds with subvertical axes. MENG (1965) is of opinion that the primary geologic structure of North Taiwan was secondarily modified by lateral movements and gravitational glidings in the latter part of the orogeny.

In the foreland geology the Chinese Petroleum Corporation drills PK–2 and PK–3 near Peikang on the west coast the logs of which reached older rocks to the depths of 1.462 m and 1.962 m respectively, are extraordinarily interesting. The older rocks are acidic tuff and purple shales in the upper 27 to 53 m. The middle 120 m or less is mainly composed of shale and sandstone and yields Albian-Aptian marine pelecypods and a few ammonites in upper horizons and Neocomian brackish pelecypods in lower horizons. The lower part consists of folded basement rocks of unknown age. The unconformity below the basal conglomerate of the Lower Cretaceous formation indicates the Wealden Oga phase of deformation. The upper volcanic rocks which is overlain by Burdigarian and younger soft rocks are comparable to Upper Cretaceous-Lower Tertiary ones in the inner zone of West Japan. The Middle Cretaceous time gap tells that like in the inner zone of West Japan the deformation here was not so strong in the Sakawa phase as in the Oga phase.

The Chuluangkeng (Shukkoko) oil field is particularly interesting for analysis of the tectonic development. There is a long anticline which is, however, bisected by an axial fault along which the eastern wing is a little sunk down. As it is a tension fault at the saddle, the displacement is presumably reduced downward. In the eastern wing, however, there is a thrust of greater displacement, and the same *Operculina* sandstone occurs twice. It is probably a dislocation in the course of the folding. The axial fault on the contrary may be the final adjustment (see Fig. 7).

The southern end of the Chuhuangkeng anticline is cut by a transverse thrust called Sancha (Sansa) along which the southern block thrusts itself upon the other. This thrust is cut by Hsinkai (Shinkai) and Tungluo (Dora) reverse faults at its lateral ends. Thus the folding developed into a compressive block movement which yielded the Sancha thrust and later the two others. Along the Tungluo fault the dislocation appears to have recurred after the deposition of the tableland gravels.

Seeing the differential movement among the brachyanticlines and brachy-

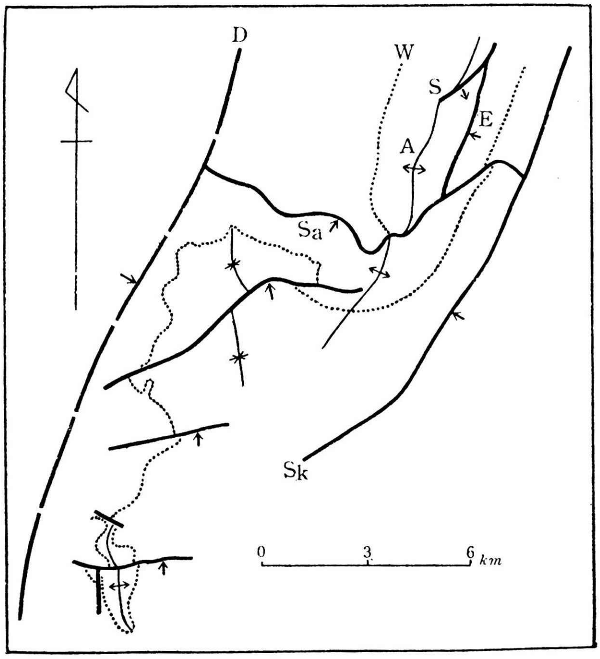


Fig. 7. Tectonic map of the Chuhuangkeng (Shukkoko) oil field. (After CHANG).

W. White sandstone
A. Chuchuangkeng anticline
S. Chuchuangkeng axial fault
E. East Chuchuangkeng thrust
Sa. Sancha thrust
Sk. Hsinkai reverse fault
D. Tungluo reverse fault

synclines and in considering their development from embryonic domes and basins alternately aligned in checker pattern, it is quite probable that the deformation of the geosynclinal sediments was controlled by the framework of their basement which belongs to the inner side of the Sakawa folded mountains. It is well known that in Japan the inner zone was already destructed into a faulted mozaic by block movements in the later Cretaceous and early Palaeogene periods.

Because the repetition of the embryonic foldings is well demonstrated by the middle Tertiary minor cycles of sedimentation in the Kiirun imbricated subzone and because neither the Kaenzan conglomerate nor the Pliocene sediment is developed there, the imbrication was nearly completed possibly before the main upheaval phase of the backbone range.

After the fundamental anticlinorium of Taiwan was built up with the Sakawa metamorphic rocks at its core, the Urai zone, instead of the Tananao zone, was most elevated. The upheaval in this phase attained its maximum in Central Taiwan instead of North Taiwan. Tectonic analysis in the west Taiwan zone has shown that the folding was followed by the compressive block movement. On the basis of these facts it is reasonable to consider that, caused by the geanticlinal upheaval, differential movements took place among blocks. The dislocation must have been especially great at the boundaries of the three tectonic zones of different plasticity. The displacement along the western boundary of the Urai zone was greater in Central Taiwan than North Taiwan, as can be recognized by a comparison between the Kushaku thrust in North Taiwan and the Nansei (Nanshih) fault in Central Taiwan. It is still a question whether the boundary is marked off by a continuous tectonic line or whether it is represented by a series of faults and thrusts en échelon. In all events it is certain that the orography was greatly changed by the upheaval of the backbone range.

As the result of such a great upheaval the Urai zone was strongly eroded. The clastic Urai rocks were transported in huge amounts beyond the western scarps through steep valleys. The Kaenzan conglomerate is such an orogenic sediment of tremendous thickness which was accumulated in a short time on the western lowland.

In the Neogene sediments rock fragments of clayslate and crystalline schists appear in Burdigarian and Helvetian in the southern part of the West Taiwan zone but were later distributed also in the northern part. Their amount increased near the end of the Miocene. In the Takuran and Tokasan formations lithic arenite containing 20 percent clayslate fragments are common in Central and South Taiwan, but their amount is reduced toward the North. Quartzite rudite of the Kaensan facies is, on the other hand, distributed in the west Taiwan zone to the north of Kagi. These sedimentological aspects reveal that the upeheaval of the central range began in the central part and accelerated toward the Miocene at one time and at another time more abruptly and greatly in the Urai zone in the late Pliocene (Huang and Lee, 1962, Lee, 1963).

Palaeo-Taiwan at this time was a peninsula connected with the continent by a land bridge probably through North Taiwan and pre-Taiwan dome. The Plio-Pleistocene mammals migrated through this bridge into the western lowland where the Shokkozan fans and deltas were alinged. The bay further to the west was extended as far as the neck of the peninsula.

On the east side of the backbone range there is the Tatung (Daito) coastal range which like the Neogene of the Uetsu subgeosyncline in North Japan, is composed of Neogene formations containing a large amount of volcanic and pyroclastic materials. The Pinanshan conglomerate, 1,800 m thick is rich in crystalline schists. It is now generally referred to Pliocene as primarily done by Ooe (1939) instead of lower Miocene as done by Hsu (1956). There the Milun conglomerate is the correlative of the Kaenzan conglomerate. It is noteworthy that the synorogenic conglomerates appeared earlier here than in the west Taiwan zone. The formations are moderately folded and cut by faults. The base of the Neogene is unexposed. The coastal range is detached from the Tananao zone by the Hualien Kang (Kwarenkei) rift valley. Whether it is a graben or not cannot actually be seen, because the rupture lines lie concealed beneath young sediments. Off the east coast there are three isles which are mostly composed of volcanic and pyroclastic materials. Quartz-schist caught in andesite as a xenolith in Kueishan isle is proof of the linking of the Sakawa mountains from the Tananao zone to the Yaeyama group. Lutao (Huoshaotao) and Lanhsu (Huangt'ouyu) are remnants of submarine volcanoes and in the latter Aquitanian limestone is inserted in andesitic tuff-agglomerate.

