Geologic Structure of North Korea and South Manchuria

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Introductory Note

Various geologic structures, each bearing its own history of tectonic development, are found in Japan, Korea and Manchuria. Their comparison is, therefore, a subject of more than local interest. I have already published the results of my studies on Japan in 1941.

In Korea and South Manchuria there are three folded zones called, from north to south, the Taitzuho, P'yeongnam and Okch'eon zones. They are separated by the P'yeongbuk and Shantung-Kyeonggi massives. The stratigraphic sequences of these zones are very different from one another, but agree in the absence of volcanic material in Palaeozoic and older sediments. In contrast, volcanic eruptions took place repeatedly in the Chichibu geosyncline from which the Japanese islands developed. The Akiyoshi, Sakawa or Oyashima folded mountains in Japan differ from the structures of the folded zones in Koreo-Manchuria in that a metamorphosed axis is present in each.

The anticlines and synclines in the Okeh'eon zone in South Korea have prolonged axes which are nearly parallel to one another and have many long thrust lines. Such parallelism is not seen in the P'yeongnam-Liaotung or the Taitzuho-Yalu zone. The P'yeongnam-Liaotung zone consists of many brachy-anticlines and -synclines, and structural domes and basins which are disposed in checker pattern. In the Liaotung peninsula remarkable differences in the stratigraphic sequence and the mode of crustal deformation between the P'yeongnam geosyncline and P'yeongbuk massif, on the south and north side of the Yatung bay respectively, are interesting. From the Taitzuho valley to the Yalu-Hunchiang tributaries one can see a great variety of deformation which occurred in kratonic and quasikratonic terrains. It is of primary importance to describe these various aspects of geologic structures to the extent that they are known in the Taitzuho-Yalu zone as well as the P'yeongnam-Liaotung zone.

Because different types of structures were produced at one place or another by the same disturbance, such differences must be attributed to the quality and quantity of sediments and the character of their basement. There are excellent examples of differential movement between plastic sediments and a rigid basement. An attempt to classify the major and minor structures is presented in the concluding chapter.

Korea and South Manchuria were consolidated almost completely by the late Mesozoic batholithic invasion of a granitic magma. After this oronization, the terrain was anoronized, as discussed in my paper on the geology of South Korea. "Geology and Mineral Resources of the Far East, vol. 1." Although little can be said of the Tertiary history of these two zones, additional information is provided in the first chapter as to fragmentation and topo graphic development of the region.

Since 1926 I have visited the continent many times to make geological surveys in the Huolienchai, Niuhsintai, Chinchiachengtzu and Wuhutsuei basins in South Manchuria and the Ch'osan, Kojang, Koweon, Mandal-san and Kyeomi-p'o areas in North Korea. In addition, I made short trips to the Hsiaoshih coalfield, the eastern area of Liaoyang, and Sanshihlipu and its vicinities in the Liaotung Peninsula and the Manp'o-jin, Huch'ang, Ch'angni, Chunghwa, Sangweon, Sariweon, and Sinmak areas in Korea to see geological sections or to make fossil collections. These geological surveys and reconnaissances were made chiefly for the purpose of studying the Eo-Palaeozoic stratigraphy and palaeontology, but I have also noted the tectonic aspects as much as possible.

In 1941 I had the opportunity to conduct geological surveys in the tectonically very important Penhsihu and Wafangtien areas with my students, and was able to visit many places in the region. Compared with the vast terrain of North Korea and South Manchuria, however, the areas I saw are very small in total, though they include key points.

Geological descriptions of many areas, some of which go into great detail, exist, and certainly Korea and South Manchuria belong to the part of Asia whose geology has been well surveyed. Nevertheless, the results so far achieved in the geology of this region have never been schematized from the tectogenetic point of view. I have taken the liberty to make such a synthesis for the P'yeongnam geosyncline and Taitzuho depression, as I have seen many places on both sides of the Yalu river, and have published the results in three papers in *Geology and Mineral Resources of Eastern Asia* in 1953. In 1956 I revised the papers and published them as "A Contribution to the Geotectonics of North Korea and South Manchuria," with the addition of an outline of the regional geology and comparative tectonics.

Thanks to the efforts of many geologists, the stratigraphy of the Sinian, Korean and Heian groups which constitute the folded areas are now so well defined that we can see their general picture. This is not the case for the Mesozoic formations, notwithstanding the fact that a knowledge of Mesozoic stratigraphy is a prerequisite for phase analysis, because the Mesozoic was the orogenic era whereas the Palaeozoic was the epirogenic era in the region. For this reason I have undertaken studies of the non-marine Mesozoic formations and fossils in Eastern Asia with several collaborators. This project advanced fairly rapidly for some years after 1941, but I still found need for careful checking of selected Mesozoic areas.

Fortunately, I was able to refer to many papers gathered by the Committee for the Compilation of Geology and Mineral Resources of the Far East of the Geographic Society of Tokyo. I have also tried to refer to recent contributions published in China and North Korea, although this could only be done to a limited extent. The Pre-Cambrian rock-sequence has been emended here on the basis of new geochronological data. Because my field experience is limited, I cannot be responsible for all the facts. However, their evaluation, interpretation and orientation in the tectonic synthesis were made on the basis of my own experience and are my responsibility. My sincere thanks are due to the many persons and organizations who provided assistance and cooperation in this study.

Two kinds of romanization of geologic terms commonly used in geology of Korea and South Manchuria (Northeast China).

Old Romanization	**New Romanization**
Bukkokuji igneous group	Pulguksa igneous group
Chokken series	Chikhyeon series
Chosen group	Jeonseon or Korean group
Daido series	Daedong series
Gishu disturbance	Ŭiju disturbance
Genzan-Keijo tectonic valley	Weonsan-Seoul tectonic valley
Greenstone series	Nogam series
Heian group	P'yeongan group
Heihoku land	P'yeongbuk land
Heinan zone	P'yeongnam zone
Honkeiko formation	Penhsihu formation
Jido series	Sadong series
Kankyo fault system	Hamgyeong fault system
Keiki land	Kyeonggi land
Keirin group	Kyerim group
Kenjiho limestone conglomerate	Kyeomip'o Limestone conglomerate
Kishu-Meisen graben	Kilchu-Myeongch'eon graben
Kobosan series	Gobangsan series
Koten series	Hongjeom series
Kuken series	Kuhyeon series
Liao-Gaima land	Liao-Kaema land
Miyanohara formation	Tayü formation
Rakuro complex, peneplain	Naknang complex, peneplain
Reinan land	Yeongnam land
Rensen system	Yeonch'eon system
Rishu piedmont plain	Yeoju piedmont plain
Roppyakusan peneplanation	Yukpaeksan peneplanation
Shichihosan horst, series	Ch'ilbosan horst, series
Shidogu series	Sadongmor series
Shiragi series	Silla series
Shogen group	Sangweon group
Shorin disturbance	Songnim disturbance
Taihakusan dislocation line	Taebaegsan dislocation line
Taiho disturbance, series	Taebo disturbance, series
Taishiin series	T'aejaweon series
Yokusen zone	Okch'eon zone
Yotoku series	Yangdeok series

I
A Geological Sketch of North Korea and South Manchuria

1. Research in the Geology of Manchuria

In 1869 Ferdinand von Richthofen travelled through South Manchuria from Yingkou to Moukden by way of Fuchou, Takushan, Fenghuangcheng and Penhsihu, and published his observations in 1882, in vol. II of *China*. His fossil collections were later described by Dames, Kayser, Schenk and Frech in vols. IV and V in 1883 and 1911. Prior to this, A. P. Kropotkin traversed the northern part of the Great Khingan range in 1864. In his journey through Central Asia, Mongolia and North China, 1892–94, W. A. Obrustchew visited Barga and East Manchuria. From 1896, when he was sent to the Far East by the Royal Geographic Society of Russia, E. Ahnert devoted his life to the geology of Central and North Manchuria and the maritime province of the U.S.S.R. and made valuable contributions until his death in 1945.

At the end of the last century, however, Manchuria was still not far removed from *terra incognita* geologically. At the beginning of this century fossil plants from Manchuria were described by F. Krasser (1905), M. D. Zalessky (1905), I. V. Palibin (1906) and M. Yokoyama (1908), and Cambrian Fossils by C. D. Walcott (1913). Subsequently many papers on Cambrian fossils, the Hokang and Peipiao coal field, etc. were published by Sun (1923), Tan (1924), Wong (1927) and others.

Among Japanese geologists, Kochibe was the first to be sent to Manchuria. He surveyed coal and gold resources in the Liaotung peninsula in 1895. Subsequently in 1905, T. Ogawa and other geologists made geological surveys of the Wuhutsuei, Yentai, Fushun and other mines. In 1907, the Geological Institute was established at the South Manchurian Railway Company at Talien. Since then systematic investigations in South Manchuria have advanced steadily.

In 1928 two geological institutes were established at the Ryojun College of Engineering and at the Manchurian Teachers' College, and a number of studies were carried out by their staffs. Among them were R. Endo's study on the Cambrian and Ordovician Fossils, Matsushita's study on the geology of the Chinchou and Talien areas, and Ogura's study on Wutailienchi and other volcanoes, etc. Since 1928 the geological institute of the railway company published the Talien sheet and several other geological maps (scale: 1/400,000) and explanatory texts for each. In 1931 this institute sent some parties to Central and North Manchuria; the results included a geological map of Manchuria (1/1,000,000) and 4 volumes of Geology of Manchuria (1937). In 1933 Tokunaga led the Manmo Science Expedition to Jehol and the results were published in a series, in which a report of explorations (1933, 1934) at Kuhsiangtun near Harbin is included.

In addition to these there are large numbers of papers written by professors and their students in the universities in Japan, e.g., YABE and HAYASAKA's "Palaeozoic corals" (1915–16), HAYASAKA's "Brachiopods from Penhsihu" (1922), M. MATSUYAMA's "Gravity anomaly in Fushun coal-field" (1924), OZAWA's "Upper Palaeozoic fossils" (1926), S. ENDO's "Cenozoic fossil plants" (1926–28), KOBAYASHI's "Cambro-Ordovician" (1927–1966), UWATOKO's "Oil shale of Fushun" (1931), YABE and OISHI's "Mesozoic plants" (1935), etc. OZAKI's "Upper Palaeozoic Brachiopods" and OKADA's "Natural Na Compounds" belong to the contributions from the Shanghai Science Institute, founded in 1928.

After 1931, or thereabouts, surveys of the mineral resources of Manchuria became very active. In 1937 the Geological Survey was transferred from Talien to Changchung; the Geological Society of Manchuria was instituted in 1939. The systematic exploration of Kuhsiangtun was undertaken in 1938 and 1939 and several valuable works in palaeontology were produced by the staff of the Manchurian Central Museum. Knowledge of the geology of Central and North Manchuria increased very rapidly in the 15 years before the end of World War II. Sinian and other Palaeozoic fossils were described by YABE, EGUCHI, NODA and several others; Mesozoic and Tertiary coal-bearing formations were clarified considerably by MORITA, NISHIDA and many others; non-marine Mesozoic fossils were studied by KOBAYASHI, SUZUKI, TAKAI and a few others; intensive studies were made of the Pre-Cambrian geology by MATSUSHITA, SAITO and some others.

In addition, there are studies on "Banded iron ore of Anshan" (MURAKAMI, 1922), "Magnesite of Tashihchiao" (NIINOMI, 1923), "Bauxite shales" (SAKAMOTO, 1924), "Kungchangling iron ore deposit" (TSURU, 1935), etc. Other contributions to economic or applied geology are too many to mention here.

The results of the geological research achieved near the end of the war largely remained unpublished, until a committee in the Tokyo Geological Society undertook the project of compiling *The Geology and Mineral Resources of Eastern Asia*. The recent advancement in stratigraphy of South Manchuria is summarized in *Scientific Reports of the Stratigraphic Conference* published in 1964 at Peking. The reader is referred to a brief note in "Geology of South Korea," in volume I of this publication, for the history of research on the geology of Korea.

2. Outline of the Geology of North Korea and South Manchuria

Between the central plain of Manchuria on the west and the Hanka-Suifun plain on the east, the mountainous land of East Manchuria extends into Korea. The Sinian or northeast trend is predominant in the orography of East Manchuria. Following this trend are the Wantashan, Laochangkuang, Sueiling and Sahalianglling ranges, all of which are parallel to the Changpaishan range and the national boundary, which is marked by the Touman and Yalu rivers, respectively on the northeast and southwest side of Mt. Paektu or Changpaishan.

In North Korea the Kaema plateau on the east side is tilted up and cut by a steep scarp on the southeast. In front of its middle part there is the Kilchu-Myeonch'eon graben and the Ch'ilbosan horst beyond the graben. On the west side of the plateau there are several ranges with a Sinian trend. The Weonsan-Seoul rift valley runs diagonally across the Korean peninsula, Following a NNE trend, as does the Myeonch'eon graben. The Taebaeksan range is the backbone of the peninsula that runs through Central Korea near the Sea of Japan. Its northern extension is the Nangim range, which parallels the Paektu volcanic range running across the Kaema plateau.

From the stratigraphic point of view Central and North Manchuria, to which the northern part of the east Manchurian mountainous land belongs, are quite different from South Manchuria, which in turn is intimately related to Korea except for the northeastern part, called the Touman area. As discussed elsewhere (Kobayashi, 1942), Central and North Manchuria was a part of the Mongolian

Table 1. Two Types of Stratigraphic Sequences of Older Rocks in Korea-Manchuria.

<table>
<tr><th>Geological Age</th><th colspan="3">South Manchuria and North Korea</th><th>North and Central Manchuria</th></tr>
<tr><td>Triassic</td><td colspan="3"></td><td>Mongolian Batholith</td></tr>
<tr><td>Permian</td><td rowspan="2">P'yeongan Group</td><td colspan="2">Nogam Series
Gobang Series
Sadong Series</td><td rowspan="4">Manmo group</td></tr>
<tr><td>Carboniferous</td><td colspan="2">Hongjeom Series</td></tr>
<tr><td>Devonian</td><td colspan="3" rowspan="2">(Kyeomip'o Ls. Cg.)</td></tr>
<tr><td>Silurian</td></tr>
<tr><td>Ordovician</td><td rowspan="2">Korean Group</td><td>Toufangian
Wolungian
Wanwanian</td><td rowspan="3">Rakuroan Complex</td><td rowspan="5">?</td></tr>
<tr><td>Cambrian</td><td>Chaumitian
Fuchouan
Mantoan</td></tr>
<tr><td rowspan="3">Cryptozoic</td><td>Sinian Group</td><td>Kuhyeon
Sadongmor
Chikhyeon</td></tr>
<tr><td colspan="3">Mach'ollyong Group</td></tr>
<tr><td colspan="3">Older Metamorphose Complex</td></tr>
</table>

geosyncline where the Manmo group had accumulated. The geosyncline was disturbed by the Akiyoshi cycle of orogeny in the Permo-Triassic period. During the orogeny, batholithic invasion of the Mongolian granitic magma oronized a major part of the geosyncline. The Triassic and Upper Palaeozoic history of this geosyncline is allied to the Chichibu geosyncline of Japan.

Korea and South Manchuria, on the contrary, occupy the northeastern part of the Koreo-Chinese Heterogen. In the positive elements of this Heterogen, the Pre-Cambrian basement is widely exposed. In the negative elements there are Proterozoic and Palaeozoic formations to which a part of the Triassic system is added. In the Hwangho basin on the north side of the Tsinlingshan, however, there is a large Middle Palaeozoic break in the stratigraphic sequence.

The tectonic lineament of Korea which I proposed in 1933 needs little emendation, but was modified in 1953 to include adjacent areas. Together with a part of North Korea, the larger part of South Manchuria belongs to the Liao-Kaema land where the ancient basement complex is largely bared. On the western side of the land, however, the positive and negative zones are arranged alternately from north to south as follows:

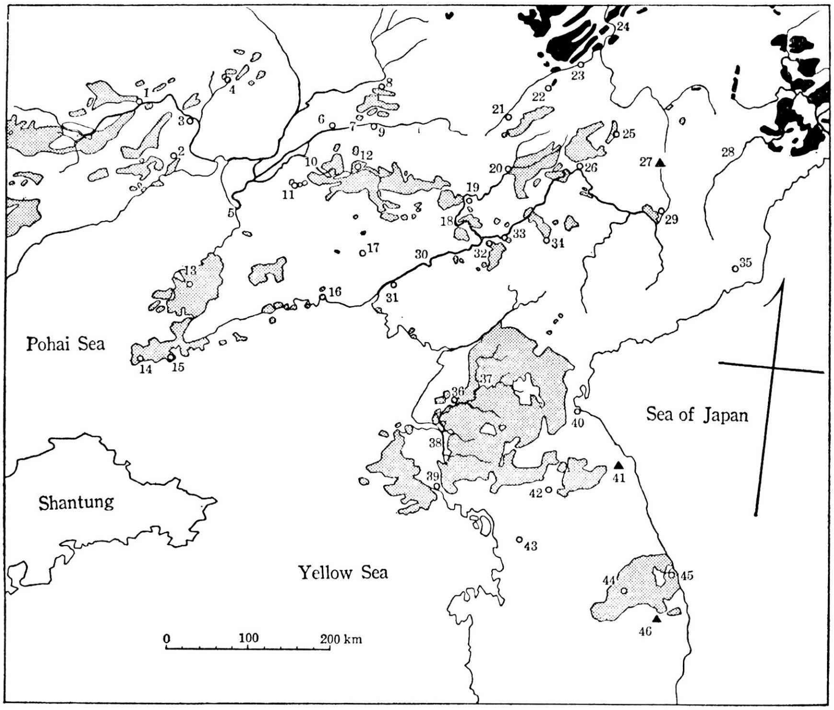
1. Kaiyuan zone of elevation
2. Tiehling zone of depression
3. Shenyang (Moukden) zone of elevation
4. Taitzuho zone of depression
5. Pyeongbuk zone of elevation

The elevated zones are bare, but the depressed zones are mantled with Palaeozoic and Proterozoic veneers. The P'yeongnam geosyncline which extends from North Korea into the Liaotung peninsula is on the south side of the fifth zone. This geosyncline is separated from the Okch'eon geosyncline in South Korea by the Kyonggi-Shantung land.

The ancient basement rocks are exposed extensively in the Liao-Kaema land. In 1926 KAWASAKI proposed the *Mach'ollyong (Matenrei) system* for metamorphic rocks in the Kaema plateau, which reveal a grand cycle of sedimentation, 12,500 m in total thickness, with the *Collenia*-bearing carbonate facies in the middle part (KINOSAKI, 1932, 38). The upper part of the system, now called the *Namtaech'eon series,* includes rocks 1600 to 1630 million years old. The Archaean basement complex of North Korea is composed of Nangim gneiss and crystalline schists, Andoli basic intrusive rocks and Yonghwasan (Renkwasan) acidic intrusives and one old intrusive rock was estimated at 2040 million years (MASAITIS et al., 1964; KIM, 1967).

In Korea the Pre-Cambrian granites were collectively called *Kokulian granite,* but TATEIWA (1926) distinguished the older or Hamhŭng (Kanko) from the younger or Seohochin (Seikoshin) granitic gneiss in North Korea. In South Manchuria the older and younger granites are called Tueimienshan and Kungchangling granite, respectively. Pre-Cambrian granites, however, are undifferentiated in most areas.

In South Manchuria the *Anshan series,* which bears banded iron ore, is unconformably underlain by the Tueimienshan granite and intruded by the Kungchangling granite (Saito, 1941). Pegmatite from the series was estimated to be 2100 to 2300 million years old (Comm. Strat. China, 1964). Muscovite from a chlorite-muscovite schist along the contact of enriched ore body of Anshan, and muscovite in the western marginal part of the Anshan series were estimated to be 2270 and 1909 million years old, respectively (Li Pu, 1965). Like the Mach'ollyong system,



Sinian, Korean and P'yeongan Groups

Manmo Group

Fig. 1. Distribution of the Rakuroan Complex and P'yeongan Group in North Korea and South Manchuria

1. Chaoyang 2. Chinchou 3. Ihsien 4. Fuhsin 5. Liaoho 6. Shenyang (Fengtien, Moukden) 7. Hunho 8. Tiehling 9. Fushun (Bujun) 10. Taitzuho 11. Anshan (Anzan) 12. Penhsihu (Honkeiko) 13. Fuchou 14. Lüshun (Ryojun, Port Authur) 15. Talien (Dairen) 16. Takushan 17. Fenghuangcheng 18. Hunchiang 19. Huanjên 20. Tunghua 21. Liouho 22. Hueinan 23. Huatien 24. Mutanchiang 25. Fusung 26. Lingchiang 27. Changpaishan, Paektu-san (Hakutosan) 28. Touman river 29. Changpai 30. Yalu river 31. Sinŭiju (Shingishu) 32. Ch'osan (Sosan) 33. Wiweon (Igen) 34. Kanggye (Kokai) 35. Kilchu (Kishu) 36. P'yeongyang (Heijo) 37. Taedong-gang (Daidoko) 38. Chaeryeong-gang (Saineiko) 39. Haeju (Kaishu) 40. Weonsan (Genzan) 41. Kŭmgang-san (Kongosan) 42. Ch'eolweon (Tetsugen) 43. Seoul (Keijo) 44. Yeongweol (Neietsu) 45. Samch'eok (Sanchoku) 46. Taebaegsan (Taihakusan)

the *Liaoho system* (SAITO, 1938) represents a large sedimentary cycle, 14,000 m at its thickest and extensive on the Manchurian side of the Liao-Kaema land. The middle part, the *Tashihchiao series,* is mainly composed of marble and dolomite and contains magnesite deposits. It was previously considered older than the Anshan, but 1400 million years was given for the age of a pegmatite in the Liaoho group. At Howfin, Anshan, the Anshan series is unconformably overlain by the *Langtzushan seires,* which is the lower division of the Liaoho group (MA and LIN, 1966). It is quite probable that the Liaoho group belongs to the same formation as the Mach'ollyong system.

The ancient basement complexes are discordantly overlain by the late Proterozoic Sinian, the Cambro-Ordovician Korean (or Chosen) and the Upper Palaeozoic to Triassic Heian (or P'yeongan) groups. The first and second groups are collectively called the *Rakuroan (Naknang) complex.*

The sequence and thickness of the Sinian group are very different in the depressed zones. It is best developed in the P'yeongnam geosyncline where it is represented by a grand cycle of sediments, several thousand meters in thickness, called the Shogen (Sangweon) group; the middle and upper parts are often separated by a disconformity. The group is totally absent, however, in the Okch'eon geosyncline of South Korea, although there is an excellent display of the Korean and P'yeongan groups. The middle and upper Sangweon group is well developed in the Tiehling zone, but no Palaeozoic formation is present. Therefore it can be said that there

Table 2. Four Types of the Stratigraphic Sequences in the Zones of Depression in Korea and South Manchuria.

Tiehling Zone	Taitzuho Zone	P'yeongan Zone	Okch'eon Zone
		P'yeongan Group	P'yeongan Group
	Taitzuho Group		
	Korean Group	Korean Group	Korean Group
Up. Fanho Series		Kuhyeon Series	
Low. Fanho Series		Sadongmor Series	
	Hsiho Series	Chikhyeon Series	

was a reciprocal relationship between the emergence of the northernmost zone and the submergence of the southernmost zone which took place at the transition from the Proterozoic to the Palaeozoic era.

The remarkable differences in the distribution of the Sangweon group among these subsiding zones is shown in Table 2.

Although the difference in facies and thickness is fairly distinct between the axial and peripheral parts of the Okch'eon geosyncline, the Korean group is monotonous in most other zones. The group in Korea was first divided into the Yangdeok series below and the Great Limestone series above. Shale and sandstone are more abundant than carbonates in the basal part; the remainder is composed mostly of limestone and dolomite. The sequences of the group in the P'yeongnam and Taitzuho zones resemble each other; their average thickness is about 1,500 m.

It is noteworthy that the Korean group is generally overlain by the P'yeongan group para-unconformably in the vast Hwangho basin, even though there is such a large stratigraphic break corresponding to the prolonged period of emergence from late Ordovician to early Carboniferous. It is quite evident that neither the Caledonian nor the Variscan orogeny existed in this region.

The P'yeongan group in Korea is divided into four series, known as the Hongjeom, Sadong, Gobangsan (Koten, Jido, Kobosan) and Nogam (Green) series. Its equivalent in South Manchuria is the Taitzuho group which is also divisible into four series, called in ascending order the Penchi, Huangchi (or Yatung), Lioutang and Tsaichia series. As shown in Table 3, however, it must not be overlooked that the Nogam series is apparently absent in South Manchuria and that the Huangchi and Lioutang series are combined into the Sadong series in Korea. Marine fossils are present in the Hongjeom and a part of the Sadong series in Korea and South Manchuria, but not in the Gobangsan and later sediments.

Silurian derived fossils in the Older Mesozoic conglomerate near Kyeomip'o (Kenjiho), North Korea, indicate a local ingression of the Silurian sea into the P'yeongnam geosyncline. It is also noted here that Devonian type corals are reported from the basal part of the P'yeonan group at two localities in the P'yeongnan and Okch'eon zones, which used to be referred to the Hongjeom series. Whether this coralline limestone is Devonian in age or whether they are relic corals in the Moscovian sea is unclear (YABE and SUGIYAMA, 1939).

The Hwangho basin was not deformed much until the Middle Triassic epoch. Therefore the Shogen, Korean and P'yeongan groups generally accumulated in the Hwangho basin or in the P'yeongnam geosyncline, the Taitzuho depression or other subsiding basins. This accumulation has para-unconformable or disconformable relations except for a few small spots where angular discordance is reported. This long-lasting basin was, however, destroyed by the Songnim disturbance.

Broadly speaking, the Palaeozoic was the epirogenic era whereas the Mesozoic was the orogenic era for Eastern Asia. Therefore the Mesozoic stratigraphy must be established before the orogenic movements can be analyzed into phases. The stratigraphic study of the Mesozoic is more difficult than the Palaeozoic, in proportion to this tectonic importance, because Upper Triassic and later formations were deposited in separate basins, each having its own history. Accordingly no two basins have the same sequence. Moreover, guide fossils are scarce in the non-marine sediments and their facies change horizontally as well as vertically, as is usual with orogenic sediments. Therefore some ambiguities remain in the Mesozoic stratigraphy of the continent. An analysis of the crustal movements by means of the Mesozoic strata is shown in Table 4.

Table 3. Relation between the P'yeongan and Taitzuho Groups.

Geological Age	Okch'eon and P'yeongan Zones		Taitzuho and Yalu Areas	
Anisic	Greenstone (Nogam)	P'yeongan Group		
Skytic				
Tartarian	Kobosan (Gobangsan)		Tsaichia	Taitzuho Group
Kazanian				
Kungurian	Jido (Sadong)		Lioutang	
Artinskian				
Sakmarian			Huangchi	
Uralian	Koten (Hong'eom)			
Moscovian			Penchi	

Table 4. Mesozoic Formations and Crustal Movements.

Palaeocene Upper Cretaceous	Pulguksa Igneous Activity and Block Movements
Middle Cretaceous	Silla Series
	Late Taiho (Taebo) Disturbance
Lower Cretaceous	Naktong Series
	Early Taiho (Taebo) Disturbance
Oolite	Jehol Series
	Gishu (Ŭiju) Disturbance
Rhaeto-Lias and Keuper	Daedong Series
	Shorin (Songnim) Disturbance
Bunter	Nogam Series

The Triassic Shorin (Songnim) disturbance was paroxysmal in the P'yeongnam geosyncline. It was, however, probably no more than embryonic folding for the Taitzuho and Okch'eon zones where the late Mesozoic Taiho (Taebo) disturbances were strong. The Songnim mountains of the P'yeongnan zone were also modified greatly by the Taebo movement.

The Daedong (Daido) series is distributed widely in Korea and contains a copious flora which KAWASAKI (1925) has referred to Lias. But a part of the series is now thought to be older than Lias, because of the occurrence of some Estherian species common to the Upper Triassic Mine series in West Japan. (KOBAYASHI, 1951). Because the series is composed of synorogenic or metaorogenic sediments, its precise classification is important for a better understanding of the Songnim disturbance.

In Central and South Manchuria plant fossils related to the Daedong flora are known to occur at Saimaki, Wafangtien and some other localities, but *Clathropteris,* which is almost ubiquitous in the Daedong localities in Korea, is not found in Manchuria except at Tienshuaifukou.

The Jehol fauna is known from Ŭiju near the embouchure of the Yalu river, whence the Gishu (Ŭiju) movement was proposed by TAKAHASHI (1950) on the basis of the discordance between this and the Daedong series. Because of the limited distribution of the Jehol series in Korea and adjacent Manchuria, however, it is difficult to distinguish the deformation of the Ŭiju phase from the later ones.

The late Mesozoic Taiho (Taebo) disturbance was strong and extensive in Eastern Asia. In South Manchuria it is well marked by discordances at the bases of the Penhsihu-Tayü formation in the Penhsihu coal-field and of the Pulantien formation at the neck of the Liaotung peninsula. In the P'yeongyang (Heijo) coal-field there is a distinct discordance at the base of the Taebo series. Hence the name Taebo (Taiho) disturbance. The lithology of this series is more like the Middle Cretaceous Silla (Shiragi) than the Lower Cretaceous Naktong series of South Korea. In South Korea the Naktong, containing *Plicatounio,* is overlain disconformably by the Silla series and the latter in turn is overlain disconformably by the Pulguksa (Bukkokuji) volcanic series. Therefore the Taebo disturbance may be split into the pre-Naktong or the first Taebo phase and the pre-Silla or the second Taebo phase. For the Wafangtien and Penhsihu basins the first Taebo movement was more important than the second.

During the Cretaceous period violent volcanic eruptions took place. The effusive rocks were mostly andesitic in the earlier stage, and liparitic in the later. At the same time as the later effusion in the late Cretaceous period there was batholithic invasion of granitic magma, which may have continued till the beginning of the Tertiary. This is called the Pulguksa igneous activity and was intimately related to the block movement. In view of the thrusting of the neighboring block upon the Penhsihu or Tayü formation, the movement was compressive at the beginning, but later became tensional. The magmatic invasion was on a grand scale and, as a result, the terrain was completely oronized or consolidated and stabilized.

Table 5. Cainozoic History of Korea and South Manchuria.

Alluvium	Salt-Field on Pohai Coast Peat Deposti; Basalt Cones in Central Manchuria
Diluvium	Naknang and Liaotung Peneplains Malan Loess Kaema Plateau Basalt
Pliocene	Yeoju and Kuangningszu Piedmont Planes (Plateau Gravels) Ch'ilbosan Volcanic Series
Miocene	Hamgyeong Fault System Yukpaek Plane Myeongch'eon Series
Oligocene Eocene	Yongdong Basalt Yongdong Series Fushun Series; Pongsan Series
Palaeocene Senonian	Pulguksa Igneous Group

Tertiary sediments are very scarce in this region. Therefore it is difficult to decipher this part of the history. At Pongsan near Sariweon, Hwanghae-do, North Korea, there is a coal-bearing formation which yielded late Eocene mammals that are intimately related to the Shara Murun and Irdin Manha faunas of Mongolia (TAKAI, 1939).

The Palaeogene coal-bearing deposits of Fushun, east of Shengyang, comprise a formation more than 1,000 m thick, overlying the ancient granitic gneiss and late Mesozoic formations. It may be coeval with the Pongsan coal-bearing formation or a little younger, because the Fushun flora is Oligocene according to FLORIN (1922), but late Eocene according to S. ENDO (1934). The latter opinion is upheld by *Anostreia manchuriana* R. ZANGERI from the oil shale of the series, which is similar to *A. ornata* LEIDY from the Eocene of North America (IMAIZUMI, 1951).

The Oligocene Yongdong (Ryudo) formation in North Hamgyeong-to is composed of coal-bearing sediments in its lower part and alkaline basalt in its upper part. It lies on the fairly level surface of the basement, which consists of the Mach'ollyong metamorphic rocks, ancient granitic gneiss and the older Mesozoic formation. It is disconformably overlain by the paralic Myeongch'eon (Meisen) formation, about 700 m thick. *Bunolophodon annectens* and other fossils from the upper part are middle Miocene in age.

Subsequently the Kaema plateau was tilted, causing faulting of the Hamgyeong (Kankyo) system in a NE to NNE direction along the southern periphery (TATE-

IWA and YAMANARI, 1925). As a result, the Kilchu-Myeonch'eon graben and the Ch'ilbosan horst appeared in front of the plateau. It is certain that this block movement occurred before the Ch'ilbosan volcanic series, which is considered Pliocene in age. On the plateau there still remains the Yukpaeksan (Roppyakusan) plane, which is the unfinished or incomplete peneplain of a previous erosion cycle. The front of the plateau was strongly dissected by the headward erosion of young rivers to form a steep scarp.

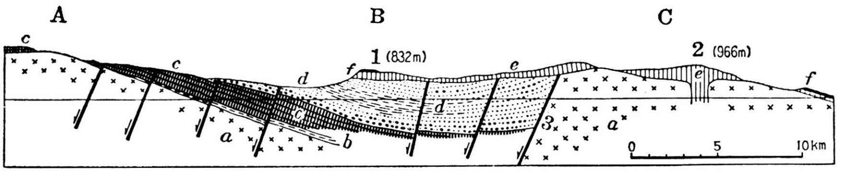


Fig. 2. Kilchu-Myeongch'eon (Kishu-Meisen) Graben and Ch'ilbosan (Shichihosan) Horst (after TATEIWA).

A. Kaema Plateau B. Kilchu-Myeongch'eon Graben C. Ch'ilbosan Horst
1. Chaeteok-san 2. Ch'ilbo-san 3. Kilchu-Myeongch'eon
a. Basement Complex b. Yongdong (Ryudo) Coal-bearing Formation
c. Yongdong Alkaline Basalt d. Myeongch'eon Series
e. Ch'ilbosan Volcanic Series f. Pleistocene Basalt

As discussed on a former occasion (1953), strong faulting occurred in the Taebaegsan (Taihakusan) dislocation zone in Central Korea during the Pulguksa igneous activity, but the subsequent peneplanation was far advanced by the Middle Tertiary period. The Taebaegsan backbone range was elevated in the middle Neogene in the form of an asymmetrical geanticline, as is traceable with the Yukpaeksan plane. The oldest deposits on the marginal peneplain are upper Miocene. They are found at Samch'eok, Yeonghae and Yeonil. All have boulder conglomerates at their base and at the last named locality lie with strong discordance on the Middle Tertiary formations. Thus there were two important phases of movements in Korea, one in late Cretaceous or early Palaeogene times and the other in Middle Tertiary or middle Neogene times.