As noted already, these isles form a volcanic chain with the northern dependent isles of Luzon. They as a whole lie on the submarine projectile from the Cagayan valley. The Neogene formations in addition to the upper Oligocene Ibulao limestone in the valley form a synclinorium between the Sierra Madre range on the east and the Cordillera Central on the west side. Like the Yaeyama formation, the lower Miocene Lubugan is a coal-bearing formation. The middle Miocene Tugaegaro sandstone becomes tuffaceous in the south till at length it merges with volcanic rocks.

In the Philippine islands the middle Miocene, frequently quite thick, must be a sediment of the orogenic epoch. Conglomerate is well developed. Clino-unconformity is extensive between the middle and upper Miocene formations, although the latter is mostly composed of fine clastic rocks and limestones and the occurrence of conglomerate is restricted.

Because the Cordillera Central belongs possibly to the Sakawa axis and because the middle Miocene attains such an extraordinary thickness, 3,000 m, in the Bueda valley near the southern end of the range, the conglomerates near Hengchun (Koshun) must be discussed.

The Tertiary formations near Hengchun are very thick and consist of sandstone, shale and conglomerate, including volcanic material in part. TAN (1941) found *Operculina ammonoides* in a shale of the Miocene formation. The Koshun formation comprises various conglomerates rich in volcanic rocks, plutonic rocks and older sedimentaries. They vary in thickness. There are still some ambiguities in their stratigraphic horizons, but these orogenic conglomerates are most probably upper Miocene and Pliocene in age. The Koshun conglomerate s. str. on the other hand is now correlated to the Kaenzan conglomerate. In view of these facts it is presumable that the Taiwan orogeny culminated in the Urai zone already in the middle Neogene.

In the southernmost part of the Urai zone TAN discovered a phyllitic conglomerate containing clayslate and another containing *Discocyclina* limestone. These boulders are probably the upper Urai members, showing intermittent emergences. In the vicinity of Yüshan (Mt. Niitaka) the Urai formation is disconformably overlain by Miocene sandy shale containing *Opereulina venosa.*

If these conglomerates are excluded, the Tertiary of Taiwan is composed of fine rocks in main and the appearance of the Kaenzan conglomerate is quite sporadical in the West Taiwan zone. The next younger is the so-called Ryukyu limestone which is the old raised coral reefs and distinctly tilted, while the younger reef limestones in three series are all subhorizontal. At the Shoushan (Kotobuki hill) of Kaohsiung, 356 m high, in South Taiwan the Takuran formation is capped by the Ryukyu limestone clino-unconformably.

The West Taiwan hills, 300 m or less above the sea, are extensively covered by gravel beds about 30 m thick. Because their tops are flat, they were called "tableland gravels," but it happens also that the flat tops are slightly tilted or gently undulated. Gravel beds are distributed also in some intermontane basins. In the Puli basin the gravel beds attain heights as high as 700 m above sea level. Beneath them there are lignite-bearing lacustrine clay beds which are gently inclined and probably near the Ryukyu limestone in age.

It is an interpretation that the gravel beds were produced in the pluvial epoch in the Diluvium. River terraces incised in the tableland are classified by Tomita (1951) into two groups. Like the tableland gravels, the higher terraces are capped by lateritic soil. Their relative height from the present river floor is generally 100 to 300 m, but this reaches 400 to 500 m on the east side of the backbone range. This difference reveals an asymmetrical geanticline caused by the upheaval of the range. The relative height of the lower terraces without lateritic soil on the top is generally 20 to 40 m and reaches 80 m at the maximum, but such a difference of height is recognizable between the two sides of the range.

While the geanticlinal upheavals were repeated, there were eruptions of dacite in the Kiirun subzone and of andesite in the Toen subzone. Because erosion is more advanced in the former than in the latter, the dacite eruption of Chinkuashih-Juifang must be a little older than the andesitic one of Tatunshan-Kuanyinshan. The early tuff of Kuanyinshan wedges into the lower part of the tableland gravels, while the piedmont of this volcano is covered by the gravels of the upper part. Therefore it is certain that the volcanoes appeared sometime in the Diluvium. Subsequent to the spreading of the tableland gravels the fault-angle basin of Taipei was brought about. It was an embayment at the beginning, because marine shells are contained in the lower part of the basin deposit.

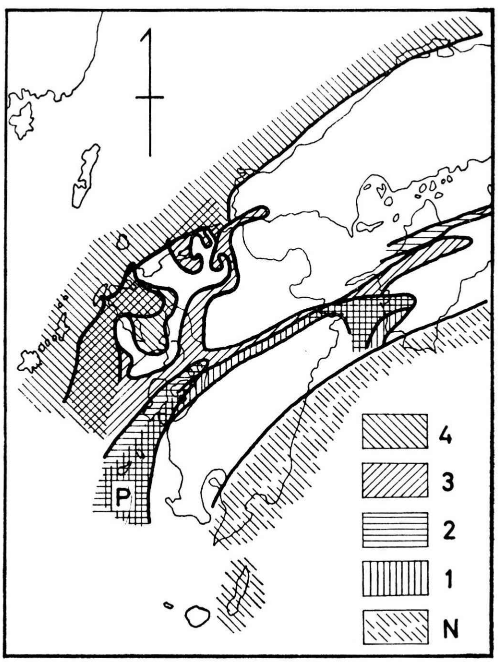
In Central and South Taiwan there is a wide coastal plain and marine shells and foraminifers are found at many places in the Alluvium. The plain is widest near Taichun. There, marine subfossils are found within 10 meters below the land surface near the eastern periphery of the plain. Therefore it was in the near past that the strand line ran along the foot of the hilly land. The retreat of the sea is vindicated by the historical record that a castle built at Anping in 1632 has been on a small island, notwithstanding that the locality is situated 2 km inland from the present shoreline.

According to Yabe the drowned valley of the Hsiatanshueichi, 329 fathoms at the deepest point, carves the Ryukyu limestone. Assuming this dating to be correct, the subsidence of the sea bottom since the Diluvium is not a small amount. The Pescaror trench may be the axis of the subsidence which is reciprocal to the upheaval of Taiwan.

Incidentally it must not be overlooked that the time length of the Diluvium inclusive of the Alluvium is about a million years which is, as discussed elsewhere (Kobayashi, 1944–45), represents a time length of an instant in pre-Diluvium history. If this time relation in the geologic history is considered, it is not surprising that present Taiwan is not yet far removed from the paroxysm of orogeny. Taiwan is in fact still in a labile state as shown by the repetition of disastrous earthquakes. Among the earthquake faults produced by the Chiai (Kagi) earthquake in 1906, Central Taiwan earthquake in 1935, and the Tainan earthquake in 1946, all in West Taiwan, it is a remarkable habit of shifting of the northern block to the east along a hinge fault in the eastnortheast trend and the downthrow of the fault is always on the south side in the east but on the north side on the west side.

Before closing this paper a few problems are discussed from the comparative tectonic point of view. The Taiwan geosyncline agrees best with the Palaeo-Shiranuhi geosyncline in western Kyushu from the tectonic position not only at the western end of a festoon arc, but also in the inner side of the Sakawa axis. Both of them are therefore subgeosynclines, namely, minor subsiding zones which were produced secondarily in the already oronized area by its destruction (see Fig. 8).

It is certainly interesting to see the migration of the subgeosyncline toward the continental side which took place in northwestern Kyushu as in Taiwan. More



1. Turonio-Cenomanian basin
2. Senonian basin
3. Palaeogene basin
4. Miocene basin
N. Pre-Miocene Nakamura geosyncline
P. Palaeo-Shiranuhi subgeosyncline

Fig. 8. Palaeogeographic map of Kyushu showing the migration of the sedimentary basin behind the Sakawa folded mountains.

precisely, the oldest of the post-Sakawa depression in Kyushu was the Gyliakian or Cenomanio-Turonian one; the next the Urakawan or Senonian one; and the third the Palaeogene one. The sea ingressed toward the northeast repeatedly through the Palaeo-Shiranuhi bay, but in the inundation phase the flooded area farther beyond was shifted from time to time toward the northwest. The shifting in this trend took place at a bound in the middle Tertiary, that is, at about the time of orogeny of the Nakamura geosyncline. Through this upheaval the hinterland of this geosyncline emerged and the Oligo-Miocene sea flooded only the northwestern periphery of Kyushu.

Sometime in the midle Neogene the Neo-Cretaceous and Palaeogene formations in the Palaeo-Shiranuhi subgeosyncline were folded as the Tertiary formation in the Taiwan subgeosyncline, but the deformation of the Tertiary formations in well consolidated northern Kyushu was a kind of Bruchfaltung.

Because I have already discussed the linking of the Japanese arc with the Ryukyu arc (1956), I do not intend to reiterate here. But I shall call attention to the fact that the phases of crustal movements in Taiwan and the Ryukyu islands may be approximately correlated with one another, as suggested by KONISHIA (1963) as follows:

Age	Taiwan	Ryukyu islands
Plio-Pleistocene	Penglai movement	Kunigami phase
Oligo-Miocene	Puli movement	Takachiho phase
Cretaceous-Tertiary	Taiping movement	Miyara phase
Middle Cretaceous	Nanao movement	Attsu phase

Nearly simultaneous crustal deformations were, however, different between the two areas and even parts of either one of these areas in intensity and mode of deformation. The pre-Tertiary discordance in the Ishigaki zone indicated between the Eocene Miyara formation and the metamorphosed Palaeozoic rocks in the Yaeyama insular group is stronger than any discordance known among the older rocks in Taiwan. In the Ryukyu arc the Takachiho disturbance was much stronger on the outer side than the other side. While the Miyara formation is only tilted and undulated, the Palaeogene Kumage formation in Tanegashima is strongly folded. The Miocene and later formations are scarcely folded in the arc, whereas the West Taiwan zone was strongly deformed by the Plio-Pleistocene Penglai movement. An exact correlation of these geological events and their bearing on the areal geology are left for a future study.

The Ryukyu limestone is extensive in the Ryukyu islands as suggested by its name. The eroded flatplane on the limestone is covered by the Kunigami gravels, the correlative of the Pleistocene tableland gravels in Taiwan. *Palaeoloxodon* and other mammalian remains found in fillings of fissures and caves of the Ryukyu limestone indicate the latest connection of the islands with the continent which seems most probable to have been maintained at the neck of the Palaeo-Taiwan peninsula. The land bridge was, however, destroyed at length probably by the southern advance of the Ryukyu islands relative to Taiwan, yielding a flexuer between them.

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Postscript:—According to HUANG drill cores of Well Pk-3 near Peikang below the 1963 m depth contains Palaeocene planctonic foraminifers such as *Globigerina triloculinoides* and *Globorotalia psuedobulloides* commonly and *Globigerina spiralis* rarely. Therefore he remarked that "the Cretaceous megafossils were reworked into the Palaeocene beds" (HUANG, T. (1968), Some Planctonic Foraminiferids from Well PK-3 at Peikang, Yunling, Taiwan. *Proc. Geol. Soc. China, no.* 11.) Is there any possibility for these foraminifers to have become derived fossils in the course of drill sampling? Such a question arose in view of the facts that the supposed reworking have scarcely damaged the illustrated megafossils and that Neocomian-Albian brackish shells and Aptian ammonites and marine pelecypods occur in the normal order of superposition in Well PK-2 near Peikang where no Palaeocene foraminifers were found. While the mixing process of Palaeocene microfossils with Cretaceous megafossils is still a question, now it is evident that Aptian and Palaeocene seas flooded into West Taiwan.

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PLACE NAMES

KOREA

Ch'eong-jin	清津
Ch'eongseong-ni	天聖里
Ch'osan	楚山
Ch'ungch'eong-bukto	忠清北道
Haewŏl-myŏn	海月面
Hamgeong-do	咸鏡道
Hang-gang	漢江
Hoeryeong	会寧
Hongjeom	紅店
Hwanghae-do	黄海道
Imok-dong	梨木洞
Kanggye	江界
Kangwŏn-do	江原道
Kikune (Kukken)	菊根
Kokeonweon	古乾原
Kosu-ri	古藪里
Kukken (Kikune)	菊根
Kukken-dong	菊根洞
Kumko-myeon	金崗面
Kŭmsal-li	金山里
Kyeomip'o	兼二浦
Kyongweon	慶源
Munsal-li	文山里
Naknang	楽浪
North P'yŏngan-do	平安北道
Okch'eon	沃川
Paegch'ŏn-onch'ŏn	白川温泉
Paektu-san	白頭山
P'eongnam	平南
Pulseok	佛石
Pyeokseong	碧城
P'yeongan-do	平安道
P'yeongyang	平壌
Sadong	寺洞
Sangsambong	上三峯
Sangweon	祥原
Segok-dong	細谷洞
Sinchang-myeon	新倉面
Songgye-ri	松渓里
Songnim-myeon	松林面
Taebaeg-san	大白山
Taedong-gang	大同江
Tannok	丹緑
Tomak	陶幕
Tomun (Tumun)	図們
Tumun (Tomun)	図們
Ŭngok	銀谷
Unsal-li	雲山里
Yeonchin	連津
Yoenbaek-kun	延白郡
Yonghung-myeon	竜興面
Yulp'o-dong	栗浦洞

MANCHURIA, NORTH and SOUTH CHINA

A

A-ling-ta ho	阿凌達河
A-mu-shan	阿木山
A-pa-ho	阿巴河
A-shih-ho	阿什河
Ai-hun-hsien	愛琿県
An-hai	安海
An-shan	鞍山
An-tu	安図
Argun River	額爾古納河

C

Cha-nan (Tscha-nan)	察南
Chan-fo-ssu	禅仏寺
Chang-cheng	長城
Chang-chou	漳州
Chang-chun	長春
Chang-ling-ssu-hui	長岺寺会
Chang-liu-shui	常流水
Chang-lo	長楽
Chang-pai-shan	長白山
Chang-ting	長汀
Chang-wu	彰武
Chao-bai-hu	趙百戸
Chao-yang	朝陽
Che-chiang (Che-kiang) Province	浙江省
Che-kiang (Che-chiang) Province	浙江省
Chen-chia-pu-tzu	陳家堡子
Chen-chu-tai-shan	珍珠台山
Chen-ho-pao	鎮河堡
Cheng-ho	政和
Cheng-ping	承平
Cheng-te	承徳
Chi-an	輯安
Chi-chao-kou	鶏爪溝
Chi-chi-ha-erh (Tsi-tsi-har)	斉々哈爾
Chi-chia-pu-tzu	祁家堡子
Chi-chia-tzu	七家子
Chi-feng-shan	七峰山
Chi-hsiang-yu	吉祥峪
Chi-hsien	薊県
Chi-jen-kou	七人溝
Chi-kan	奇乾
Chi-lin (Kirin)	吉林
Chi-lin-kou	麒麟溝
Chi-ma-chieh	薩馬街
Chi-tung-yu	吉洞峪
Chia-chia-pu-tzu	賀家堡子
Chia-mu-ssu	佳木斯
Chiang-hsi (Kiang-si) Province	江西省
Chiang-lo	将楽
Chiao-tzo	焦作
Chien-hsien-shih	前線石
Chien-ning	建寧
Chien-ou	建甌
Chien-shan	千山
Chien-shan-tzu	尖山子
Chien-tao	間島
Chien-yang	建陽
Chih-feng	赤峰
Chin-chia-pu-tzu	金家堡子
Chin-chiang	晉江
Chin-chou	錦州
Chin-chuan-hsien	金川県
Chin-hsi	錦西
Chin-ling-ssu	金岺寺
Chin-shan-ssu	金山寺
Chin-shui	金水
Chin-shui-ho	清水河
Chin-tzu-pu-tzu	金子堡子
Ching-cheng-tzu	青城子
Ching-erh-yu	景児峪
Ching-ho	清河
Ching-hsing	井陘
Ching-kou-tzu	青溝子
Ching-liang-shan	青涼山
Ching-lung-hsien	青竜県

Ching-shan-pai	青山杯
Ching-shan-ssu	青山寺
Ching-tsui-tzu	青咀子
Ching-tui-tzu	青堆子
Ching-tze-yao	青碰窰
Ching-tzu-kou	榛子溝
Ching-yuan	靖遠
Chiu-lung-shan	九竜山
Cho-erh-ho (Chuo-er-ho)	綽児河
Chuan-shan-tzu	転山子
Chung-an	崇安
Chung-chao	中朝
Chuo-er-ho (Cho-erh-ho)	綽児河