In Manchuria the Middle and Upper Cretaceous Sungari series, which forms the bottom of the central basin, is mostly underformed, but is tilted up along the Taheishan range. Behind the range at Kangyao and other places there is a spatulate depression where the Palaeogene formation overlies the Upper Palaeozoic Chilin formation. Granite intrudes it and dips to the other side, forming some undulations.

The Palaeogene of Fushun fills a narrow trough along the Hunho river, and dips 20 to 30 degrees to the north. It is cut by a strike fault or, in part, an upthrust. The southerly inclined Diluvium near Yungantai indicates the recurrence of movement along the same trend in the near past. The Palaeogene monocline is thrust from the northwest. This disturbance belongs to the Liao system of dislocation, from which the Sungari and Kangyao formations have suffered.

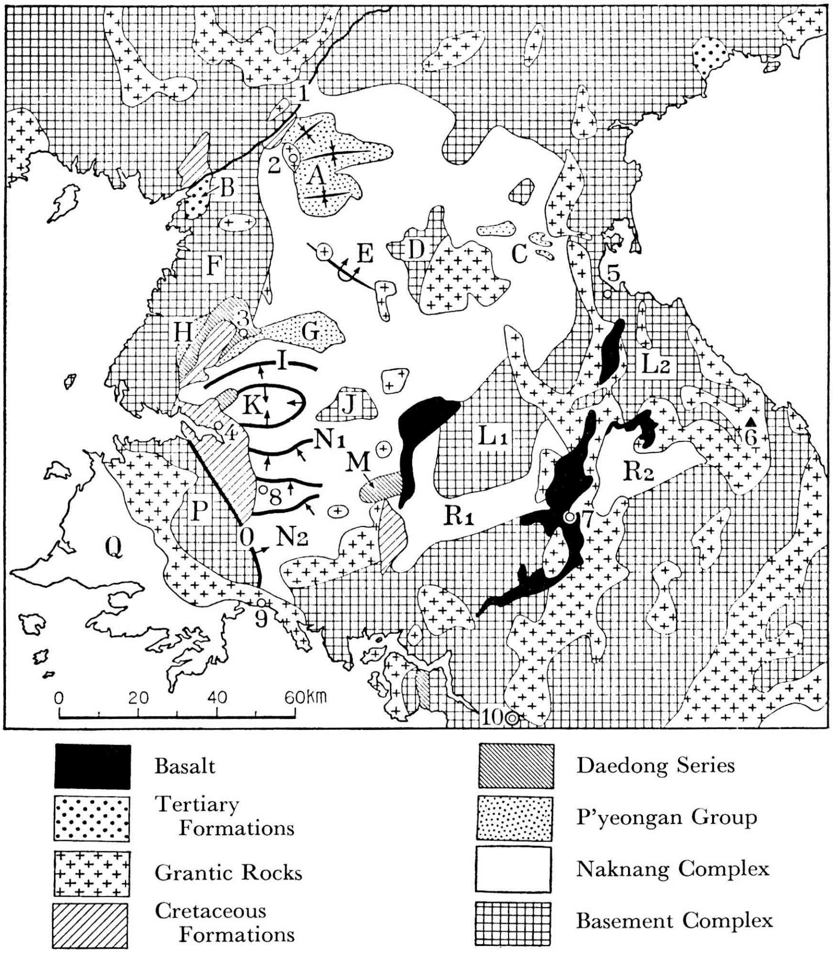


Fig. 3. Tectonic Division of the Orogenic Zone in North Korea

A. North P'yeongan-namdo Coal-Field
B. Anju (Anshu) Tertiary Formation
C. Koweon (Kogen) Coal-Field
D. Yangdeok (Yotoku) Dome
E. Seongch'eon (Seisen) Anticlinorium
F. P'yeongweon (Heigen) Block
G. Kangtong (Koto) Coal-Field
H. Kangseo (Kosai) Coal-Field
I. Chunghwa (Chuwa) Disturbed Zone
J. Chungbongsan (Sohozan) Dome
K. Hwangju (Koshu) Basin
$L_1/_{-2}$ Ich'eon-T'ongch'eon (Isen-Tsusen) Basement Anticline
M. Pongsan (Hosan) Group
$N_1/_{-2}$ Chaeryeong-gang (Saineiko) Disturbed Zone
O. Annak (Angaku) Fault
P. Sinch'eon (Shinsen) Block
Q. Changyeon (Choen) Disturbed Zone
$R_1/_{-2}$ Kumch'eon-Kumhwa (Kinsen-Kinkwa) Syncline

1. Ch'ongch'eon-gang (Seisenko) 2. Kaech'eon (Kaisen) 3. P'yeongyang (Heijo)
4. Kyomip'o (Kenjiho) 5. Weonsan (Genzan) 6. Kŭmgang-san (Kongozan)
7. Ch'eolweon (Tetsugen) 8. Sariweon (Shariin) 9. Haeju (Kaishu) 10. Seoul

The Chinchou fault in the Liaotung peninsula is also parallel to the Liao tectonic line which delimits East Manchuria. Its southwestern extension is occupied by the I-Wei graben which divides the Shantung block into two parts. The Palaeogene Kuanchuang series and older formations and rocks in Western Shantung are repeatedly cut by a series of step-faults with the downthrow on the southwest side. This faulted block is truncated by the I-Wei graben.

Unless the gravel beds, which are overlain by the Kaema plateau basalt on the Yukpaeksan plane, is Pliocene, no sediment of this age is present in South Manchuria. During this period of emergence the mountainous lands were fringed by piedmont steps called the Yeochu (Rishu) plane in Korea and the Kuangningszu (Koneiji) plane in Liaotung.

According to TATEIWA (1925), 3 or more series can be distinguished among the Diluvium and later basalts, among which the Kaema basalt is the oldest and most widespread.

Near P'yeongyang there is a low peneplain called the Naknang (Rakuro) peneplain, 20 to 50 m above sea-level. Its equivalent at a similar altitude in Liaotung is called the Liaotung peneplain or the Pitzuwe (Hishikwa) plane. It is dissected by valleys in which peat was deposited during subsidence. The latest emergence is indicated by salt fields around the Liaotung peninsula or the Pohai sea.

II
THE P'YEONGNAM (HEINAN) OROGENIC ZONE IN NORTH KOREA

1. **Introduction** (see Geological Map I)

I proposed the name "Heinan geosyncline" for the zone extending from P'yeongan-namdo and Hwanghae-do in North Korea to the Liaotung peninsula in 1930, because the very thick Shogen (Sangweon) group distributed in this zone is overlain by the Korean and Heian (P'yeongan) groups, which are also thick. These groups were strongly folded and thrust by the Middle Triassic Shorin (Songnim) disturbance. The Daedong series was subsequently deposited as a lacustrine sediment in intermontane basins of this folded zone. Its structure was later greatly modified by the Taiho (Taebo) disturbance at the transition from Jurassic to Cretaceous. During the Cretaceous period strong igneous activity took place and the Silla series, rich in pyroclastic material, accumulated there. The volcanic eruptions were followed by a batholithic invasion of granitic magma, through which the zone was well oronized. There was block movement near the end of the Cretaceous or the beginning of the Tertiary period. During the tranquil Palaeogene period, the land was levelled by erosion. In the Middle Tertiary period intense block movement occurred. The marginal peneplain called Rakuro (Naknang) is a product of later erosion.

a. Tectonic Lineament.

In North Korea the P'yeongnam folded zone is delimited by the Ch'ong-ch'eongang (Seisenko) river on the north and the Haeju-Ch'eolweon line on the south. The P'yeongbuk massif lies to the north and the Kyeonggi massif to the south. The zone is divided into two parts by a basement ridge which wedges to the ENE through Ich'eon and T'ongch'eon, the principal part being on the north-west side. On the other side there is a narrow auxiliary part through Kŭmch'eon and Kŭmhua. The Sangweon group forms a broad syncline in the Kŭmseong area with the axis trending ENE (Takahashi, 1955). The principal part is a subquadrate basin which is called the "Daidoko (Daedonggang) basin." It is separated by the Annak fault from the Sinch'eon tilted block to which the Changyeon folded zone of the Sangweon group is added to the west. The P'yeongweon block exists north of this block.

The Daedonggang basin consists of disturbed belts and folds with short axes. The basement domes of Yangdeok and Chŭngbongsan are aligned with the Sinch'eon block and the Pyeongp'ung-san projectile in a line nearly parallel to the basement ridge of T'ongch'eon and Ich'eon.

The distribution of the P'yeongan group indicates the sites of brachysynclines. More precisely, a few patches of the group, to the east of the Yangdeok dome, form the Koweon coal-field. On the northwest side of the dome is the north P'yeongan-namdo coal-field where the group forms a triaxial structural basin. Near P'yeong-yang the Kangtong and Kangseo coal-fields of P'yeongyang lie on the east and west side, respectively, of the Daedonggang river. The Hwangju basin which lacks the P'yeongan group, is further south. All of these basins have equatorial axes. The Seongch'eon disturbed belt is found between the P'yeongyang and north P'yeon-gan-namdo basins. The Chunghwa belt is found between the P'yeongyang and Hwangju basins. South of the last basin is the broad Chaeryeonggang disturbed belt, which branches off into two wings in the east by the insertion of the Ich'eon-Tongch'en ridge. These disturbed belts are anticlinoria which are, however, in some way strongly deformed. They are distributed alternately with the structural basins. It is the general tendency for calcareous rocks of the disturbed belt to be deformed more than the coarse clastics of the coal basins. The Imch'eon shale, Sunch'eon clayslate or the like often serves as a lubricant in tangential displace-ment.

In the eastern part of the Daedonggang basin the rocks are largely metamor-phosed. The Sangweon group is wider there than in the west. The Korean group is almost unfossiliferous except for the Koweon and Munch'eon coal-fields where some fossils occur in Ordovician limestones as well as in the P'yeongan rocks (Kodaira, 1930). Much still remains to be studied on the geology of this part.

In marked contrast with this, the geological survey is well advanced and the structure is known in great detail in the western part along the Seoul Sinŭiju railway line. There the Daedonggang basin measures about 200 km from north to south. In the northern 50 km or so is the northern basin of the P'yeongan group, which is surrounded by belts of the Korean and Sangweon groups. The Seong-ch'eon belt is a complicated anticlinorium, with the Sangweon group in the core and the Korean group on the two wings. The P'yeongyang coal-fields mark the median synclinorium of the P'yeongan group. The southern 70 km, called the Chaeryeong belt, are composed chiefly of the Sangweon group. This section of the Daedonggang basin can be divided broadly into the following three parts:

1. The northern part, composed of the Sangweon, Korean and P'yeongan groups; many thrusts toward the south or southwest in the Seongch'eon belt.
2. The median part, composed mostly of the Korean and P'yeongan groups; many thrusts toward the north in the Chunghwa belt.
3. The southern part, composed of the Sangweon group.

The boundaries of the parts are not sharp. The Kangtong thrust is taken here as the boundary between the northern and median parts. The median part is most sunken. The thrusts in the Seongch'eon and Chunghwa belts are directed toward the synclinal axes of the P'yeongyang coal-fields. With regard to the Seongch'eon anti-clinoriumt he north P'yeongan-namdo coalfield may be called a hinter basin. The southern part, devoid of the Korean and P'yeongan groups, is the most elevated. The Chang'yeon disturbed belt represents its western extension. Tilted up along the Annak fault, the sedimentary blanket was taken off and the basement exposed widely in the Sinch'eon block. The P'yeongweon block, on the other hand, is a dome elevated reciprocally to the subsidence of the northern coal-basin. The Sangweon group still remains on some isles and the coast of the west Korean bay. (TAKAHASHI, 1952).

b. Crustal Movements.

The folded structure of the Daedonggang basin was first thought to be a product of the late Mesozoic Taebo disturbance. I emphasized the great importance of the Songnim disturbance in 1930 when I discovered a remarkable clino-unconformity between the Ordovician and Daedong formations at Songnim-ni (Shorin-ri), Kyeomi-p'o at the northwest side of the Hwangju basin. Subsequently HORIUCHI also found a clino-unconformity at the base of the Jurassic formation at Wafang-tien at the neck of the Liaotung peninsula, which belongs to the same zone of folded mountains. Still later KOBATAKE and others found several examples of the pre-Daedong clino-unconformity in the coal-field. Thus MATSUSHITA, KOBATAKE and IKEBE (1952) referred the principal folding and thrusting of the P'yeongyang coal-field to the Songnim disturbance. They further concluded that the already folded terrain was secondarily deformed by reverse faulting and sliding in the Taebo disturbance.

The early Mesozoic Songnim disturbance was an important phase of crustal deformation through which the P'yeongnam geosyncline became folded mountains. The Daedong series is made up of orogenic sediments deposited in inter-montane basins. It is distributed most extensively from P'yeongyang to the western coal-field of this town. In addition, a patch of the series is found on the north-western side of the Hwangju basin. Its age can be determined on the basis of the

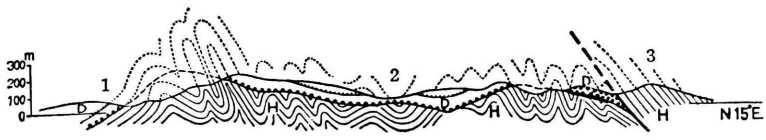


Fig. 4. Clino-unconformity of the Songnim phase in the West P'yongyang Coal-Field. (After Matsushita, Kobatake and Ikebe).

D. Daedong Series H. Pyeongan Group
1. Songui-ni 2. Anjong-ni 3. Songhak-san

plants, molluscans and estherians present. East of Sinmak near the bifuraction of Chaeryeong disturbed belt, there is the so-called Posan (Hosan) formation of unknown age. Judging from the clino-unconformity at its base, its lack of volcanic material and its equatorial axis of folding, this formation most probably belongs to the Daedong series (Kobayashi, 1930). On the northwest side of the northern coal-basin there is a small Mesozoic area which extends along the south bank of the Ch'ongch'eon-gang. Other patches of a Mesozoic formation are found on both sides near the mouth of this river. They have not, however, been well surveyed.

Subsequent to the Taebo disturbance strong volcanic eruptions took place. The Silla series is a sediment of this age. It is extensive in the lower Ch'aeryeong-gang valley and the western coal-field of P'yeongyang and yields early Cretaceous plants in rare instances. Cut by a meridional fault, the red formation of P'yeongsan, 800 to 900 m thick, forms a half basin along the Yeseong-gang (Reiseko) river. It consists of tuff and conglomerate and is separated into lower and upper parts by a middle tuffaceous shale and mudstone. This red formation is considered a member of the Silla series (Takahashi, 1955). The Pongsan coal-field to the east of Sariweon is a small basin in the Sinian Sangweon terrain where early Eocene mammalian remains were discovered (Takai, 1939). At the mouth of the Ch'ongch'eon-gang on the south bank there is the so-called Anju formation which may be Palaeogene in age (Hatai, 1952). The Silla series in the lower Ch'aeryeong-gang is cut by the Annak fault. This fault extends in a straight line from the vicinity of Haeju to the north northwest for about 100 km as far as Kyeomi-p'o and then shifts a little to the east in the north of this town. The Pongsan Palaeogene is cut by this fault system (Matsushita, Onoyama and Maejima, 1935). Therefore it is certain that dislocation has recurred in this fault system due to the Middle Tertiary disturbance. The Weonsan Seoul rift valley cuts obliquely across the basement ridge of T'ongch'eon and Ich'eon and the southern wing of Kŭmch'eon and Kŭmhwa. Basalt effused during the Pleistocene in this valley and also in the valley of the Yeseong-gang, which flows 60 to 70 km west of the tectonic valley. At these NNE tectonic lines the eastern block is shifted repeatedly to the south. The late Mesozoic batholith is exposed extensively near the tectonic valley, but exposures are limited to small areas within the Daedonggane basin. A granite mass of moderate size is found in the Yangdeok area. Patches of smaller exposures are in parallel arrangement 10 or 20 km west of the Yeseong-gang valley. Farther west a large granite mass is found to penetrate the Changyeon folded belt as well as the basement complex of the Sinch'eon block. This granitic mass is elongated in a NW direction. The acidic rocks which are distributed from Kaech'eon to P'yeonggang through the Yang'deok area run parallel to the preceding.

c. Stratigraphic Sequence.

Little is known of the basement complex. MATSUSHITA's Keirin (Kyerim) system (1941) in the southern area is composed of mica-schist, quartzite or quartz-schist, and a small amount of lenticular limestone. It is intruded by the Kokulian granite. Similar rocks are found in other places also. The extensive display of paragneiss and orthogneiss and the minor inclusions of carbonate rocks are two characteristics of the basement complex.

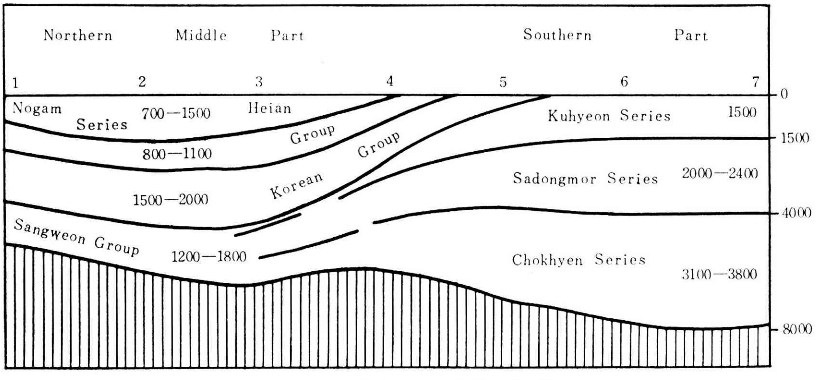


Fig. 5. Variation of Thickness of the Sediments in the P'yeongnam Geosyncline in North Korea. Number = thickness in m.