D

Dja-lai-te-wang-fu	札賚特王府

E

E-mao-kou	鵞毛口
Er-tao-kou	二道溝
Er-tseng-tien-tzu	二層甸子
Erh-tai-tzu	二台子
Erh-tao-ho-tzu	二道河子

F

Fan-ho	汎河
Fan-le-ma-yu	范勒馬峪
Fang-shen-kou	房身溝
Fen-shui	分水
Feng-chen	豊鎮
Feng-ning	豊寧
Feng-tien (Mukden)	奉天
Fu-an	福安
Fu-chien (Fu-kien) Province	福建省
Fu-chou	福州
Fu-chou	復州
Fu-erh-kou	富児溝
Fu-hsin	阜新
Fu-kien (Fu-chien) Province	福建省
Fu-shun	撫順

H

Ha-hai-ho	哈海河
Ha-la-ha-ho	哈拉哈河
Hai-cheng	海城
Hai-la-erh (Hailar)	海拉爾
Hailar (Hai-la-erh)	海拉爾
Han-chia-kou	韓家溝
Hanka Lake	興凱湖
Hao-erh-shih	猴児石
Hao-kang	鶴岡
Hao-li Ho	鶴立河
Hao-li Hsien	鶴立県
Harbin	哈爾浜
Hei-cheng-tzu	黒城子
Hei-lao-wu-shih	黒老烏石
Hei-lung-chiang (Hei-lung-kiang)	黒竜江
Hei-lung-kiang (Hei-lung-chiang)	黒竜江
Hei-shan	黒山
Hei-tai-chen	黒台鎮
Hei-ting-shan	黒頂山
Hei-yu-kou	黒魚溝
Heng-shan	恒山
Ho-lung (Huo-lung)	和竜
Ho-pei Province	河北省
Hou-kou	後溝
Hou-lung-men	霍竜門
Hou-pai-chai-tzu	後白寨子
Hou-shan	霍山
Hsi-fang-shen-kou	西房身溝
Hsi-ho	細河
Hsi-kou	西溝
Hsi-kuang-shan	錫鉱山
Hsi-lao-niu-pai	西老牛背
Hsi-lin-ke-lo-meng	錫林格勒盟
Hsi-mu-cheng	析木城
Hsi-pei-chia	西北岔
Hsia-fang-shen	下房身
Hsia-ma-ling	下馬岺
Hsia-pu	霞浦
Hsia-sun-chia-liang	下孫家梁
Hsia-sun-chia-wan-tzu	下孫家湾子
Hsiao-chia-chi	小佳気
Hsiao-fang-shen	小房身
Hsiao-kao-chuang-tun	小高荘屯
Hsiao-pien-kou	小辺溝
Hsiao-sheng-shui-ssu	小聖水寺
Hsiao-shih	小市
Hsiao-sui-fen-ho	小綏芬河
Hsiao-tien-tzu-kou	小奠子溝

Hsieh-chia-wei-tzu 謝家崴子
Hsieh-shao 斜哨
Hsin-ching 新京
Hsin-kai-ling 新開嶺
Hsin-yao 辛窰
Hsing-an Province 興安省
Hsing-cheng 興城
Hsing-hua 興化
Hsing-kai 興凱
Hsing-lung 興隆
Hsing-lung-hsien 興隆県
Hsing-lung-kou 興隆溝
Hsing-shan 興山
Hsing-tung 興東
Hsiu-yen 岫巌
Hsiung-yo-cheng 熊岳城
Hsuan-hua-hsien 宣化県
Hsuan-ling-hou 旋岺后
Hsuan-lung 宣竜
Hsun-te-tun 峻徳屯
Hu-to 滹沱
Hua-shu-lin-tzu 樺樹林子
Hua-tien 樺甸
Hua-tien Hsien 樺甸県
Hua-tung-kou 化銅溝
Huai-jen 懐仁
Huai-nan (Wei-nan) 准南
Huan-jen 桓仁
Huang-chi 黄旗
Huang-ku-tun 黄姑屯
Huang-ling 横岺
Huang-pai-yu 黄柏峪
Huei-nan (Hui-nan) 輝南
Hui-nan (Huei-nan) 輝南
Hun-yuan 渾源
Hung-chi-shan 紅旗山
Hung-shan 紅山
Hung-shui-chuan 紅水泉
Hung-tu-ling-tzu 紅土嶺子
Huo-lung (Ho-lung) 和竜
Hwang-lung 黄竜

I

I-chou 義州
I-chun 伊春
I-hsien 義県
I-shun 義順
I-tung Hsien 伊通県

J

Je-ho (Jehol) 熱河
Jehol (Je-ho) 熱河
Ji-su 哲斯

K

Kai-lu 開魯
Kai-luan 開灤
Kai-ping 蓋平
Kai-shan-tun 開山屯
Kai-yuan 開原
Kalgan 張河ロ
Kan-ho 甘河
Kang-chia-chang-tzu 康家杖子
Kang-chia-yu 康家峪
Kao-chia-yao 高家窰
Kao-li 高麗
Kao-li-cheng-shan 高麗城山
Kao-shan-chen 高山鎮
Kao-yu-chuang 高于荘
Ken-li-ho 根里河
Ken-tu-ho 根図河
Kiang-si (Chiang-hsi) Province 江西省
Kirin (Chi-lin) 吉林
Kou-chuan 口泉
Kuan-ma-shan 官馬山
Kuan-ma-tsui-tzu 官馬咀子
Kuan-men-shan 関門山
Kuan-shan 冠山
Kuan-tien 寛甸
Kuan-tung 関東
Kuang-tse 光沢
Kuang-tung-ling 鉱洞岺
Kuang-tung-tzu 鉱洞子
Kuei-chou 貴州
Kuei-hua 帰化
Kuei-tzu-ha-ta 櫃子哈達
Kung-chang-ling 弓張岺
Kung-chu-ling 公主岺
Kuo-chia-kou 郭家溝

L

La-lao-tu 拉老兎

Lan-chia-kou	藍家溝
Lan-feng-chih	藍鳳池
Lan-ping	滦平
Lang-tu-kou	狼兎溝
Lao-chang-kuang-suei-ling	老張広歳岺
Lao-mu-kou	老母溝
Lao-tao-kou	老道口
Lao-yao-kou	老窰溝
Lao-yeh-miao-kou	老爺庙溝
Li-shu-kou	梨樹溝
Liao-ho	遼河
Liao-yang	遼陽
Lien-cheng	連城
Lien-chiang	連江
Lien-chiang-kou	蓮江口
Lien-hua-shan	蓮花山
Lien-shan-chiang	蓮山江
Lien-shan-kuan	連山関
Lin-hsi (Lin-si)	林西
Lin-si (Lin-hsi)	林西
Ling-yuan	凌源
Liu-chiang (Liu-kiang)	柳江
Liu-ching	陸鏡
Liu-ho	柳河
Liu-kiang (Liu-chiang)	柳江
Liu-tao-kou	六道溝
Lo-pei	蘿北
Lu-chia-nan-kou	芦家南溝
Lu-chuan	鹿圏
Lu-chuan-tzu	鹿圏子
Lu-kou	鹿溝
Lung-ching	竜井
Lung-hua	隆化
Lung-men	竜門
Lung-yen	竜烟
Lung-wang-miao	竜王庙

M

Ma-chou	馬州
Ma-chuan-tzu	馬圏子
Ma-ho-ssu	馬和寺
Ma-i-hsiang	馬邑郷
Ma-ma-chieh	媽々街
Ma-pao-kou	麻包溝
Ma-shan	麻山
Man-chou-li (Mandschuri)	満洲里
Mandschuri (Man-chou-li)	満洲里
Mei-yu-kou	煤峪口
Meng-chiang	濛江
Meng-ku-ying-tzu-tsun	蒙古営子村
Mergen (Nen-chiang)	嫩江
Mi-shan	密山
Miao-erh-kou	庙児溝
Miao-kou	庙溝
Min-cheng	明城
Min-ching	閩清
Min-hou	閩侯
Ming-yueh-kou	明月溝
Mo-erh-ken-ho	莫爾根江
Mongugai	蒙古街
Mu-chi	木奇
Mukden (Feng-tien)	奉天