1. Kaech'eon 2. Seongch'eon 3. P'yeongyang
4. Hwangju 5. Sariweon 6. Haiju

The Shogen (Sangweon) group consists of the following three parts in ascending order: (1) the Chokhyeon (Chokken) series, which is chiefly composed of quartzite and shale, (2) the Sadongmor (Shidogu) series, which contains limestone and dolomite as the principal components and slate and phyllite as accessories, and (3) the Kuhyeon (Kuken) series, which consists of quartzite, slate and phyllite. The total thickness of the three series attains 7,700 m in Hwanghaedo. The Shogen group, however, becomes thinner in the median and northern parts, where it measures 1,200 to 1,800 m in thickness.

The Korean group measures 1,500 to 2,000 m in thickness. The middle and upper parts consist of calcareous rocks, and have been called "the Great Limestone

Series." Shaly rocks are the leading members in the Imcheon shale and the lower part of the group, called the Yangdeok (Yotoku) series.

The Heian or P'yeongan group is divisible into the Hongjeom, Sadong and Gobangsin series in addition to the top division which is called the Nogam series or the T'aejaweon (Taishiin) series. Hornstone and limestone are inserted only in the Hongjeom series and in the lower Sadong. The remainder is composed of sandstones and shales. Their total thickness ranges from 1,500 to 2,600 m.

The Korean and P'yeongan groups are separated by a para-unconformity indicating the stratigraphic break from late Ordovician to early Carboniferous. At the base of the Daedong series near Kyeomi-p'o, however, a limestone conglomerate containing abundant limestone (SHIMIZU, OZAKI and OBATA, 1934) suggests a local ingression of the Silurian sea which was invited by the embryonic folding of the Hwangju basin (KOBAYASHI, 1951). Devonian types of corals are reported at Ch'eonseong-ni near Seongch'eon (YABE and SUGIYAMA, 1939), although the existence of any Devonian formation has not yet been proven conclusively.

The Daedong series which overlies the Sangweon, Korean or P'yeongan group in clino-unconformity is composed of lacustrine sediments in which the facies and thickness vary greatly. Ammonites and a few other marine shells were once reported to occur in it (TOKUNAGA, 1931), but their source is doubtful. It is an orogenic sediment attaining a thickness of more than 1,300 m and is estimated to be about 1,500 m thick north of Kyeomi-p'o. It is thrust locally, but not much disturbed on the whole. There is a remarkable limestone conglomerate at the base of the Posan formation and the subjacent Sangweon group is the source of the material.

The Silla series is a red formation rich in andesitic lavas and tuffs. Its thickness is about 2,000 m in the western coal-field of P'yeongyang and more than 2,450 m in the Chaeryeong-gang valley. The Pongsan formation is an Eocene sediment of about 350 meters' thickness in a small basin. The reported occurrence of marine shells in this formation (TOKUNAGA in KOBAYASHI, 1931) was later found to be erroneous. There are small basins north of Kŭmgang-san (Kongozan) which yield Middle Tertiary plants. They are located on the basement ridge of T'ong-ch'eon-Ich'eon.

2. Kaech'eon-Teokch'eon (Kaisen-Tokusen) Area

The description given here is based chiefly on the geological map of the anthracitic coal-field of north, P'yeongan-namdo (KODAIRA and SHIRAKI, 1927) and a study of the Ordovician formation surrounding this coal-basin and a reconnaissance from the Naech'ang area to the Sunch'eon area which I made in 1927–30.

The P'yeongan group forms here a triaxial synclinorium, about 25 km meridionally as well as equatorially. The three main axes strike from east to west; the middle one is the longest. This structural basin is surrounded by an Ordovician formation, 400 to 500 m thick. The Taedong-gang gorge penetrates the saddle between the middle and southern brachysynclines, crosses the eastern part of the middle syncline at right angles and then trends northward. From Teokch'eon to Yeongweon one can see a good display of the Korean and Sangweon groups. At Samsang-dong, 13 km northeast of Teokch'eon, here is a *Cryptozoon* limestone at the base of the Ordovician formation. South of this boundary the great limestone formation which belongs mostly to the Ordovician repeats anticlines and synclines having equatorial axes or axes trending slightly north of east.

The P'yeongweon massif is on the southwest side of the basin. It is composed chiefly of paragneiss and is covered by basal quartzite of the Sangweon group. Above the quartzite is a thick formation of mica-schist, slate and clayslate. This is overlain by another formation of greater thickness which is composed of well bedded and massive limestones and dolomites. These formations evidently belong to both the Sangweon and Korean groups. It is not easy, however, to draw the boundary between the two groups, because of their metamorphism and the absence of key beds except in the uppermost part where Ordovician fossils occur.

On the west side of the basin the Naknang complex strikes almost meridionally and dips toward the east. There are, however, several faults in the WNW or ENE direction through which its base is dislocated. Cut by meridional faults or thrusts, the basal clastic rocks of the Sangweon group occur repeatedly at some places. Several NW or NE faults are found in the limestone and dolomite terrain. Some other faults are found within the basin of the P'yeongan group, most faults being on its north side.

Along the Ch'ongch'eon-gang there is a narrow strip of Mesozoic rocks. Their exact age has not yet been determined. This formation forms a monocline with a NW dip and is cut by faults at right angles. Its northwestern margin is marked by a fault trending slightly north of east. The west side of the basin is intruded by the granite by which iron ore was deposited at Kaech'eon (Kaisen).

On the south side of the basin the Hongjeom and Sadong series are thrust upon the Ordovician. At Solbong southeast of Teokch'eon the lower Pyeongan group is slipped over the Cambro-Ordovician limestone formation at the eastern end of the middle syncline. Such horizontal displacements are seen more commonly in the Seongch'eon area.

3. Seongch'eon-Sunch'eon (Seisen-Junsen) Area

The geologic structure of this area is discussed here chiefly on the basis of TATEIWA's survey of four sheet maps (1931). It is a disturbed belt of the Naknang complex between the above-mentioned basin and another of the eastern P'yeongyang basin, both of which are composed of the P'yeongan group. Broadly speaking, it is an anticlinorium striking from NW to SE through Seongch'eon, the axis being indicated by distribution of the Sangweon group. Resisted by the Yangdeok massif, however, the folding of its northern wing is strongly disturbed. On the west side resistance of the P'yeongweon massif produced the Ap'ari thrust.

As noted already, there are several thrusts near the southern margin of the northern basin. The longest of them is the Yeongdaeni thrust, which consists of two arcs. Cut by a fault, the eastern arc terminates at a distance of 6 km from the node, but the western one extends for more than 35 km, describing an outer circle around the basin. The Imcheon shale or Sunch'eon clayslate is quite liable to be displaced along its boundary plane along with the superjacent or subjacent limestone. Due to this habit the imbricated arc of Sinch'ang was produced in front of the Yeongdaeni thrust. Likewise another imbricated arc of Soha-ri was brought about east of the Sinch'ang arc. Farther east the Ŭnsan (Inzan)

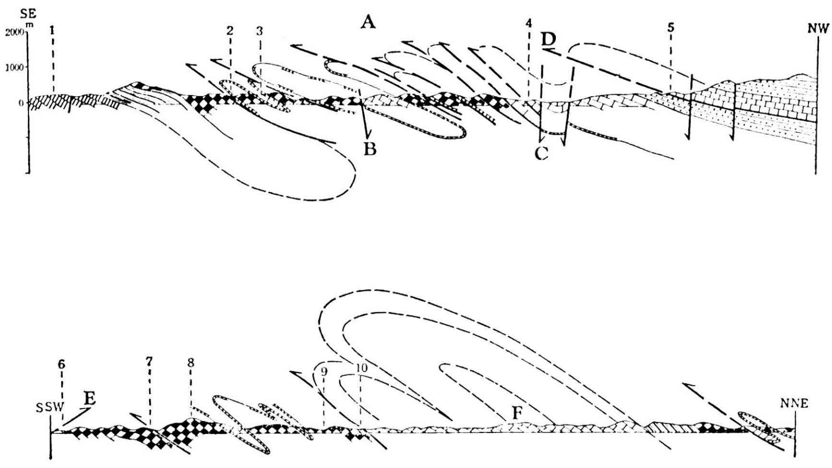
Table 6. Stratigraphic Sequence of the Seongch'eon-Sunch'eon (Seisen-Junsen) Area (after TATEIWA).

P'yeongan Group	Nogam Series	+300 m
	Gobangsan Series	500 m
	Sadong Series	−100 m
	Hongjeom Series	−300 m
	Discordance	
Korean Group	Great Limestone Series	−1,500 m
	Imch'on Shale	−80 m
	Sunch'eon Clayslate	+1,000 m
Sangweon Group	Yangdeok Quartzite	−200 m
	Sadongmor Series	−2,100 m
	Chikhyeon Series	700 m
	Discordance	
Ancient Gneiss and Schist		

limestone which occupies the major part of the lower Great Limestone series is slipped upon the Sunch'eon clayslate along a long tectonic line of Sadosan. This already belongs to the northern wing of the Seongch'eon isoclinal anticline of the Sangweon group. The wing comprises the gentle structural basin of Hyangp'ung-san in the east and a gentle anticline on its northeast side, but it is cut by the Changnim fault with the downthrow on the north side. The pre-Sangweon basement is exposed on its south side.

On the east side of the Hyangp'ungsan basin is the dome of Pueom with the Yangdeok quartzite at its center and the small Yeongtae-san basin on its east side. The Sangweon group dips to the west as far as the Yangdeok dome and slips up to the east along the base of the Sadongmor series.

The Sangweon group along the axis of the large Seongch'eon anticlinorium and the lower Korean group on its south wing repeat isoclinal foldings with the northeast dip. The upper Korean group thrusts up along the Ap'ari thrust, cutting the above anticlinorium obliquely.



P'yeangan Group
Upper Great Limestone Formation
Imch'on Shale
Lower Great Limestone Formation
Yangdeok Series
Naknang Group

Fig. 6. Two Profiles of the Songch'on or (Seisen) Disturbed Belt (After TATEIWA).

A. Sunch'ang (Shinso) Imbricated Arc
B. Changnim (Chorin) Fault
C. P'yogasan (Hyokasan) Fault
D. Yeongdoeni (Reiyari) Thrust
E. Ap'ari (Ahari) Thrust
F. Seongch'eon (Seisen) Isoclinal Anticlinorium

1. Munweol-li 2. Weont'ong-ni 3. Sinsam-ni
4. Kwich'ol-li 5. Unch'ol-li 6. Hyangsu-ni
7. Unyong-ni 8. Hyeongmyeong-san 9. Piryu-gang
10. Yongbong-ni

Running through the axial zone is the Majollyong fault, which is a strike fault with downthrow on the south side. The Changnim fault parallel to the Majollyong fault cuts a subordinate axis of the northern fold. The Hyang'p'ungsan basin and Pueom dome located between the two faults are destroyed by faults in the E to W as well as WNW direction. In the eastern part of the area there is a fault system having meridional and submeridional trends. The Sakkŭm-ni and Hoeeom-san faults are two of prime importance. These two systems of faults cut each other, but more commonly the meridional ones are cut by the others.

The granite mass of Kuryong-myeon in the south-eastern part of the area is elongated meridionally. It is an intrusive mass younger than these faults. The granite mass of S'unga-san in the west is cut by faults and is surrounded by a broad contact aureole.

There is no Mesozoic or Tertiary formation in this area. Because of the lack of the Daedong series it is difficult to break down the tectonic development into the Songnim and Taebo phases. It is evident, however, that the most important element is the principal Seong'ch'eon anticline accompanied by the auxiliary Changnim anticline. They diverge to the east by the insertion of the Yangdeok block. While basins and domes were produced between the two anticlines, the zone between the auxiliary axis and the northern basin was strongly disturbed, forming the imbrication. Sliding is also very common there. There horizontal dislocations generally occur between a limestone and clayslate bed or within a clayslate or shale bed. The imbricated arcs of Sin-ch'ang and Sohari are deformed anticlinoria of the Ŭnsan limestone. On the southern margin the limestone slips up on the gentle dome of Sado-san.

The Seongch'eon and Changnim anticlines, gentle folds on the sides of the latter, brachyanticline in the farther north and the gentle folds near the Yangdeok block must all be primary tectonic elements. With increasing lateral compression, these embryonic folds developed into the Seongch'eon isoclinal anticlinorium or the imbrication north of the Sadosan basin. The compression was, however, released by the Sadosan sliding. This folded zone is slipped up *en bloc* east along the Pyeolgunni line. Caused by the compression between the P'yeongweon and Yangdeok blocks, this sliding presumably appeared in the latter part of the crustal deformation almost simultaneously with the Ap'ari thrusting, which may be referred to the Taebo rather than the Songnim phase.

After the Seongch'eon belt had been strongly disturbed, block movements occurred. The meridional or submeridional faults common in the eastern part are mostly older than the equatorial ones. Later, granitic magma intruded into this terrain. Some of the faults, however, probably date from still later.

4. P'yeongyang (Heijo) Coal-Field (see Profile Va)

A long history of research is connected with this coal-field. First, NISHIWADA (1898), FUKUCHI and SUGIMOTO (1905), IKI (1906), YOKOYAMA (1906), KOCHIBE (1908) and others made contributions to the geology of the coal-field. The stratigraphy of the coal-bearing formations was later clarified in great detail by TOKUNAGA (1919), YABE (1919), KIKKAWA (1925) and others. The Ordovician formation below the coal-bearing was classified by KOBAYASHI (1930, 31). Prior to this NAKAMURA (1918) and KONNO (1928) respectively pointed out the significance of the Jido and Taiho thrust. Since 1934 NAKAMURA has conducted a research project on the complicated structure of the coal-field and its surroundings in collaboration with his students. The geology of the coal-field was compiled by MATSUSHITA (1938), and later the research was summarized by MATSUSHITA, KOBATAKE and IKEBE (1952). The last tectonic interpretation differs from previous ones in some details, but detailed discussions are here omitted.

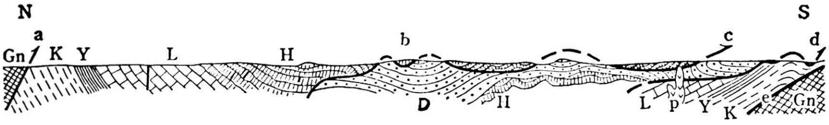
The coal-field is divided into eastern and western parts by the synclinal basin

Table 7. Stratigraphic Sequence of the P'yeongyang Coal-Field (after MATSUSHITA, KOBATAKE and IKEBE).

Pulguksa Series			
---------- Intrusive Contact ----------			
Taebo Series			2,000 m
---------- Discordance ----------			
Daedong Series			1,300 m
---------- Discordance ----------			
P'yeongan Group	Taijaweon Series		650 m
	Gobangsan Series	300—	500 m
	Sadong Series	150—	300 m
	Hongjeom Series	250—	300 m
---------- Discordance ----------			
Korean Group			1,420 m
---------- Discordance ----------			
Sangweon Group	Kuhyeon Series	10—	200 m
	Discordance ----------		
	Middle and Lower Parts	1,060—	1,700 m
---------- Discordance ----------			
Kokulian Granite			
---------- Intrusive Contact ----------			
Kyerim Group			

of the Daedong series, which extends to the northeast from P'yeongyang city as far as Taeseong-san. The western or Kangseo coal-field is located south of the P'yeongweon block. Its gneiss complex thrusts itself upon the Kuhyeon series on the southeast side along the Kinsai (Kŭmche) thrust. This thrust plane is steeply slanted toward the northwest. The paragneiss of the complex, however, forms a low hill of Ch'e-bong, west of P'yeongyang and is thrust upon the Daedong series. Two small *Klippen* are found at Todu-san and its vicinity to lie on the series beyond the thrust front. According to MATSUSHITA (1938), this thrust together with the *Klippen* reveals the frontal part of the Kŭmche thrusting mass. One cannot trace the outline of the thrusting mass from the front to the root continuously, as it is interrupted by a porphyrite mass which was intruded into the thrusting mass, but the Kŭmche thrusting mass was transported for about 15 km toward the southeast, assuming this interpretation to be correct.

Beneath the Kŭmche thrusting sheet there is the Taebo thrusting sheet which consists of the Kuhyeon series, the Korean and P'yeongan groups. They form a synclinal basin and thrust themselves upon the Daedong series on the south-east side. Because the thrusting plane of the Taebo thrusting sheet is subhorizontal in the main, its frontal margin is considerably protruded to the southeast in Tongjinmyeon and Taebo-myeon. On its rear side the underlying Daedong series is exposed at three small windows.



p. Porphyrite
D. Daedong Series
H. P'yeongan Group
L. Great Limestone Series
K. Kuhyeon Series
Y. Yangdok Series
Gn. Gneiss.

a. Kŭmche (Kinsai) Thrust
b. *Fenster* at Taeryong-dong
c. Taebo (Taiho) Thrust
d. Yongjeong (Ryusei) Thrust
e. Muhaksan (Bukakusan) Fault

Fig. 7. Profile of the Western Part of the West P'eoyngyang Coal-Field (after MATSUSHITA).

At Kambuk-san, north of P'yeongyang, the P'yeongan group, which is capped by the Daedong series at Ami-san is thrust upon the Daedong series on the south side and is thrust by the group on the north. The Kuhyeon series is sliced and shut in along the latter thrust line. These thrusting sheets are considered to belong to the Taebo *Decke,* although this part is separated from the main mass of the *Decke* by the intrusion of porphyrite.

South of Kambuk-san there is a gentle synclinal basin of the Daedong series where the city of P'yeongyang lies, but it is thrust by the Hongjeom series from the southeast side. This is called the Giyo (Kiyang) thrust, because it is traceable from Taeseong-san to Kiyang. Beyond the last locality, it is considered by NAKAMURA to be bent up abruptly toward the north, although the bending point is cut off by the Muhak-san fault. This northern section was formerly called the Yongjeong thrust, where the Daedong series was thrust on the Kuhyeon or lower Korean group. The amount of displacement, however, is in question. Because the Daedong is incorporated with the Yongjeong, Taebo and Kŭmche dislocations, it is quite evident that they are products of the Taebo disturbance. All are cut by the Muhak-san fault which marks the western border of the west P'yeongyang coal-field.

On the southeast side of the Kiyang thrust is the Sadong thrust, along which the Chunghwa series and the higher formations on the southeast side thrust themselves upon the Hongjeom and Sadong series on the other (SAKAKURA, 1936). In front of the Sadong thrust is the Taeseongni thrust. Near Taeseong-ni it is marked by the boundary thrust of the eastern P'yeongyang coal basin, which runs between the Hongjeom and Sadong series. On its south side the Hongjeom and Ordovician formations are repeatedly folded. Farther south the Ordovician formation around

Mandal-san (Bantatsusan) is cut by the Sadong thrust and a subordinate thrust, termed post-Sadong (Kobayashi, 1930).

East of Mt. Mandal the Sadong thrust outlines the Koyeongsan thrusting sheet which is composed of the middle and upper Sangweon and Korean group. The Taeseongni thrust, on the other hand, becomes a low angle thrust to the east, called the Teoksan thrust by Ikebe (1937). According to him the Teoksan *Nappe* or *Decke,* consisting of the Hongjeom and older formation, has ridden over the Sadong and younger formations toward the northeast. Because of its tangential

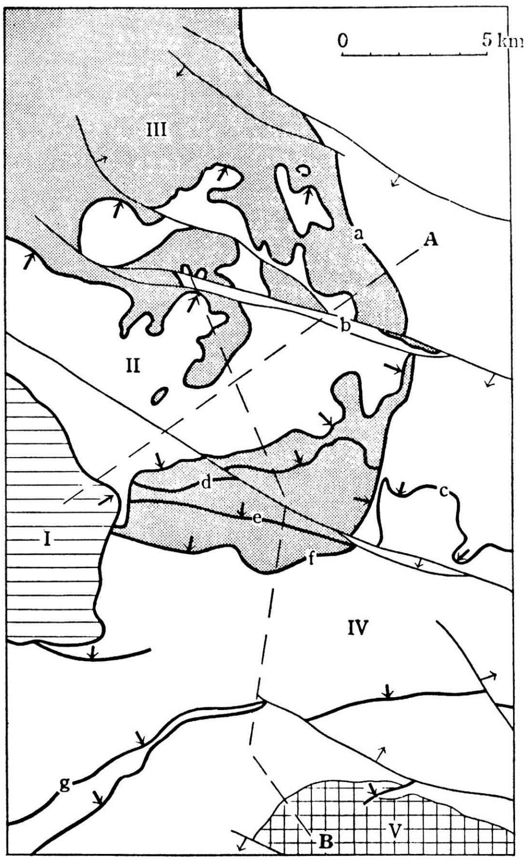


Fig. 8. Tectonic Map of the Samdŭng Area (After Ikebe).

I. Koyeongsan (Koreizan) Thrusting Sheet
II. Teoksan (Tokusan) Nappl
III. Parautochthonous Coal-Basin
IV. Autochthonous Sediments
V. Chung'bongsan (Sohosan) Basement Dome

a. Suip (Suinyu) Thrust
b. Samdŭng (Santo) Graben
c. Suich'eonni (Suisenri) Thrust
d. Taedalli (Daitatsuri) Thrust
e. Sinmadong (Shinmado) Thrust
f. Kojeongsan (Koteizan) Thrust
g. Sangweon (Shogen) Thrust

displacement, the thrust line has a peculiar meander. There are several *Klippen, Windows* and *Halfwindows.* a further complication stems from the development of the *Decke* into three or four *Teildecken.*

The basement of the *Decke* is also parautcohthonous in this part of the coal-basin. The Hongjeom series and upper Korean group have ridden upon the middle and lower Korean group along the Suip tectonic line on the northeastern border of the basin. It is thought to continue to the Kojeongsan tectonic line in the south of Samdŭng, but there are two or more subordinate dislocations behind the Kojeosan line.

The Suip line is traceable as far as Kangtong. On the south side of Kangtong there are several dislocation lines along which sliding has taken place within the Hongjeom series. At Hyeongje-san in the northwest, the Hongjeom series thrusts upon the Sadong on the south side.

If the tectonic complication near Samdŭng is ignored, the P'yeongan group in the east P'yeongyang coal-field is rather simple. It forms a subtriangular basin, but it is polyaxial, taking the form of a synclinorium. Its northeastern margin is marked by the Suip line. The Ap'ari upthrust mentioned above probably occupies its northern extension. The Kangtong thrust which extends from Kangtong to the west southwest marks the boundary between the Seongch'eon anticlinorium and the P'yeongyang coal-field.

Because the Daedong series plays a role in this complicated structure of the P'yeongyang coal-field, it has long been thought to be the product of the Taebo disturbance. It was found, however, that the Daedong series of the P'yeongyang basin lies clino-unconformably on the Korean group and the Kuhyeon series at Taeseong-san where there is a conglomerate, 80 to 100 m thick, at the base of the Daedong series. The Taejawean and Gobangsan series of Kambuk-san and Ami-san on the north side of the P'yeongyang basin is also overlain clino-unconformably by the Daedong series which consists of conglomerate, breccia and coarse sandstone. In the west P'yeongyang coal-field the Daedong series beneath the Taebo *Decke* is gently undulating. At Seogŭi-ni and Anjong-ni of Taebo-myeon the basal conglomerate and coarse sandstone lie clino-unconformably on the Hongjeom and Sadong series which are intensely folded parallel to the equatorial axis (See Fig. 4). These facts in general show that the Songnim disturbance was strong in this region.

The Daedong series near the town of P'yongyang forms a basin structure with the NE axis which gently undulates in the form of a wavy synclinorium. Its base is unexposed, but it is known that the upper or Yukyeong (Ryukyo) formation is 600 m thick and the lower or Seonseon (Senken) formation, more than 700 m thick. They are composed of sandstone and shale, but the lowest sandstone of the Seonseon formation contains quartzite pebbles, suggesting the approach to the base of the series. The conglomerate at Chueom-san, which is detached from the main Daedong area by a fault, consists of round pebbles of quartz, quartzite and other rocks in the northwest but angular limestone blocks in the southeast, where quartzite is very rare. The series of the basin yields plant fossils in several horizons. Molluscan shells and a fossil forest are present in the Yukkyeong formation (MAEJIMA, 1935).

The Daedong series at Taeseong-san consists of the Taeseongsan (Taiseizan) basal conglomerate, 80 to 100 m thick, the Taesongni (Daijoshi) sandstone, 80 m thick and the Noseongni (Roseiri) black shale, more than 150 m thick. Plants occur in various horizons and molluscan shells are contained in the Noseongni black shale. The basal part of the series is also known to exist at Ami-san and Kambuk-san, as mentioned earlier (KOBATAKE, 1941).

The lower part of the Daedong series in the west P'yeongyang coal-field consists of the Okkabong (Gyokukaho) formation, 300 m thick, chiefly composed of black shales containing plants and divided in two by Ch'aeseoksan (Saisekizan) sandstone, 50 m thick; the upper part yields Molluscan shells, the basal conglomerate, only 15 m thick, contains shale and quartzite pebbles.

The upper formation of the Daedong series is more than 1,000 m thick, contains plants, shells and Estherians, and is subdivided into Tosolli (Tosanri) black shale, over 350 m thick, Munhyeon (Bunken) conglomeratic sandstone, 250 m thick, and Kunoni (Kurori) alternation of sandstone and shale, over 400 m thick; coal seams are contained in the Kunoni alternation and the Okkabong formation, and aluminous shale is found in the lower part of the latter (IKEBE, 1935).

In short, the Daedong series in the western and central P'yeongyang areas is a formation more than 1,300 m thick, and its sequence is different between the two areas. The variation in consitution and thickness is especially significant in the basal conglomerate. This suggests the great variation of its basement and also of the topographic relief at the beginning of the sedimentation. The conglomerate, however, is restricted to the base, if the Munhyeon conglomeratic sandstone is neglected. Aluminous shale in the lower part may be an erosion product of a temporary upheaval of the margin. The Munhyeon conglomeratic sandstone, together with the fossil forest, suggests the emergence and revival of the topographic relief.

Judging from these facts, it may be concluded that the crustal movement did not cease at the end of the Daedong epoch. The Daedong series is a sediment ranging from late Triassic to Liassic in age. Although its age cannot be determined more precisely, the part in the P'yeongyang area may be younger than that in the western area.

MATSUSHITA, KOBATAKE and IKEBE (1952) analyzed the dislocations of the P'yeongyang coal-field into two types, namely the A type, which is developed from intense folding, and the B type, which is unrelated and subsequent to the folding. They concluded that the former is a product of the Songnim disturbance, while the latter is mostly a product of the Taebo disturbance. The distribution of the Daedong series, however, is restricted on the one hand and the secondary deformation in the Taebo phase goes too far on the other. For these reasons it is not easy to restore the Songnim folded mountains. Presumably, however, the eastern synclinal basin of P'yeongyang between the embryonic anticlinoria of Chunghwa and Seongch'eon must have extended into the western area as far as the Daedong is distributed. Because the series lies on the folded Pyeongan group, the Daedong basin must have been brought to being in the latter part of the Songnim disturbance. The Kiyang tectonic line which cuts the southeastern and southwestern margins of the basin belongs to the Taebo deformation. The Taebo thrust is another deformation of secondary origin. The Daedong basin must have been large, as can be recognized from the Daedong series at the windows. It was in the Taebo phase that the frontal part of the P'yeongweon block rode over the Taebo *Decke* to the south for a long distance, assuming that the geneiss mass of Ch'e-bong indicates the frontal' margin of the Kŭmche *Decke*.

It is impossible to determine whether it was in the Taebo disturbance or in the latter part of the Songnim disturbance that the Taeseong thrust developed southeastward into the Teoksan thrust in the Samdŭng area. It appears reasonable, however, to attribute the Suip dislocation to the Taebo disturbance, if it belongs to the same system as the Ap'ari upthrust.

West of P'yeongyang the Taebo series dips to the southeast at 30 to 45 degrees. Its sequence at Pongsu-ri of Yongsan-myeon consists of (1) basal conglomerate, (2) red shale containing limestone lenses, (3) reddish purple tuffaceous breccia containing porphyrite pebbles, (4) tuff or sandstone containing round pebbles among which quartzite and other sedimentaries are more common than volcanic rocks, and (5) top conglomerate. The total thickness is estimated to be about 2,000 m or so, and the lower two beds (1–2) are intruded by porphyrite and quartz-porphyrite.

The Taebo series is cut by NE and NW trending faults. The Muhaksan fault at the western end of the coal-field occupies the northern terminus of the long Annak fault. It is a large NW fault with a NE dip at 30 degrees or so. In addition, there are several long parallel faults on the east and west sides of P'yeongyang. Some of them cut the Taebo series. This fault system is also found in the east P'yeongyang coal-field. Near Samdŭng there is a narrow graben trending west northwest. Dykes of acidic rock are sometimes encountered along these post-Taebo faults.

5. Chunghwa-Sangweon-Hwangju (Chuwa-Shogen-Koshu) Area

The area from the Taeseongni or Sadong thrust as far south as Hwangju consists chiefly of the Korean group. The Chunghwa brachyanticlinorium is in the north and the Hwangju brachysynclinorium is in the south. On the east side of the latter there is the Chŭngbongsan dome which is surrounded by the Sangweon group.

The front of the Chunghwa anticlinorium is marked by the Taeseongni or Sadong thrust. Near the southern margin of the Sadong thrust the lower P'yeongan group is found to occupy small areas. The pre-Chunghwa *Decke* thrusts itself upon the Sadong *Decke*. On the south side of the pre-Chunghwa thrust are the Chunghwa and Chuyeomjong thrusts. All of the thrusts are convex toward the north and in the east bend abruptly to the south or even to the southwest.

The younger formations become better developed in the northern thrusting sheet, but the reverse is true for the southern ones. The Chuyeomjong, Ch'udangni and Kuhyeonch'i thrusts describe parallel arcs on the north side of the Hwangju basin. This is the axial part of the Chunghwa anticlinorium which is composed of the lower Korean and the upper Sangweon group; the anticlinorium is asymmetrical because the Hwangju basin is sunken (K. SAITO, 1937).

The Hwangju basin is a brachysyncline or brachysynclinorium of elliptical outline with the major diameter twice as long as the minor one. The Ordovician, Cambrian and Kuhyeon formations are aligned concentrically, but their distribution is disordered to some extent by folding and thrusting near the periphery. The southern thrusts are centrifugal like the Kuhyeonch'i and other northern ones (TAKEHARA, 1934; SAWADA, 1941).

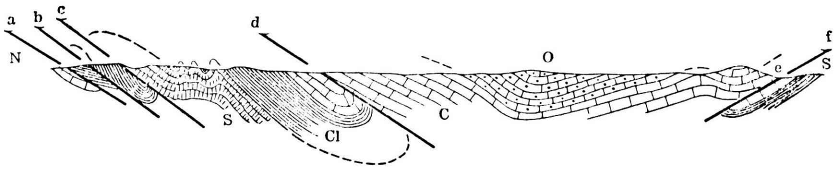


Fig. 9. Profile of the Eastern Part of the Hwangju (Koshu) Basin (after TAKEHARA).

O. Ordovician Formation
C. Upper and Middle Cambrian Formations
Cl. Lower Cambrian Formation
S. Kuhyeon Series

a.	Chuyeomjeong Thrust	b.	Ch'udangni Thrust
c.	Kuhyeonchi Thrust	d.	Hukkyo Thrust
e.	Yeongp'ung-ch'eon	f.	Ch'onjŭ-san

To the east of this structural basin is the Chŭngbongsan dome, which is nearly triangular in outline and is composed of gneissose granite which belongs to the pre-Sangweon basement complex. The dome is surrounded by the Sangweon group. On the northwest side it is folded with a northwest dip and is thrust toward the southeast. Among the thrusts two important ones are the Sangweon and pre-Sangweon thrusts (see Fig. 8). They appear to correspond to the Kuhyeonch'i and Chuyeomjong thrusts in the west, but the direction of thrusting is opposite for the two sides, showing torsion of the Sangweon group between the centripetal thrusting toward the Chungbangsan dome and the centrifugal thrusting from the Hwangju basin.

In the northwest part of the Hwangju basin is the Daedong' series, about 1,500 m thick (SHIMAMURA, 1929). It begins with the Kyeomip'o limestone conglomerate, which is a talus debris containing angular boulders of Silurian limestone (KOBAYASHI, 1935). The lower Daedong is a deltaic sediment containing Estherians. The middle and upper parts of the series consist of sandstone and shale accumulated on a lake bottom. Plant fossils are found therein. The middle part contains conglomerate, conglomeratic sandstone and some coal seams. The southerly dipping Ordovician of the Hwangju basin is overlain unconformably by the Daedong series with a northwest dip. Their contact is found in Songnim-myeon, whence the "Shorin (Songnim) phase." was proposed (KOBAYASHI, 1930). The series covers the lower Korean group in the north and is cut by a fault at the northwestern end. As mentioned above, the Kenjiho (Kyeomip'o) limestone conglomerate is a Mesozoic talus deposit. Therefore it must be the earliest sediment in the intermontane basin, surrounded by rugged mountains after the Songnim disturbance. At that time the Silurian formation must have been on the Ordovician. Except for the basal conglomerate, limestone boulders are seldom found. Round pebbles 2 to 3 cm across are mostly quartzite, clayslate and shale. These pebbles are thought to have been brought by a river from fairly far off, probably from the south, and to have been deposited in a delta. On the northwest side there was a lowland of the lower Korean group which was later submerged and covered by lacustrine sediments.

6. The Chaeryeong-gang (Saineiko) Valley

The Sinch'eon block is limited by the Annak fault on the east side. East of this fault is the lowland of the lower Chaeryeong-gang valley. The Taebo series forms low hills above the broad flood plain of the river. Beyond the valley there is an excellent display of the Sangweon group. East of Sariweon a patch of the Eocene series fills a small basin of Pongsan in the limestone tableland of the group. The stratigraphy of the group in this region was immensely clarified by the efforts of MATSUSHITA (1935, 1941, 1943).

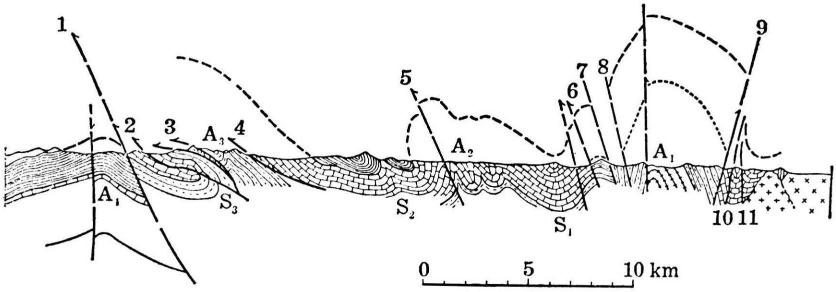
The Kokulian granite is extensive in the southernmost part. Its injection has produced the mica-schist of the Kyerim (Keirin) group, but the schist is not extensive at present. The relation of the Kyerim to the Sangweon group has not been determined. The Yulla (Ritsura) group is composed of micrographic granite, quartzite, crystalline siliceous limestone, sericite-schist, sericite-quartz-phyllite, quartz-schist, and a small amount of mica-schist. The Yulla granite looks younger than the Kokulian.