N

Na-tan-ha-ta-ling	那丹哈達岺
Nan-ching	南京
Nan-fen	南坟
Nan-hsin-chuang	南信荘
Nan-kang	南崗
Nan-kou	南口
Nan-ling	南岺
Nan-piao	南票
Nan-ping	南平
Nan-ta-tien-tzu	南大甸子
Nan-tai	南台
Nen-chiang (Mergen)	嫩河
Ni-chiu-ho	泥鰍河
Ning-hua	寧化
Ning-te	寧徳
Ning-yang	寧洋
Niu-chuan-tzu	牛圏子
Niu-chuang	牛荘
Niu-hsin-shan	牛心山
Nu-erh-ho	女児河

P

Pa-li-ho	八里河
Pa-tao-chiang	八道江
Pai-chia-tien	白家店
Pai-chia-pu-tzu	白家堡子
Pai-hu-shan	白虎山
Pai-tu-yao	白土窰

Pai-tung	白洞
Pai-tung-tsun	白洞村
Pai-yun-ssu	白雲寺
Pan-shih	盤石
Pang-chia-pu	龐家堡
Pao-chin	保晋
Pao-tou	包頭
Pao-tsang	宝蔵
Pei-chen	北鎮
Pei-ching	北京
Pei-ssu-tao-kou	北四道溝
Pei-ta-ling	北大嶺
Pen-chi	本渓
Pen-hsi-hu	本渓湖
Pi-chia-shan	筆架山
Pi-tzu-wo	貔子窩
Pin-chiang Province	浜江省
Ping-chuan	平泉
Ping-erh-fang	平二房
Ping-lu	平魯
Ping-nan	屏南
Ping-ting	平定
Ping-wang	平旺
Po Hai	渤海
Pu-cheng	浦城
Pu-chow	蒲州

S

Sa-la-chi	薩拉斉
Sai-chia (Tsai-chia)	彩家
San-cha-kou	三岔口
San-chiang (San-kiang) Province	三江省
San-ho	三河
San-ho-tun	三河屯
San-kiang (San-chiang) Province	三江省
San-tao-kou	三道溝
San-yang	三陽
Sang-kan	桑乾
Sang-kan-ho	桑乾河
Sha-hsien	沙県
Sha-kou	沙口
Shan-hsi Province	山西省
Shan-kiang-an	山江安
Shan-sung-kang	杉松崗
Shan-tung Province	山東省
Shang-hai-kuan	山海関
Shang-hang	上杭
Shang-nien	上年
Shang-pien	上辺
Shang-tsai-hsiu-tung	上彩秀洞
Shao-wu	邵武
Shen-shu	神樹
Sheng-shui-ssu	聖水寺
Shieh-hu-shan	射虎山
Shih-chien-feng	石千峰
Shih-ho-tzu	石盒子
Shih-hui-yao-tzu	石灰窰子
Shih-hui-yao	石灰窰
Shih-lai-yao	十來要
Shih-li-ho	十里河
Shih-tou ho	石頭河
Shih-tsui	石嘴
Shou-hsien	朔県
Shou-shan	寿山
Shou-yang	寿陽
Shuang-kang-tun	双崗屯
Shui-chuan	水泉
Shui-mo	水磨
Shun-chang	順昌
So-lun (Soron)	索倫
Soron (So-lun)	索倫
Ssu-chien	寺前
Ssu-lao-kou	四老溝
Ssu-ping-chieh	四平街
Su-hu-ho	蘇呼河
Su-tzu-ti-lu	蘇子狄洛
Sui-fen (Suifung)	綏芬
Sui-hua	綏化
Suifung (Sui-feng)	綏芬
Sung-chi	松渓
Sung-chia-chang-tzu	宗家杖子
Sung-hua-chiang (Sungari) River	松花江
Sung-shu-chen	松樹鎮
Sung-shu-wu	松樹卯
Sungari (Sung-hua-chiang) River	松花江

T

Ta-ching-kou	大井溝

Ta-ching-shan	大青山
Ta-hang-shan	大行山
Ta-huang-pai-yu	大黄柏峪
Ta-ku-shan	大孤山
Ta-li	達里
Ta-lien	大連
Ta-ling	大峇
Ta-miao	大庙
Ta-min-shan	大名山
Ta-pei-ling	大北峇
Ta-ping-shan	大平山
Ta-shan	他山
Ta-shih-chiao	大石橋
Ta-ta-shan	大塔山
Ta-tien	大田
Ta-tien-tzu	大甸子
Ta-tung	大東
Ta-tung	大同
Ta-tung-kou-tsun	大通溝村
Tai-chi-ying-tzu	台吉営子
Tai-ning	泰寧
Tai-shan	泰山
Tai-tzu-ho	太子河
Tai-yang	太洋
Tai-yuan	太原
Tai-yueh-chen	岱岳鎮
Tan-shan	潭山
Tang-ho	湯河
Tang-kang-tzu	湯崗子
Tang-ke-tung	唐克東
Tao-nan	洮南
Tao-shan	桃山
Te-hua	徳化
Ti-tao-shan	適道山
Tiao-wo-tsui	刁窩咀
Tieh-ling	鉄嶺
Tieh-ma-tu-kou	鉄馬土溝
Tien-nan-kou	店南溝
Tien-pao-shan	天宝山
Tou-man-chiang	豆満江
Tou-tao-kou	頭道溝
Tou-tsun	竇村
Tsai-chia (Sai-chia)	彩家
Tsai-hsiu-tung	彩秀洞
Tsao-ho-kou	草河口
Tscha-nan (Cha-nan)	察南
Tsi-tsi-har (Chi-chi-ha-erh)	斉々哈爾
Tsin-pei	晋北
Tso-yun	左雲
Tu-man	豆満
Tu-men-chiang	図們江
Tuan-piao	円瓢
Tung-an	同安
Tung-an	東安
Tuna-an-chen	東安鎮
Tung-chia-liang	同家梁
Tung-chia-wo-pu	柊家窩堡
Tung-hua-hsien	通化県
Tung-ke-yu	東葛峪
Tung-ku-lan	東古蘭
Tung-liao	通遼
Tung-pao-sha	東泡沙
Tung-shan	東山
Tung-ta-kou	東大溝
Tung-yu	東峪
Tung-yuan-pu	通遠堡
Tzu-hsien	磁県

U

Ussuri	烏蘇里

W

Wa-fang-tien	瓦房店
Wa-tui-kou	瓦砼溝
Wa-yao-kou	甕窰溝
Wai-tou-shan	歪頭山
Wan-pao-kai-tzu	万宝蓋子
Wan-ta-shan	完達山
Wang-chia-chuang	王家庄
Wang-chia-pu-tzu	王家堡子
Wang-chiang-tzu	王杖子
Wang-pien-chuang	王卞庄
Wei-chia-kou	魏家溝
Wei-nan (Huai-nan)	淮南
Wu-chia-yao	呉家窰
Wu-mi-shan	霧迷山
Wu-nu-erh	烏奴爾
Wu-ping	武平
Wu-tai	五台
Wu-tun Ho	烏屯河

Y

Ya-pa-tien	啞叭店

Yalu River	鴨緑江
Yang-chia-chang-tzu	楊家杖子
Yang-chia-tien	楊家甸
Yang-chia-wan	楊家湾
Yang-chuang	楊荘
Yang-shan	羊山
Yao-tzu-fang	窰子坊
Yao-tzu-tou	窰子頭
Yen-chi	延吉
Yen-shan	燕山
Yen-yai	雁崖
Yin-shan	陰山
Yin-tang-kou	銀塘溝
Yin-tzu-kou	銀子溝
Ying-hao	英豪
Ying-kou	営口
Ying-tao-yuan	桜桃園
Yu-chi	尤渓
Yu-chuan	玉泉
Yu-feng	裕豊
Yu-yu-hsien	右玉県
Yuen-chien-shan	眼前山
Yun-hsiao	雲霄
Yun-kang	雲崗
Yun-kang-chen	雲崗鎮
Yung-an	永安
Yung-chi	永吉
Yung-chun	永春
Yung-ting	永定
Yung-ting-chuang	永定荘