The Chikhyeon series is 3,100 to 3,800 m thick, the Sadongmor 2,000 m to 2,400 m thick and the Kuhyeon about 1,500 m thick. The total thickness of the Sangweon group is estimated to be 7,000 to 7,500 m. As it is cut by thrusts, however, no continuous sequence of the Chikhyeon series can be observed. The Changbong arkose quartzite at the lowest part of the series is conformable with the superjacent beds, but apparently it is para-unconformable with the subjacent ones. The arkose material of the quartzite is inferred to have been supplied from the Yulla granite.

In a distance of more than 35 km from Hwangju to the east of Haeju, the

Table 8. Stratigraphic Sequence of the Sangweon Group in the P'yeong'nam Geosyncline.

Central Hwanghae-do (Kokaido)		Liaotung Peninsula	
Kuhyeon Series, 2,000–2,500 m	Unbong'ni Slate, 370 m	Nanshan Stage, 400–800 m	Nanshan (or Chinhsien) Series 500–1,000 m
	Pirangdong Conglomeratic Phyllite, 900 m		
	Kusan Slate and Quartzite, 250–1,500 m		
	Okuhyeonni Siliceous Limestone, 50–330 m	Machiatun Siliceous Limestone, 50–200 m	
	Seolhwasan Slate, 250–450 m	Shihsanlitai *Collenia* Limestone, 50–150 m	
Sadongmor Series, 1,500–2,000 m	Ch'eongseoktu Limestone, 450–600 m	Yingchengtzu Limestone, 370–400 m	Kuantung (or Lutai) Series 2,500–3,000 m
		Onoda Limestone, 270–400 m	
	Teokchae Dolomite, 250–540 m	Kanchingtzu Dolomite, 450–700 m	
	Ŭngeok Limestone, 700–1,000 m	Nankuanling Limestone, 800–1,000 m	
Chikhyeon Series, 3,100–3,800	Ansimryeong Calcareous Phyllite, 625 m	Changlingtzu Phyllitic Limestone, 700 m	
	Changsusan Quartzite, 1,000 m	Lungtou Quartzite, 450 m	Tahoshangshan (or Hsiho) Series, 3,200 m
		Yingkeshih Phyllitec and Limestone, 30–200 m	
		Chakou Quartzite, 1,000 m	
	Obongni Slate, 500–1,800 m	Lungwangtang Slate and Quartzite, 800 m	
		Waitoushan Quartzite, 500 m	
		Huangmichuan Slate, 330 m	
	Changbong Feldspathic Quartzite, 600–1,000 m	Base unexposed	



	Pulguksa Granite		Chikhyeon Series
	Lower Cambrian Formation		Yulla Group
	Kuhyeon Series		Kokulian Granite
	Sadongmor Series		Kyerim Group

Fig. 10. Profile of the Chaeryeong-gang (Saineiko) Disturbed Zone (after MATSUSHITA).

A_1. Yulla Anticlinorium
S_1. Seolhwasan Syncline
A_2. Changsu Anticlinorium
S_2. Ch'ailbong Synclinorium
A_3. Obongni Anticline
S_3. Nodongni Syncline
A_4. Pirangdong Anticline

1. Toch'i Thrust 2. Teongmor Thrust 3. Cheongbangsan Thrust 4. Pongsan Thrust
5. Ŭllyong Thrust 6. Songhyangni Thrust 7. Ch'ilbongsan Thrust 8. Kwanamni Thrust
9. Chakch'eonni Thrust 10. Samch'eonni Thrust 11. Ch'ucheongni Thrust

Sangweon group forms 4 anticlines and 3 synclines. The southernmost is the Yulla anticline, or anticlinorium with the Yulla group at its axis. On its south wing the Yulla group is overlain by the Changbong arkose quartzite, and farther to the south the superjacent sequence extends as far as the lower Sadongmor series, but it is separated from the Kokulian granite by an intrusive mass of late Mesozoic granite. In the northern wing the two formations are separated by a high angle thrust. Farther north is the Seolhwasan syncline of the Sadongmor series, whose axis is subvertical. On its north side is the Changsusan anticlinorium and then the Ch'allbong synclinorium. The former consists of the lower and middle Sadongmor and the latter of the upper Sadongmor and the lower Kuhyeon series. Their folding axes are inclined to the south. On the north side of this recumbent folding are the strongly destroyed Obongni anticline and Nodongni syncline. The former is composed of the Chikhyeon series, whereas the latter comprises the formations from the upper Chikhyeon to the lower Sadongmor series. These two are again overturned toward the north. At length one reaches the Pirangdong anticline, which is composed of the Lower Cambrian and Kuhyeon series. It is an asymmetrical anticline with a vertical axis, having a gentle northern and a steep southern limb.

Looking at the whole section, it is evident that the Yulla and Obongni anticlines composed of the Chikhyeon series in main are deformed strongly by thrusting, but the Sadongmor series in their interval is deformed to a much smaller degree. The fold axis is high-angled in the south, but it becomes overturned toward the north and at length the Nodongni syncline is thrust upon the Pirangdong anticline along the Toch'i thrust line.

This fundamental structure is deformed considerably by secondary thrusting and faulting. On the northern and southern side of the Yulla anticline are several high angle thrusts. On the southern part of the southern wing the thrusts are directed to the south, but in the northern part they are directed to the north like those in the northern wing. Farther north the quartzite of the Chikhyeon series protrudes into the limestone of the lower Sadongmor series forming an elliptical dome. These deformations may be attributed to the compressive block movement of secondary origin. There are the Ŭllyong thrusts in the central folded zone and the Pongsan thrust in the north. This thrust plane is low-angled in the west, but becomes steep in the east. The Obongni anticline and Nodongni syncline farther to the north are strongly deformed by the Cheongbangsan and Teongmon thrusts. The Cheongbangsan thrust in particular is low-angled and branches off in the western terminus. Two minor *Klippen* are found in front of this western part. It is, however, high-angled in other places. This disturbed zone is delimited by the Toch'i thrust at the northern end.

Some of these thrusts are thought to be the products of the Songnim disturbance, but many others are upthrusts, thought to be caused by compressive block movement in the Taebo phase, because the dislocation is inconsistent with the folding.

After the geologic structure of the Sangweon group had thus been constructed by the Taebo disturbance, the Taebo series was deposited in the lower Chaeryeong-gang valley and now forms low hills. According to SHIMAMURA (1929) it can be divided in descending order as follows:—

3. Honanri or P'onamni formation, over 350 m thick; black shale and dark gray or light brown sandstone; ripple marks common in the latter; plant fossils uncommon.
2. Kanposan or Hanbongsan formation, 750 m thick; tuffaceous gray shale, sandstone and limestone; green or reddish brown shale containing plants; angular gravels of porphyrite in basal conglomerate.
1. Goryusan or Oryongsan formation.
   - b. Upper part, 750 m thick; thick andesite lava flow with intercalations of reddish brown tuff.
   - a. Lower part, 600 m thick; tuff, tuffaceous shale, sandstone, conglomerate, shale and quartzite; round or angular pebbles, 60 cm at the largest, of quartzite, clayslate, sandstone, limestone, quartz-porphyry and porphyrite in conglomerate.

Various kinds of porphyrite, i.e., compact pyroxene porphyrite, quartz porphyrite, brecciated porphyrite and so forth intrude the Hanbongsan and older formations. The eruptions of these andesitic rocks were repeated several times before the deposition of the Oryongsan formation. In the late Oryongsan epoch strong effusions of lava recurred.

At present the Taebo series widely covers the southwestern margin of the Hwangju basin. In the lower Chaeryeong-gang valley it is cut by faults on the east and west sides, but south of Sariweon it lies unconformably and gently undulating on the Sangweon group, forming a basin. The western margin of this basin is marked by the Annak fault which is traceable for more than 100 km in a NNW trend, and dips gently to the east northeast at about 30 degrees. It is indicated by a shuttered zone of several meters in breadth, which is penetrated at places by dykes of beresite and felsite.

In the southern part, the Okuhyeon fault, which is parallel to the preceding, runs along the east side of the valley. Its downthrow is on the east side. The Tohyeon fault in the north is parallel to the Sariweon fault and its downthrow is on the west side. It cuts a strike fault with downthrow on the south side. Thus the strike fault is older than the meridional one and may be coeval with or even older than the Annak fault. The block movement is supposed to have changed from compression in the Taebo phase to tension later. The strike fault may be a product of the beginning of the latter movement.

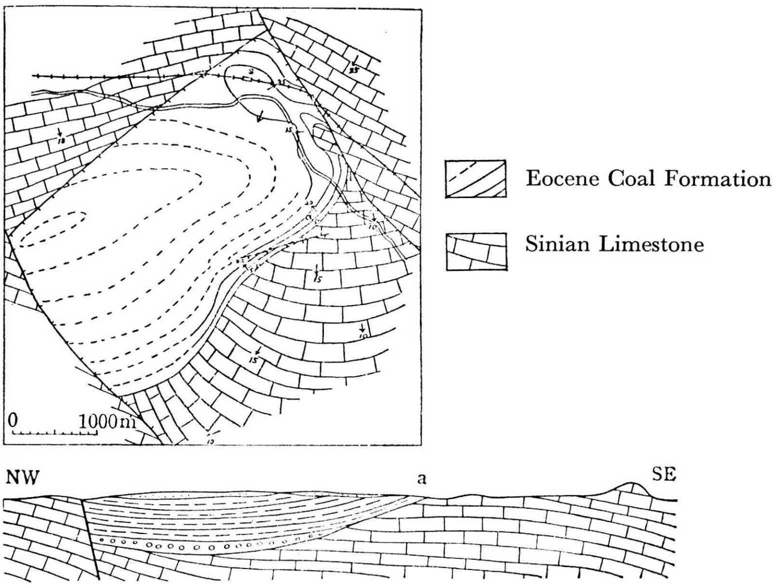


Fig. 11. Geological Map and Profile of the Pongsan (Hozan) Coal-Field (after MATSUSHITA, ONOYAMA and MAEJIMA).

a in the profile is the Sariweon (Shariin) Coal Mine; a, b and s in the map indicate respectively the main pit of the Pongsan Coal Mine, the first pit of the Sariweon Coal Mine and Sin-Pongsan Station.

The Chaeryeong-gang depression is presumed to have been produced by downwarping. Volcanic eruptions took place and the Taebo series accumulated there. Subsequently the Sinch'eon block was yielding the Annak dislocation line. Thus, the block movement was related to the Pulguksa igneous activity, which continued with the batholithic invasion of granitic magma, causing a grand culmination and renewed tension faulting. Beresite and felsite dykes along the meridional faults as well as the Annak fault suggest that they are products of successive block movements, although the Annak fault is older than the meridional ones.

The Eocene Pongsan series was deposited in a small basin on the Sinian limestone. Marine shells have erroneously been reported from the series. The basal conglomerate, about 50 m thick, is restricted to the central part of the basin. It is overlapped by coal-bearing sediments, about 300 m thick, which yield plants, fresh-water shells and late Eocene mammalian remains. This series forms a gentle basin structure, having its major axis in an east northeast trend. It is cut by faults on three sides, the northwest, northeast and southwest. It is a small but typical fault angle basin, about 4 km long from NE to SW and a little broader than 2 km. The basin is thought to have been faulted down by the Middle Tertiary disturbance (Matsushita, Onoyama and Maejima, 1935).

Differential erosion is well displayed in the Sangweon terrain. Quartzite and allied rocks are resistant, while clayslate and slate form low lands. Numerous dolines are found on the wide tablelands of calcareous rocks. Flat-topped piedmont plateau or rock terraces are especially well developed along the Seohŭng-gang tributary, which is an eastern branch of the Chaeryeong-gang.

7. Discussion and Summary

The tectonic development of the P'yeongnam geosyncline is thought to have commenced in North Korea with embryonic domes and basins disposed in checker pattern. There were at least four disturbances—Songnim, Taebo, early Tertiary and middle Tertiary. The Songnim phase of crustal deformation is responsible for most of the fundamental architecture. The original folds and thrusts were, however, considerably modified by later thrusting and sliding in the Taebo disturbance which was succeeded by vigorous volcanic eruptions and intrusion of granite. While these Mesozoic deformations were compressive, the Tertiary ones were characterized by tension and dyke rocks were intruded. Still later, basalt was effused extensively along the weak lines. Controlled by rigid domes, trends of the fold axes and dislocation lines vary to a great extent. Nevertheless, the equatorial trend is so predominant that it is recognizable that the P'yeongnam geosyncline was compressed meridionally. The Tertiary faults take either the NNW or NNE to NE direction, forming a complicated mesh.

The thickness of the Sangweon group attains 7,700 m at the maximum. The Korean and P'yeong an group are respectively 2,000 and 2,600 m at the thickest. Their total thickness is therefore more than 10,000 m. The embryonic folds at the beginning of the deformation were the Yangdeok dome, the basins at its northwest and southwest sides, the Seongch'eon anticline, the Chŭngbongsan dome, the Hwangju basin to its west side and the anticlines on the north and south sides of this basin.

The Chaeryeong belt is a large asymmetric anticlinorium which lacks the

Korean and Pyeongan groups. The axis of folding is subvertical in the southern part of the belt, but inclined and thrust toward the north in the middle and northern parts of the belt. The Hwangju syncline is very gentle and its axis short and vertical. Its south side is bordered by the Pirangdong anticline. The anticline on the northern margin is deformed by the Kuhyeonch'i and other thrusts along which the Kuhyeon series is exposed. The Chunghwa anticlinorium is complicated by thrusting and the Kuhyeon series well developed on its southeast side, where the thrusting in the early stage was directed toward the Chŭngbongsan dome. Later, however, the Koyeongsan and other elements of the Chunghwa anticlinorium were pushed toward the northeast. The tangential movement of the Teoksan *Decke* may be a local event of the early Taebo disturbance, if not of the late Songnim.

Matsushita (1943) has distinguished the thrusting or the A-type dislocation from the B-type dislocation, or a kind of upthrusting, and referred the former to the Songnim disturbance and the latter to the Taebo disturbance. It is, however, also possible that the change from thrusting to upthrusting occurred in the latter part of a disturbance, because the difference between the two kinds of dislocation depends principally upon the plasticity. At all events, it is clearly shown by the structure of the Sangweon group in the Chaeryeong area that the A-type thrusting has generally proceeded to the B-type thrusting.

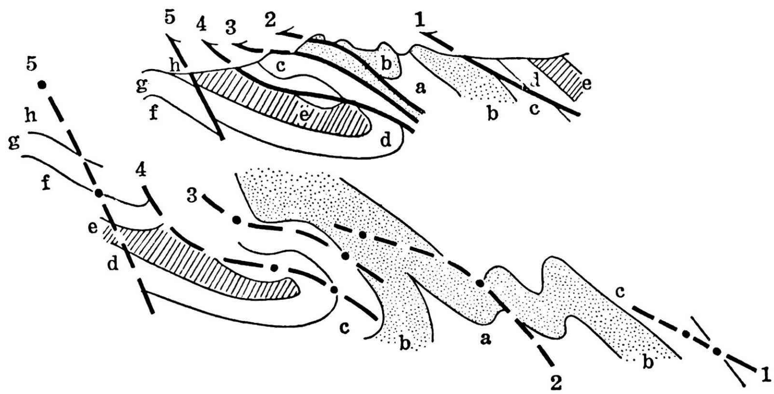


Fig. 12. A and B Types of Thrusts in the Chaeryong (Sainei) Zone (after Matsushita).

1. Pongsan Thrust
2. Cheongbangsan Thrust
3. Pre-Cheongbangsan Thrust
4. Teongmor Thrust
5. Toch'i Thrust

h. Unbongni Slate
g. Pirangdong Boulder-bearing Phyllite
f. Kusan Slate
e. Teokchae Dolomite
d. Ŭnjeok Limestone
c. Ansimnyeong Calcareous Phyllite
b. Changsu Quartzite
a. Obongni Slate

In the west P'yeongyang coal-field the Taebo and other thrusts which were produced by the Taebo disturbance can be distinguished clearly from the deformation of the Songnim phase. There the B-type dislocation, with which the Daedong series is incorporated, sometimes developed into horizontal transportation for long distances. Some *Fenstern* and *Klippen* are met with in this area.

It is seen at Taeseongni and its adjacent area in the east P'yeongyang coal-field that the thrust line runs between the Sadong and Hongjeom series. Farther east one can see a highly complicated horizontal dislocation as far as Samdŭng. According to IKEBE the Teoksan, Koyeongsan and Piseoktong thrusting sheets are piled up there one above another, but the amount of displacement is no more than 10 km. It is remarkable that the Kojeongsan and a few other southern thrusting sheets are ridden over toward the south.

The northerly thrusting cannot be seen beyond Kangtong. The axis of the Seongch'eon anticlinorium is inclined to the northeast. Beyond it there are many thrusts and slides toward the south, or toward the southeast in the part where the Yangdeok block has rested. Without the Daedong series this tectonic development is difficult to separate into the Songnim and Taebo phases.