TAIWAN

A

A-li-shan (Arisan) 阿里山
An-ping (Anpin) 安平
An-tung-chun-shan (Antōgunzan) 安東軍山
Anpin (An-ping) 安平
Antōgunzan (An-tung-chun-shan) 安東軍山
Arisan (A-li-shan) 阿里山

B

Banrikyōkei (Wan-li-chiao-chi) 万里橋渓
Banro (Fan-lu) 番路
Basshi (Pa-tzu) 抜子
Beironsan (Mi-lun-shan) 米崙山
Bōkyō (Wang-hsiang) 望郷
Butanzan (Wu-tan-shan) 武丹山
Byōbitō (Miao-pi-tou) 猫鼻頭
Byōran (Mao-lan) 猫蘭
Byōransan (Mao-lan-shan) 猫蘭山
Byōritsu (Miao-li) 苗栗

C

Chang-hua (Shōka) 彰化
Chao-chou (Chōshū) 潮州
Chen-tou-shan (Tintōsan) 枕頭山
Chen-tso-liao (Chinsekiryō) 陳厝寮
Chen-yu-lan-chi (Chinyūrankei) 陳有蘭渓
Chi-chi-ta-shan (Shūshūtaisan) 集々大山
Chi-hsing-shan (Shichiseizan) 七星山
Chi-hsing-yen (Shichiseigan) 七星岩
Chi-kou-tai (Keikōdai) 渓口台
Chi-lai (Kirai) 菁萊
Chi-li-wa (Kiriga) 唭哩呱
Chi-mu-ling (Keiborei) 鶏母嶺
Chi-shan (Kizan) 旗山
Chi-ting (Kichō) 崎頂
Chia-la-pu 加蚋埔
Chia-li (Kagi) 嘉義
Chia-li-shan (Karizan) 加里山
Chia-nan (Kanan) 嘉南
Chia-yang (Kayō) 佳陽
Chiao-pan-shan (Kappanzan) 角板山
Chien-ko-tao (Senkakutō) 尖閣島
Chien-shan-hu (Senzanko) 尖山湖
Chih-kan (Sekkan) 赤崁
Chikunan (Chu-nan) 竹南
Chikushikōkei (Chu-tzu-keng-chi) 竹子坑渓
Chikutō (Chu-tung) 竹東
Chikuzan (Chu-shan) 竹山
Chin-hua-shih (Kinkaseki) 金瓜石
Chin-shui (Kinsui) 錦水
Ching-pu-wei 青埔尾
Ching-shui-chi (Seisuikei) 清水渓
Ching-shui-tan (Seisuitan) 清水潭
Ching-tan (Seitan) 清潭
Chinsekiryō (Chen-tso-liao) 陳厝寮
Chinyūrankei (Chen-yu-lan-chi) 陳有蘭渓
Chippon (Tze-pen) 知本
Chiu-chiang (Kyūkō) 旧港
Chiu-liang-ping-hsia (Kuraheikyō) 久良屛峡
Cho-kou-chi (Dakkōkei) 濁口渓
Cho-kou-shan (Shokkōzan) 触口山
Cho-lan (Takuran) 卓蘭
Cho-shui-chi (Dakusuikei) 濁水渓
Chong-kuei (Jūki) 銃櫃
Chōshū (Chao-chou) 潮州
Chu-chi (Takezaki) 竹崎
Chu-huang-keng (Shukkōkō) 出礦坑
Chu-lu (Hatsushika) 初鹿
Chu-nan (Chikunan) 竹南
Chu-shan (Chikuzan) 竹山
Chu-tung (Chikutō) 竹東
Chu-tzu-keng-chi (Chikushikōkei) 竹子坑渓

Chung-li Chūreki) 中壢
Chung-yang-chien-shan (Chūōsenzan) 中央尖山
Chūōsenzan (Chung-yang-chien-shan) 中央尖山
Chūreki (Chung-li) 中壢

D

Daiankei (Ta-an-chi) 大安渓
Daibusan (Ta-wu-shan) 大武山
Daiho (Ta-pu) 大埔
Dainanō (Ta-nan-ao) 大南澳
Dainanōkei (Ta-nan-ao-chi) 大南澳渓
Dainanshō (Ta-nan-chuang) 大南庄
Dairyō (Ta-liao) 大寮
Daiseisui (Ta-ching-shui) 大清水
Daisuikutsu (Ta-shui-ku) 大水窟
Daitonsan (Ta-tung-shan) 大屯山
Dakkōkei (Cho-kou-chi) 濁口渓
Dakusuikei (Cho-shui-chi) 濁水渓

F

Fan-lu (Banro) 番路
Fen-niao-lin (Funchōrin) 粉鳥林
Feng-ping (Toyohama) 豊浜
Feng-shan (Hōzan) 鳳山
Fu-li (Tomisato) 富里
Funchōrin (Fen-niao-lin) 粉鳥林

G

Gaikadōkō (Wai-chia-tao-keng) 外加道坑
Garanbi (Gua-lan-pi) 鵞鑾鼻
Giran (I-lan) 宜蘭
Girandakusuikei (I-lan-cho-shui-chi) 宜蘭濁水渓
Gojō (Wu-cheng) 五城
Gōkankei (Ho-huan-chi) 合歓渓
Goki (Wu-kuei) 五鬮
Gua-lan-pi (Garanbi) 鵞鑾鼻
Gyochi (Yu-chih) 魚池
Gyokuzan (Yu-shan) 玉山
Gyūsōshoku (Niu-hsiang-cho) 牛相触

H

Hai-kou (Kaikō) 海口
Hai-shan (Kaizan) 海山
Hakkei (Pa-kua) 八卦
Hakushaton (Pai-sha-tun) 白沙屯
Hassenzan (Pa-hsien-shan) 八仙山
Hasshōkei (Pa-chang-chi) 八掌渓
Hatsushika (Ch'u-lu) 初鹿
Hattūkan (Pa-tung-kuan) 八通関
Heichin (Ping-chen) 平鎮
Heichō (Ping-ting) 平頂
Heichōho (Ping-ting-pu) 坪頂埔
Heigansan (Ping-yen-shan) 平岩山
Heitō (Ping-tung) 屏東
Heng-chun (Kōshun) 恒春
Hinode (Jih-chu) 日の出
Ho-huan-chi (Gōkankei) 合歓渓
Ho-shang-tou-shan (Oshōtōsan) 和尚頭山
Hōkashō (Peng-chia-hsu) 彭佳嶼
Hokkōkei (Pei-chiang-chi) 北港渓
Hōkotō (Peng-hu-tao) 澎湖島
Hokutan (Pei-tan) 北旦
Hori (Pu-li) 埔里
Hou-li (Kōri) 後里
Hōzan (Feng-shan) 鳳山
Hsia-tan-shui-chi (Shimotansuikei) 下淡水渓
Hsiao-kuan-shan (Shōkanzan) 小関山
Hsiao-kuan-yin-shan (Shōkannonzan) 小観音山
Hsiao-lu-chiu-hsu (Shōryūkyūsho) 小琉球嶼
Hsiao-mei (Koume) 小梅
Hsien-hsia-ling (Senkarei) 仙霞渓
Hsin-cheng (Shinjō) 新城
Hsin-chu (Shinchiku) 新竹
Hsin-hua (Shinka) 新化
Hsin-kai-yuan (Shinkaien) 新開園
Hsin-pu (Shimpo) 新埔
Hsin-tien (Shinten) 新店
Hsin-wu-lu-chi (Shinburokei) 新武路渓
Hsiu-ku-luan-chi (Shūkorankei) 秀姑巒渓
Hsu-lin-kou (Jurinkō) 樹林口
Hsueh-shan (Setsuzan) 雪山
Hu-kou (Kokō) 湖口
Hua-lien-chiang (Karenkō) 花連港

Hua-ping-hsu (Kaheisho) 花瓶嶼
Hung-tou-hsu (Kōtōsho) 紅頭嶼
Huo-shao-tao (Kashōtō) 火焼島
Huo-yen-shan (Kaenzan) 火炎山

I

I-lan (Giran) 宜蘭
I-lan-cho-shui-chi (Girandakusuikei) 宜蘭濁水渓

J

Jih-chu (Hinode) 日の出
Jih-yueh-tan (Jitsugetsutan) 日月潭
Jitsugetsutan (Jih-yueh-tan) 日月潭
Ju-ku-shan (Nyūkozan) 乳姑山
Jui-pao (Zuihō) 瑞宝
Jūki (Chong-kuei) 銃櫃
Jurinkō (Hsu-lin-kou) 樹林口

K

Kaenzan (Huo-yen-shan) 火炎山
Kagi (Chia-i) 嘉義
Kaheisho (Hua-ping-hsu) 花瓶嶼
Kaikō (Hai-kou) 海口
Kaizan (Hai-shan) 海山
Kanan (Chia-nan) 嘉南
Kannonzan (Kuan-yin-shan) 観音山
Kano (Ku-yeh) 鹿野
Kanshirei (Kuan-tzu-ling) 関子嶺
Kantōzan (Kuan-tao-shan) 関刀山
Kanzan (Kuan-shan) 関山
Kao-hsiung (Takao) 高雄
Kappanzan (Chiao-pan-shan) 角板山
Karenkō (Hua-lien-chiang) 花連港
Karizan (Chia-li-shan) 加里山
Kashōtō (Huo-shao-tao) 火焼島
Kayō (Chia-yang) 佳陽
Kee-lung (Kiirun) 基隆
Keiborei (Chi-mu-ling) 鶏母嶺
Keichikurin (Kuei-chu-lin) 桂竹林
Keikōdai (Chi-kou-tai) 渓口台
Ken-ting (Kontei) 墾丁
Kenkai (Yen-hai) 研海
Kichō (Chi-ting) 崎頂
Kiirun (Kee-lung) 基隆
Kinkaseki (Chin-hua-shih) 金瓜石
Kinsui (Chin-shui) 錦水
Kirai (Chi-lai) 寄萊
Kiriga (Chi-li-wa) 唭哩岸
Kizan (Chi-shan) 旗山
Kizantō (Kuei-shan-tao) 亀山島
Kōkan (Kung-kuan) 公館
Kokō (Hu-kou) 湖口
Kokō (Ku-keng) 古坑
Kokusei (Kuo-hsing) 国姓
Kontei (Ken-ting) 墾丁
Kōri (Hou-li) 後里
Kōshun (Heng-chun) 恒春
Koteikō (Ku-ting-keng) 古亭坑
Kōtōsho (Hung-tou-hsu) 紅頭嶼
Koume (Hsiao-mei) 小梅
Ku-chih (Kusshaku) 屈尺
Ku-keng (Kokō) 古坑
Ku-ting-keng (Koteikō) 古亭坑
Kuan-shan (Kanzan) 関山
Kuan-tao-shan (Kantōzan) 関刀山
Kuan-tzu-ling (Kanshirei) 関子嶺
Kuan-yin-shan (Kannonzan) 観音山
Kuei-chu-lin (Keichikurin) 桂竹林
Kuei-shan-tao (Kizantō) 亀山島
Kung-kuan (Kōkan) 公館
Kuo-hsing (Kokusei) 国姓
Kuraheikyō (Chiu-liang-ping-hsia) 久良屏峡
Kusshaku (Ku-chih) 屈尺
Kyūkō (Chiu-chiang) 旧港

L

Lao-nung-chi (Rōnōkei) 荖濃渓
Lei-kung-hua (Raikōka) 雷公火
Li-tung-shan (Ritōzan) 李崠山
Lien-hua-chih (Rengechi) 蓮華池
Lin-kou (Rinkō) 林口
Ling-tzu-chi (Reishisai) 苓子斉
Liu-chia (Rokkō) 六甲
Liu-kuei (Rokki) 六亀
Liu-shih-shih-shan (Rokujukkokusan) 六十石山
Liu-wu (Takkiri) 立霧
Lo-lo-chi (Rakurakukei) 楽々渓
Lo-tung (Ratō) 羅東
Lu-ku-chuang (Shikatanishō) 鹿谷庄
Lu-liao (Rokuryō) 鹿寮
Lu-yeh (Kano) 鹿野

M

Ma-chiu-ta (Makutō) 馬久塔
Ma-tai-lin (Matairin) 馬太林
Ma-wu-tu (Mabutoku) 馬武督
Mabutoku (Ma-wu-tu) 馬武督
Makutō (Ma-chiu-ta) 馬久塔
Mao-hsieh-hsueh (Mōkaiketsu) 毛蟹穴
Mao-lan (Byōran) 猫蘭
Mao-lan·shan (Byōransan) 猫蘭山
Marikei (Wan-li-chi) 万里渓
Matairin (Ma-tai-lin) 馬太林
Menkasho (Mien-hua-hsu) 棉花嶼
Mentenzan (Mien-tien-shan) 面天山
Mi-lun-shan (Beironsan) 米崙山
Miao-li (Byōritsu) 苗栗
Miao-pi-tou (Byōbitō) 猫鼻頭
Mien-hua-hsu (Menkasho) 棉花嶼
Mien-tien-shan (Mentenzan) 面天山
Min-hsiung (Tamio) 民雄
Minamisōtōsan (Nan-shuan-tou-shan) 南双頭山
Mizuho (Jui-sui) 瑞穂
Mōkaiketsu (Mao-hsieh-hsueh) 毛蟹穴
Mokkakei (Mu-kua-chi) 木瓜渓
Mokusaku (Mu-cha) 木柵
Mu-cha (Mokusaku) 木柵
Mu-kua-chi (Mokkakei) 木瓜渓
Mukaku (Wu-hao) 舞鶴

N

Naisaku (Nei-cha) 内柵
Nan-ao (Nanō) 南奥
Nan-chiang-chi (Nankōkei) 南港渓
Nan-hu-chi (Nankokei) 南湖渓
Nan-hu-ta-shan (Nankodaisan) 南湖大山
Nan-kan-chi (Nankankei) 南崁渓
Nan-shih-keng (Nanseikō) 南勢坑
Nan-shuan-tou-shan (Mimamisōtōsan) 南双頭山
Nan-tou (Nantō) 南投
Nan-tzu (Nanshi) 湳子
Nan-tzu-hsien-chi (Nanshisenkei) 南梓仙渓
Nankankei (Nan-kan-chi) 南崁渓
Nankōdaikō (Nan-chiang-ta-keng) 南港大坑
Nankodaisan (Nan-hu-ta-shan) 大湖大山
Nankokei (Nan-hu-chi) 南湖渓
Nankōkei (Nan-chiang-chi) 南港渓
Nanō (Nan-ao) 南奥
Nanseikō (Nan-shih-keng) 南勢坑
Nanshi (Nan-tzu) 湳子
Nanshisenkei (Nan-tzu-hsien-chi) 南梓仙渓
Nantō (Nan-tou) 南投
Nei-cha (Naisaku) 内柵
Neng-kao (Nōkō) 能高
Neng-kao-shan (Nōkōzan) 能高山
Niu-hsiang-cho (Gyūsōshoku) 牛相触
Nōkō (Neng-kao) 能高
Nōkōzan (Neng-kao-shan) 能高山
Nyūkozan (Ju-ku-shan) 乳姑山

O

Oshōtōsan (Ho-shang-tou-shan) 和尚頭山
Ōsono (Ta-yuan) 大園

P

Pa-chang-chi (Hasshōkei) 八掌渓
Pa-hsien-shan (Hassenzan) 八仙山
Pa-kua (Hakkei) 八卦
Pa-tung-kuan (Hattūkan) 八通関
Pa-tzu (Basshi) 抜子
Pai-ho (Shirakawa) 白河
Pai-sha-tun (Hakushaton) 白沙屯
Pei-chiang-chi (Hokkōkei) 北港渓
Pei-tan (Hokutan) 北旦
Peng-chia-hsu (Hōkasho) 彭佳嶼
Peng-hu-tao (Hōkotō) 澎湖島
Pi-nan (Pinan) 卑南
Pi-nan-chu-shan (Pinanshuzan) 卑南主山
Pi-nan-shan (Pinanzan) 卑南山
Pinan (Pi-nan) 卑南
Pinanshuzan (Pi-nan-chu-shan) 卑南主山
Pinanzan (Pi-nan-shan) 卑南山
Ping-chen (Heichin) 平鎮
Ping-ting (Heichō) 平頂
Ping-ting-pu (Heichōho) 坪頂埔