This orogenic zone is overlain by the Silla series and intruded by granitic rocks by which the folded zone was well consolidated. Subsequently the zone was broken into blocks. There must have been block movement near the end of the Cretaceous or the beginning of the Tertiary period. Faults which cut the Eocene series at Pongsan are not very large and were probably produced by the Middle Tertiary block movement.

III
THE P'YEONGNAM OROGENIC ZONE IN THE LIAOTUNG PENINSULA

1. Introduction

In his geological reconnaissance through South Manchuria in 1860, RICHTHOFEN traveled from Fuhsien through the Wuhutsuei basin. He was the first to pay attention to the Yungning sandstone. Subsequently in 1903 BLACKWELDER made a trip through Fuchou and Hsiungyüeh cheng and gave a chapter in *Research in China* (1907). During his visit to the Far East in 1909, IDDINGS made a rich collection of Cambrian fossils at Changhsingtao, which were later described by WALCOTT in *Cambrian Faunas of China,* 1913.

Systematic research into the geology of the Liaotung peninsula, however, was not undertaken before the geological survey at the South Manchurian Railway Company was instituted in 1907. In the same year MURAKAMI compiled the results of the survey of the Kuantung District. The geological outline of the Liaotung peninsula was presented for the first time with a geological map of the Dairen sheet (scale 1/400,000) with an explanatory text.

Since then a number of papers have been published, including SAWATARI's on the Liaotung gneiss complex (1936), MATSUSHITA's on the Sinian system and on the geologic structure in the west of the Chinchou fault (1930, 31, 40). SAITO's on the Pre-Cambrian stratigraphy (1938), studies on the stratigraphy and palaeontology of the Korean group by ENDO (1924, 32, 35, 37) and KOBAYASHI (1930, 31, 33), on the P'yeongan group by OZAWA (1927), INAI (1935), NODA (1941, 42, 50), and HANZAWA (1944), on the geology of Chinchiachengtzu and Hsitao by NAKAMURA and SOO (1942), on the topography by HANAI (1928) and TSUCHIDA (1952), etc. In addition to these studies by Japanese geologists, there are reports on the Wuhutsuei coal-basin by CHAO (1926) and WANG (1928). Finally, a Jurassic mammal descibed by YABE and SHIKAMA (1938) and the article on the budding of *Nelumbo* seeds from the peat deposit of Pulantien by OHGA (1927) are of special interest to palaeontologists and neontologists.

The area dealt with here extends from the P'yeongnam geosyncline to the P'yeongbuk massif, Yatang bay lying at their boundary. In North Korea, the

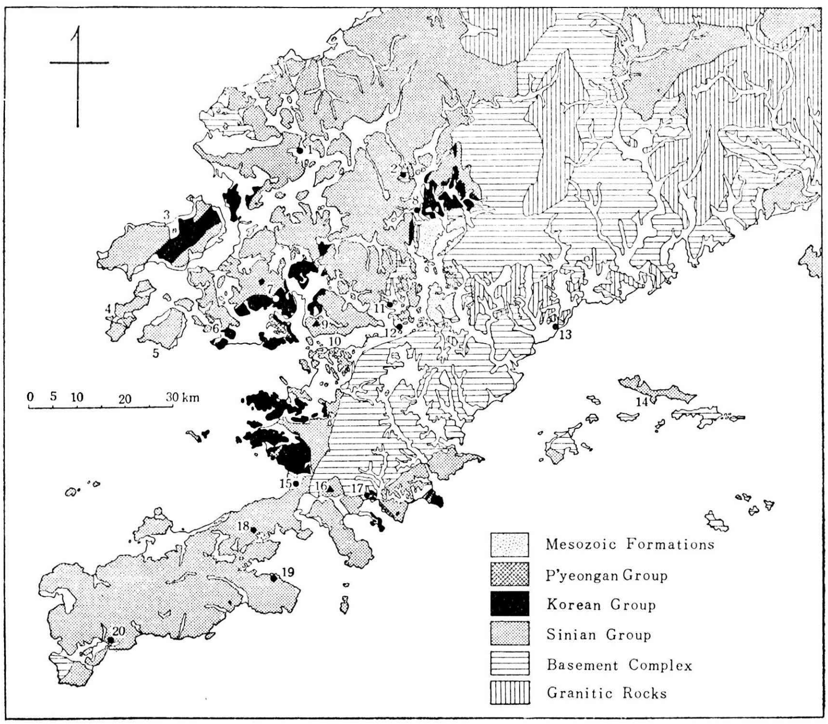


Fig. 13. Geological Map of the Liaotung Peninsula (after AOJI et al.)

1. Fuchou
2. Taipingkou
3. Changhsingtao
4. Hsichungtao
5. Fengmingtao
6. Hsitao
7. Chinchiachengtze
8. Wafangtien
9. Wangpashan
10. Yatang Bay
11. Sankuanmiao
12. Pulantien
13. Chinchou
14. Pitzuwe
15. Tachangshantao
16. Tangchiakou
17. Tahoshangshan
18. Nankuanling
19. Talien (Dairen)
20. Lüshun, (Ryojun, Port Arthur)

displacement along the Ch'ongch'eon-gang (Seisenko) river is so great that the P'yeongbuk massif side is bared by erosion. The relation between the massif and geosyncline is a problem of the Liaotung peninsula which should be investigated. It can hardly be overlooked that the pre-Songnim formations are thinner and stratigraphic break larger in the massif than in the geosyncline.

The mode of crustal deformations caused by the Songnim and Taebo disturbances is also quite different between the two tectonic elements. When intense folding and thrusting were taking place in the geosyncline, basins and domes were formed on the massif by undulation, or upthrusting and sliding at some places. There are Mesozoic formations but no Tertiary in this peninsula. Therefore it is difficult to discriminate later block movements. The Chinchou fault is a clear-cut tectonic line, the scarp of which has topographic significance. Compared to North Korea the Sinian trend is well emphasized in the fault system.

2. Stratigraphy

This region is composed of (1) an ancient gneiss complex, (2) Sinian group, (3) Korean group, (4) lower P'yeongan group, (5) older Mesozoic Wafangtien formation, (6) Cretaceous Pulantien formation, (7) igneous rocks and (8) Diluvium and Alluvium.

a. Ancient Gneiss Complex.

This is widely exposed in the peninsula to the east of the Chinchou fault. It was called the *Liaotung gneiss system* by SAWATARI. Epidote-biotite schist and epidote- and mica-bearing granitic gneiss are the leading members; some hornblendite and heleflinta are included. All are intruded by aplite. The metamorphic rocks are considered originally igneous rocks, mostly andesitic or dioritic, but the original rock of the heleflinta must have been trachytic.

MATSUSHITA designated a formation of 250 to 400 meters' thickness on the northwest side of Tahoshangshan, which rests on the gneiss complex and is overlain by the Tahoshangshan series, the "Hsiangshueiszu series". It consists of mica schist and phyllite in the lower part and limestone and clayslate in the upper. As its relation to the Tahoshangshan appears conformable, it may be a lower member of the Tahoshangshan series lying on the gneiss with an intrusive contact. However, there are probably two granites to be distinguished in the region. One intrudes the Hsiangshueiszu but the other intrudes only the Liaotung gneiss.

b. Sinian Sangweon Group.

The sequence of this group differs considerably on the two sides of the Yatang bay. In the peninsular part on the south side its base is unknown. Elsewhere its sequence is complete and very thick. On the north side the upper Sangweon is absent and there are breaks in the middle and lower parts, most of which are comparatively thin.

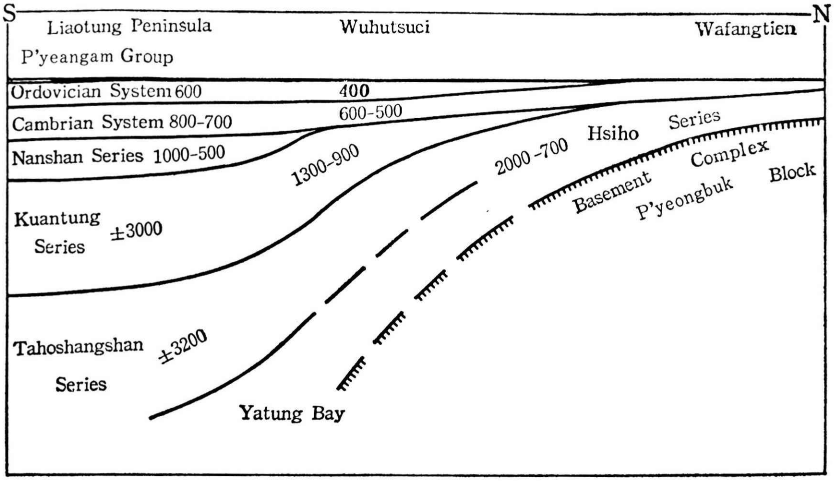


Fig. 14. Variation of Thickness of Sediments in the P'yeongnam Geosyncline in the Liaotung Peninsula. Numbers Thickness in m.

The group occupies an extensive area of the southern part west of the Chinchou fault and was studied in detail by MATSUSHITA and SAITO. As a result it can be classified into 3 series and 14 stages (see Table 8). The lower or Tahoshangshan series is more than 3,200 m in thickness and comprises 6 stages, the leading component being quartzite, but in addition it contains siliceous slate, calcareous phyllite and phyllitic limestone. This series plus the lowest stage of the middle or Kuantung series is correlated by MATSUSHITA to the Chokhyeon series in Hwanghae-do, North Korea. The Kuantung series, about 3,000 m thick, comprises 5 stages. Its major part is occupied by limestone and dolomite, but phyllitic clayslate is intercalated in the basal stage. *Collenia* is sometimes found in the middle part.

The upper or Nanshan series, which overlies the Kuantung disconformably, varies from 500 to 1,000 m in thickness and consists of 3 stages. The lower stage is represented by *Collenia* limestone and the middle one by light-colored thin-bedded siliceous limestone. The upper 400 to 800 meters, called the Nanshan stage, is built up of clayslates with intercalation of quartzite, quartzose sandstone and limestone. The facies and thickness, however, are quite variable through this stage. The Nanshan series is correlated to the Kuhyeon series in North Korea.

The group north of Yatang bay was first classified by AOJI (1928), and later revised by SAITO (1938) and others. AOJI distinguished the Hsiho and Wuhangshan series in the group and divided the Hsiho into the Tiaoyütai quartzite, Nanfen shale and marl and the Chiaotou quartzite, and the Wuhangshan series into the

Kaochiatun shale and sandstone and the Chinchia black limestone. The Tiaoyütai quartzite rests on the Liaotung gneiss complex with remarkable discordance.

According to a recent opinion put forth by MATSUSHITA, the Chiaotou quartzite, 200 to 700 m thick, can be correlated to the upper 5 stages of about 3,000 m of the Tahoshangshan series. The Hsiho series is only 700 to 2,000 m in total thickness. The Wuhangshan series, the correlative of the Kuantung series, is also thin and about 900 to 1,300 m thick. The Nanshan series is absent in this area. There sediments of only a little more than 2,000 meters' thickness accumulated in the early and middle Sinian periods, while on the south side of Yatang bay, the thickness of the sediments attained about 7,000 m. Subsequently the northern area became land by the end of the Sinian period, whereas 1,000 meters' sediments accumulated in the southern area after an emergence between the middle and upper Sinian period.

In the vicinity of Chunghwa in North Korea there are the *Protolenus* beds between the Kuhyeon series below and the *Redlichia* beds above. The three lie one above the other. In the Liaotung peninsula the *Redlichia* beds appear to lie on the Nanshan stage without any sharp boundary.

Near Chinchou in the southern area the *Redlichia* beds seem to be conformable to the Nanshan stage, but the relation of the beds to the upper Wuhangshan series is evidently disconformable in the northern area at the neck of the peninsula. Around the Wuhutsuei basin, it is recognized that the stratigraphic break beneath the *Redlichia* beds becomes larger from the Hsitao to the Chinchia-chengtzu area. For example, the Panlatao limestone at the top of the Wuhangshan series is present in the former area, but absent in the latter (NAKAMURA and SOO, 1942). Southwest of Wafangtien the red conglomeratic shale lies on the undulating erosion plane of the Chiaotou quartzite.

At Sungshu and Teiliszu north of Wafangtien, and in the vicinity of Fuchou north of the Wuhutsuei basin, there is the Yungning sandstone, whose age has been under discussion. This is reddish purple false-bedded sandstone derived from quartzite and granitic rocks. It is a kind of deltaic sediment in which conglomerate is intercalated. Because of its young appearance it was once considered Mesozoic. According to SAITO (1939), the formation consists of two parts. The lower part unconformably overlies the Nanfen shale and marl or gneiss and merges laterally with the Kaochiatun shale and sandstone. The upper part is conformable with the lower, but lies unconformably on the Kaochiatun shale and sandstone. Therefore, the Yungning sandstone must be the remains of a Pre-Cambrian delta on the western margin of the P'yeongbuk massif.

Near Kaiping, further north, only the thin Tiaoyütai quartzite exists. The Hsiho series is best developed in the Taitzuho tributary at its type locality. Because it reveals a cycle of sedimentation, it was once regarded as a minor cycle in the Taitzuho depression, corresponding to the major Sinian cycle in the P'yeongnam geosyncline (KOBAYASHI and KIM, 1931). The Hsiho series is really very thin compared to the tremendous thickness of the Sinian group. Therefore, there is another interpretation that the Hsiho series is the equivalent of the lower or upper part of the Sinian group. This problem has not yet been solved completely. Nevertheless, it is undeniable that the Hsiho in the Taitzuho valley is so similar in lithic aspects to the so-called Hsiho series at the neck of the Liaotung peninsula that AOJI's correlation between them is now generally accepted.

Whatever this correlation problem may be, it is certain that the subsidence of the geosynclinal zone was as large as that indicated by the group, i.e., about 8,000 m in the peninsula, four times thicker than the group on the P'yeongbuk massif at the neck of the peninsula.

c. Korean Group.

The fossils from the Fuchou series at Changhsingtao which were described by WALCOTT are Middle Cambrian. In the vicinity of Chinchia-chengtzu one can see an excellent Cambrian sequence, from lower to upper, which is provided with numerous fossil horizons, and overlain by the Ordovician. They were studied in detail by ENDO, KOBAYASHI and others, among whom NAKAMURA and SOO (1942) have presented a detailed study of the Cambrian stratigraphy of the Chinchia-chengtzu and Hsitao areas.

The Lower Cambrian, 220 m thick, is chiefly composed of reddish purple shale with some limestone. Above this there is micaceous sandstone at the base of the Middle Cambrian formation. This formation is about 200 m thick. Shale is not uncommon in the lower part, but the middle part consists mostly of limestone and the upper part of slabby limestone and marl. Slabby limestone and intra-formational limestone conglomerate are the leading components of the Upper Cambrian, which is about 170 m thick. Shaly layers are intercalated in the middle part.

At the base of the Ordovician is *Cryptozoon* limestone, which contains a few of brachiopods. This fauna, as noted by KOBAYASHI (1933), is quite different from that of the *Cryptozoon* limestone in the Taitzuho zone. Above this there is slabby limestone which is accompanied by dolomite and intraformational limestone conglomerate. This sequence appears similar to that of the Wanwanian series in the Taitzuho zone, but their correlation is not well endorsed by palaeontological evidence.

The next beds are composed of chert or flint-bearing massive and well-bedded limestone. The lithic aspect reminds one of the Wolungian, but the limestones are unfossiliferous. Actionoceroids and other Middle Ordovician fossils are abundant in the still higher limestone, through which its reference to the Toufangian can be confirmed. The Ordovician formation is about 400 m thick.

The Korean group in the vicinity of Wafangtien belongs mostly, if not entirely, to the Cambrian.

On the south side of Yatang bay, there is a group near Chinchou and San-shihlipu. According to MATSUSHITA (1930), the Lower Cambrian measures about 350 m, the Middle and Upper Cambrian about 400 m, and the Ordovician about

600 m in thickness. Thus, the total thickness attains more than 1,300 m in the Chinchou area, while it is about 1,000 m in the Wuhutsuei basin. Thus it is thicker here than in the Wuhutsuei basin, but the difference in thickness is much less in the Korean group compared with that of the Sinian group.

In the Chinchou section there is a formation, 350 m thick, beneath the *Redlichia* beds. It is composed mostly of slate and quartzite, but limestone and quartzose sandstone are intercalated in the slates. MATSUSHITA previously regarded it as the basal part of the Cambrian, but now it is taken for the top division of the Nanshan series. This formation is absent both in the Chinchiachengtzu and the Hsitao area. It is noteworthy that the marl of the Kushan stage and the intraformational limestone conglomerate common in the Upper Cambrian of the Wuhutsuei basin are apparently undeveloped in the Chinchou area.

d. Lower P'yeongan Group.

Surrounded by Ordovician ridges, this group occupies the central part of the Wuhutsuei basin and yields the so-called Fuchou fire clay and anthracite. It forms low hills and consists of the Penchi, Yatang and Lioutang series. The Penchi is the approximate equivalent of the Hongjeom series; the Yatang and Lioutang are combined into the Sadong in Korea. The so-called G bed or the fire clay bed at the base of the Penchi series overlies the Toufangian limestone; the Penchi limestones contain Moscovian fossils. The series is 70 to 90 m thick. The limestone at the top is overlain by the fire clay at the base of the Yatang series with erosional unconformity. The clay bed contains angular limestone boulders which were derived from the upper Penchi.

The Yatang series is about 100 m thick. It has a persistent limestone layer in the middle part, and limestone lenses above and below the middle limestone all yield Sakmarian fossils; coal seams are found below the middle limestone bed.