Shūshūtaisan (Chi-chi-ta-shan)	集々大山
Siryō (Ssu-leng)	四稜
Sobunkei (Tsen-wen-chi)	曽文渓
Sokutsu (Tsu-ku)	粗窟
Sōnan (Tsao-nan)	草湳
Sōreitan (Tsao-ling-tan)	草岺潭
Sōzan (Tsao-shan)	草山
Su-ao (Suō)	蘇奥
Ssu-kou (Shikō)	四溝
Ssu-leng (Siryō)	四稜
Suiakutsu (Shui-wa-ku)	水蛙窟
Suibi (Shui-wei)	水尾
Suichōryū (Shui-chang-liu)	水長流
Suirikei (Shui-li-chi)	水裡渓
Suiryūtō (Shui-liu-tung)	水流東
Suishasuibikei (Shui-she-shui-wei-chi)	水社水尾渓
Suō (Su-ao)	蘇奥

T

Ta-an-chi (Daiankei)	大安渓
Ta-chia-chi (Taikōkei)	大甲渓
Ta-ching-shui (Daiseisui)	大清水
Ta-chuang (Taishō)	大庄
Ta-heng-ping-shan (Taiōheisan)	大横屏山
Ta-keng-chi (Taikōkei)	大坑渓
Ta-ko-liao (Taikaryō)	大科寮
Ta-liao (Dairyō)	大寮
Ta-lin (Tairin)	大林
Ta-mao-pu (Taibōho)	大茅埔
Ta-nan-ao (Dainanō)	大南澳
Ta-nan-ao-chi (Dainanōkei)	大南澳渓
Ta-nan-chi (Tainankei)	大南渓
Ta-nan-chuang (Dainanshō)	大南庄
Ta-ping-ting (Taiheichō)	大平頂
Ta-pu (Daiho)	大埔
Ta-shui-ku (Daisuikutsu)	大水窟
Ta-tu (Taito)	大肚
Ta-tung-shan (Daitonsan)	大屯山
Ta-wu-shan (Daibusan)	大武山
Ta-yuan (Ōsono)	大園
Tai-chung (Taichū)	台中
Tai-lu-kuo (Taroko)	太魯閣
Tai-nan (Tainan)	台南
Tai-niu-keng (Taigyūkō)	刣牛坑
Tai-pa-liu-chiu (Taparakau)	太巴六九
Tai-pei (Taihoku)	台北
Tai-ping-chi (Taiheikei)	太平渓
Tai-ping-shan (Taiheizan)	太平山
Tai-tung (Taitō)	台東
Taibōho (Ta-mao-pu)	大茅埔
Taichū (Tai-chung)	台中
Taigyūkō (Tai-niu-keng)	刣牛坑
Taiheichō (Ta-ping-ting)	大平頂
Taiheikei (Tai-ping-chi)	太平渓
Taiheizan (Tai-ping-shan)	太平山
Taihoku (Tai-pei)	台北
Taikaryō (Ta-ko-liao)	大科寮
Taikōkei (Ta-chia-chi)	大甲渓
Taikōkei (Ta-keng-chi)	大坑渓
Tainan (Tai-nan)	台南
Tainankei (Ta-nan-chi)	大南渓
Taiōheisan (Ta-heng-ping-shan)	大横屏山
Tairin (Ta-lin)	大林
Taishō (Ta-chuang)	大庄
Taito (Ta-tu)	大肚
Taitō (Tai-tung)	台東
Takao (Kao-hsiung)	高雄
Takeyama (Chu-shan)	竹山
Takezaki (Chu-chi)	竹崎
Takkiri (Liu-wu)	立霧
Takopan (Te-kao-pan)	徳高班
Takuran (Cho-lan)	卓蘭
Tamai (Yu-ching)	玉井
Tamasato (Yu-li)	玉里
Tamio (Min-hsiung)	民雄
Tan-shui-he (Tansuiga)	淡水河
Tan-ta-shan (Tandaisan)	丹大山
Tandaisan (Tan-ta-shan)	丹大山
Tansuiga (Tan-shui-he)	淡水河
Tao-mi-keng (Tōbeikō)	桃米坑
Tao-yuan (Tōen)	桃園
Taparakau (Tai-pa-liu-chiu)	太巴六九
Taroko (Tai-lu-kuo)	太魯閣
Te-kao-pan (Takopan)	徳高班
Teng-hsien-hsia (Tosenkyō)	登仙峡
Tenshiko (Tien-tzu-hu)	店子湖
Tien-tzu-hu (Tenshiko)	店子湖
Tintōsan (Chen-tou-shan)	枕頭山

Tōbeikō (Tao-mi-keng) 桃米坑
Tōbenkōkei (Tou-pien-keng-chi) 頭汴坑渓
Tōen (Tao-yuan) 桃園
Tōi (Tou-wei) 頭囲
Tōjinpo (Tou-jen-pu) 頭人埔
Tōkazan (Tou-ko-shan) 頭嵙山
Tomisato (Fu-li) 富里
Tompo (Tung-pu) 東埔
Tōō (Tung-ao) 東澳
Toroku (Tou-liu) 斗六
Tōsei (Tung-shih) 東勢
Tosenkyō (Teng-hsien-hsia) 登仙峡
Tōsha (Tou-she) 頭社
Tou-jen-pu (Tōjinpo) 頭人埔
Tou-ko-shan (Tōkazan) 頭嵙山
Tou-liu (Toroku) 斗六
Tou-pien-keng-chi (Tōbenkōkei) 頭汴坑渓
Tou-she (Tōsha) 頭社
Tou-wei (Tōi) 頭囲
Toyohama (Feng-ping) 豊浜
Tsao-ling-tan (Sōreitan) 草岺潭
Tsao-nan (Sōnan) 草湳
Tsao-shan (Sōzan) 草山
Tsen-wen-chi (Sobunkei) 曽文渓
Tso-chen (Sachin) 左鎮
Tso-chi (Sakei) 左渓
Tsu-ku (Sokutsu) 粗窟
Tsūshō (Tung-hsiao) 通霄
Tung-ao (Tōō) 東澳
Tung-hsiao (Tsūshō) 通霄
Tung-pu (Tompo) 東埔
Tung-shih (Tōsei) 東勢
Tze-pen (Chippon) 知本

U

Ugyūran (Wu-niu-lan) 烏牛蘭
Unrinken (Yun-lin-hsien) 雲林県
Unsui (Yu-shui) 沄水
Urai (Wu-lai) 烏来
Utokutsu (Wu-tu-chu) 烏塗屈

W

Wai-chia-tao-keng (Gaikadōkō) 外加道坑
Wan-li-chi (Marikei) 万里渓
Wan-li-chaio-chi (Banrikyōkei) 万里橋渓
Wang-hsiang (Bōkyō) 望郷
Wu-cheng (Gojō) 五城
Wu-hao (Mukaku) 舞鶴
Wu-kuei (Goki) 五鬮
Wu-lai (Urai) 烏来
Wu-niu-lan (Ugyūran) 烏牛蘭
Wu-tan-shan (Butanzan) 武丹山
Wu-tu-chu (Utokutsu) 烏塗屈

Y

Yen-hai (Kenkai) 研海
Yu-chih (Gyochi) 魚池
Yu-ching (Tamai) 玉井
Yu-li (Tamasato) 玉里
Yu-shan (Gyokuzan) 玉山
Yu-shui (Unsui) 沄水
Yu-shui-keng (Yūsuikō) 有水坑
Yun-lin-hsien (Unrinken) 雲林県
Yūsuikō (Yu-shui-keng) 有水坑

Z

Zuihō (Jui-pao) 瑞宝