At a point east of Feichiatun, NODA observed that the false-bedded coarse sandstone of the Lioutang series lies on the dark brown shale of the Yatang in clino-unconformity. Nevertheless, the two series are generally conformable. The Lioutang is built up of sandstone, shale, fire clay and coal seams and contains land plants but no marine fossils.

At Tiaohutsu and Chienshihhueiyaotzu near Chinchou and at Tangchiakou, east of Tahoshangshan, there are small areas of the Penchi and Yatang series.

e. Wafangtien Formation.

This is found as small patches east of the town of Wafangtien. Its structure is so complicated that its sequence is difficult to determine. It is composed of shale and sandstone, in addition to conglomerate and coal seams. According to HORIUCHI, it lies on the Lower Cambrian southwest of Wafangtien and Lichiayao and on the Upper Cambrian east of Wafangtien. At Tangchiatun it overlies the Ordovician (?) and Upper Cambrian in clino-unconformity. At Wangchiatun, however, the relation between its basal conglomerate and the Lower Cambrian is disconformable. It lies unconformably on the Middle Cambrian north of Chatzuyao and disconformably on the Lower Cambrian east of that village. Furthermore, it lies unconformably on the Middle and Upper Cambrian at Taikumiao but disconformably on the Upper Cambrian at Hsiaolinchiatun. It lies unconformably on the Hsiho series at Luchiatun.

Because I visited this area in 1939 in summer when the exposure is at its worst, I could examine only a part of these contacts. The rock facies are quite changeable. Some conglomerates are composed mostly of limestone, but others contain no limestone. Pebbles of these conglomerates are not always very large. They must have originated as a lacustrine sediment in an intermontane basin whose topographic relief and geologic structure were fairly complicated. Jurassic plants therein belong probably to the Daedong flora. In addition, molluscan shells and fish-scales are known to occur but have not yet been studied. *Manchurodon simplicidens* YABE and SHIKAMA discovered at Chatzuyao in a coal seam is a Jurassic mammal in the family Amphidontidae of the Pantotheria.

f. Pulantien Formation.

This covers a large area east of the railway line between Wafangtien and Pulantien, and is quite different from the Wafangtien formation in that the degree of deformation is much less. It reveals the following two cycles:

e. Shale with sandstone and conglomerate, 350 m thick.
d. Sandstone with some conglomerate, 350 m thick.
c. Conglomerate, 500 m thick.
b. Shale and sandstone with some conglomerate, 450–580 m
a. Variegated tuffaceous sandstone and shale with a basal conglomerate, 1,000 m thick.

It lies discordantly on the Pre-Cambrian rocks; the basal conglomerate contains a great deal of quartzite, phyllite and gneiss in addition to some shale, limestone, porphyrite, quartz-porphyrite and volcanic rocks. The boulders of the conglomerate are often large, attaining 80 cm in diameter, and the conglomerate is sometimes interbedded with sandstone. It is probable that the surrounding land was rugged at the beginning of the Pulantien epoch. *Protocedroxylon araucarioides* (GOTHAN) was procured from the variegated tuffaceous beds. *Plicatounio naktongensis* KOBAYASHI and SUZUKI in the next higher bed at Hifumi pass suggests that the lower Pulantien (a-b) belongs to the Naktong series. Accordingly, the upper Pulantien (c-e) is probably a member of the Silla series.

g. Volcanic Rocks.

Diorite, porphyrite and porphyry are found at some places in the eastern gneiss area. On the east side of Tahoshangshan some sheets of granite porphyry are imbedded in the Tahoshangshan series.

On the west side of the Chinchou fault, the igneous rocks intruding the sedimentaries are mostly basic hypabyssals. Sheets of nephrite-like rock are the most common and attain 50 to 100 m in thickness. Basic dykes are found along faults, or fissures parallel to the faults, and their breadth generally measures several meters, but one near Sanshihlitun is 700 m wide and 1,600 m long.

For dating the most important is the Mesozoic terrain. Andesite and diorite are found at the thrust which disturbs the Lower (?) Jurassic Wafangtien formation. At Kanchiatum, dolerite intruding the Middle Cretaceous Pulantien formation extends N15°–35°E, forming a dyke. From these facts it can be judged that some of the igneous rocks are related to the late Jurassic Taebo disturbance, but others are younger.

While andesite boulders are found in conglomerates of the Pulantien formation, it is mainly tuffaceous and intercalates with a flow of andesite northwest of Sunchiatun and is intruded by andesite dykes at some places. Thus, there are andesites of various ages. At the same time it is certain that volcanic eruption has taken place in the Cretaceous period. It can be inferred also that the intrusion of diabasic rocks along some faults are related to the late Cretaceous or Tertiary block movement.

h. Younger Sediments and Topography.

Remnants of an old flat plane are found in the mountainous region at an altitude of 300 to 400 m. It may be a correlative of the Yukpaeksan plane in Korea. A clear-cut monadnock stands on this peneplain at Tahoshangshan. This cycle of erosion terminated with the middle Tertiary block movement. Subsequently, the piedmont plane, called Koneiji (Kuangningszu), came to being in this region. It is mainly rolling hills 120 to 200 m above sea-level. Loess on the slope or in depressions in these hills seldom exceeds 25 m in thickness. Since the plane is covered by loess, it is older than the Malan stage.

Redeposited loess is distributed in the lowlands. Mammoth remains were discovered in a clay bed at Lunwangtang in Talien. Similar clay beds are found in lowlands near Pulantien, Kaiping, Takushan and elsewhere. The low plane at the top is 20 to 34 m high. This is called the *Liaotung peneplain* or the Hishikwa (Pitzuwe) plane and is considered to be the correlative of the Rakuroan (Naknang) peneplain in North Korea.

The present valley carves this plane. Due to the slight subsidance in the near past, peat beds accumulated at places along the coasts of the Pohai and Hwanghai seas. Among these beds the one at Pulantien is famous for the inclusion of *Nelumbo* seeds still capable of budding. Salt fields at Tailen, Wuhutsuei and several other places are intertidal flats, or places where the sea bottom emerged in the final phase of upheaval.

3. The Eastern Part of the Peninsula

The peninsula on the east side of the Chinchou fault is mainly occupied by the ancient basement complex. The Sinian group, however, appears at Pitzuwe and Heitao. A typical display of the Tahoshangshan series is found at Tahoshangshan, east of Chinchou, whence its name is derived. It forms a monadnock on the high plain and is folded and cut by faults in the Sinian and Korean directions.

At Tangchiakou the lower Pyeongan group, along with the Ordovician formation, is folded and sunken in the form of a graben trending NW. The quartzite of the Sinian group lies on its northeast side and the limestone of the Sinian group lies on the other side of the graben.

It is noteworthy that the overturned folding near Chinchou, of which a lengthy description is given below, becomes vertical and gentle toward the east. This tendency of deformation is suggestive of the folded structure which has existed on the gneiss basement near the south coast of this area.

OGURA (1933) called attention to parallel dykes which he had studied at Liangchiatien, Pitzuwe and Wolungtun. South of Pulantien, for example, are innumerable dykes of quartz porphyry running NNE to SSW. They are independent of the gneissosity in this region in that the leading trend of the latter is equatorial. The dykes are discrepant also with the Chinchou fault in the NNE direction.

4. The Western Part of the Peninsula (see Geol. Map II)

Because the folds and thrusts in this area are cut by a complicated mesh of faults, it is very difficult to restore the original structure. Thanks to MATSUSHITA's elaborate work, however, recumbent folds and thrusts toward the northeast have

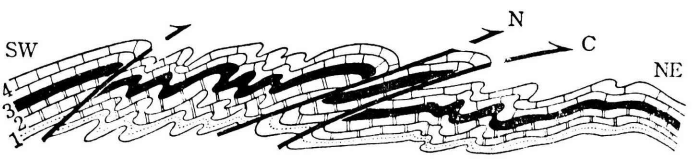


Fig. 15. Generalized Profile of the Liaotung Peninsula (after MATSUSHITA, but modified).

N. Nanshan Thrust
C. Chinchou Thrust
1. Tahoshangshan Series
2. Kuantung Series
3. Nanshan Series
4. Palaeozoic Formations

emerged by elimination of the secondary displacement. This folded zone is composed of the Sinian group, about 7,000 m thick, the Korean group, about 1,300 m thick and the thin lower P'yeongan group, about 200 m thick, or a total of about 8,500 meters of the three sedimentary groups. The gneiss complex at their base is not exposed. Broadly speaking, it is a large synclinorium. Hence the Tahoshangshan series is exposed on the northern and southern peripheries and is especially extensive in the Lüshun projectile west of Talien. This synclinorium, however, is dissected by the Chinchou thrust. One can see the three groups in the northern terrain, while its south side is occupied by the Sinian group. Therefore the large synclinorium can be divided into the southern anticlinorium and the smaller scale northern synclinorium, which are separated by the Chinchou thrust.

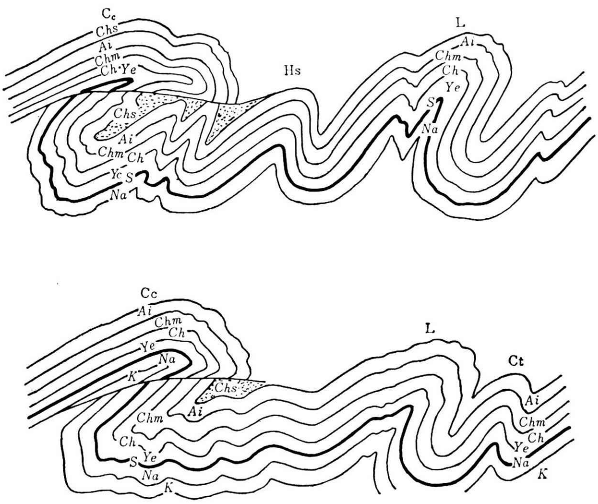


Fig. 16. Two Restored Profiles of Chinchou Area (after MATSUSHITA). (Upper and lower profiles respectively through the western and eastern part of this area).

Chs.	Lower P'yeongan Group	Na.	Nanshan stage
Ai.	Middle Ordovician Formation	K.	Kuantung Stage
Chm.	Lower Ordovician Formation	Cc.	Chinchou Anticline
Ch.	Upper and Middle Cambrian Formations	Hs.	Houshihhueiyaotun Anticline
Ye.	Yenchialu Stage	L.	Lashushan Anticline
S.	Sanshihlipu Stage	Ct.	Chitingshan Anticline

In the northern synclinorium the P'yeongan group is found at Chienshihhueiyaotzu, northwest of Chinchou. Thus, the main axis of the synclinorium is much deviated to the south. The southern anticlinorium is thrust upon this subsided part of the northern synclinorium, the front of the thrusting body being marked by the Chinchou thrust line. The central and southern parts of this synclinorium, to the south of Sanshihlipu, is mainly occupied by the Korean group. The Lashushan homoclinal anticline extends southeast from the Lashushan projection, and divides the Korean group into northern and southern parts. On each side of this principal anticline is an auxiliary anticline, the Chitingshan on the north and the Houshihhueiyaotun on the south. Farther south is the small Chienshihhueiyaotzu syncline, the axis of which is indicated by the P'yeongan group. The northwest side of this area is intensely folded, but the folding decreases southeastward till it results in gentle undulations near the Chinchou fault.

The northern synclinorium is thus quite asymmetrical, having its main axis near its southern margin. The Chinchou anticline within the synclinorium is recumbent and is thrust upon itself, as seen at Lungwangmiao on the western shore. The major part of this *Decke* is now eroded out, but north of Taiweichiatunhuei, Chienshihhueiyaotun and Yaochiatun, it can still be seen that the Lower Ordovician formation lies on the lower P'yeongan group.

In the stretch between the Chinchou thrust and south Talien, there is an extensive display of the middle and upper Sinian group. On the south side of the Chinchou anticline is the recumbent anticline of Nanshan which is thrust upon the former, forming the Nanshan thrust.

The lower limb of the Nanshan anticline is cut off by thrusting. Its upper or southern limb is indicated by a broad saddle of the Kuantung series which is gently inclined toward the south. Further south are a syncline and an anticline. The latter is the Kuanchingtzu anticline, whose northern limb is cut by the Kuanchingtzu and Haimiaotuotzu thrusts. The northern syncline beneath the Haimiaotuotzu thrust forms a minor anticline near the Chuanshueiyentzu thrust along the northern margin, where it is thrust upon the Nanshan anticline.

The Kuanchingtzu anticline strikes equatorially east of Choushueitzu, but turns abruptly to the north in the west. There it develops into an anticlinorium comprising the eastern and western Yüshan anticlines. This is a narrow fluted zone between the south limb of the Nanshan anticline and the Yuchiatun dome. Further on is the Panchüantzu basin of the Nanshan series on the Pohai coast. The Yuchiatun dome, which is composed of the lower Kuantung series, reveals a northern projection of a large anticlinorium in which the Tahoshangshan series is well developed.

The above mentioned structure is further complicated by three systems of faults. The oldest is the strike fault system (I). NNE to ENE trending faults belong to the next system (II). The last system is represented by the NNW to NW trending faults (III). The first system comprises reverse (Ia) and normal faults (Ib). For example, the upthrust extending southward from the northern limb of the Lashushan anticline belongs to the Ia group. No thrust of the Ia group is found on the south side of the Chinchou thrust. It is a general tendency for the Ib group of faults to have the downthrow on the side of a syncline, instead of an anticline. Among the Ib group of tension faults there are three kinds, as follows:

Ib^1 Those parallel to the thrust, e.g., Chinchou-Tungmen fault.

Ib^2 Equatorial to NE trending faults at Tahoshangshan, Luotuoshan, Chipanme, Lioushutun and other places, and their companion faults, some of which are hinge faults. Some are intruded by diabase.

Ib^3 NW trending fault of Chungkechenpao and WNW trending fault of Taimaoyingtzu, where the former is a hinge fault and the latter has its downthrow on the north side.

The faults of the II group commonly trend in a NNE direction and less commonly in a NE or ENE direction. They are mostly normal faults, but some are hinge faults. Some of them have topographic significance. The most important among them is the Chinchou fault which bisects the peninsula. This fault is indicated by a disturbed zone dipping about 40 degrees, along which the western block has slipped down several hundred meters. A short distance west are some parallel faults, which as a whole may be called step faults, although a few exceptions have the downthrow on the opposite side. Further west, the terrain is dissected into horsts and grabens by faults of the same trend.

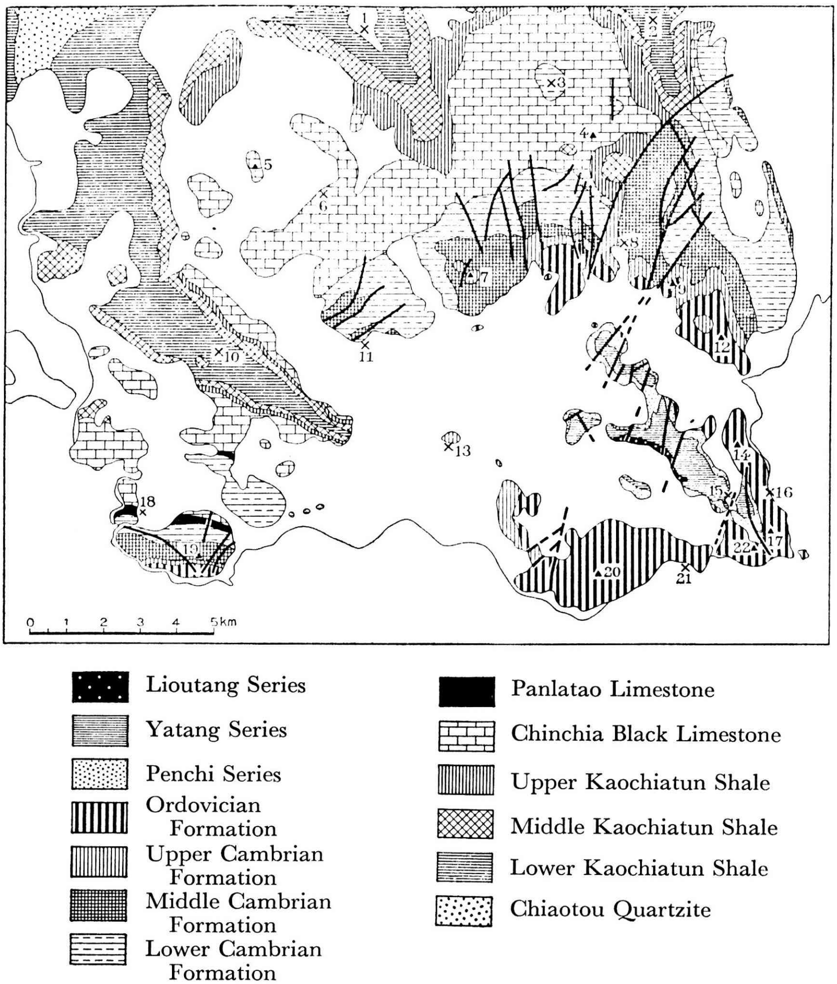


Fig. 17. Geological Map of the Chinchiachengtzu-Hsitao Area (after AJOI, KOBAYASHI, NAKAMURA, SOO and NODA).

1. Laoyufang
2. Hanchiachuang
3. Yuanchiakou
4. Wuhangshan
5. Pachiashan
6. Chientafangshên
7. Mapanshan
8. Chinchiachengtzu
9. Paichiashan
10. Sanchingkung
11. Lienhuashan
12. Taishan.
13. Taipaotzu
14. Loutuoshan
15. Tingchiatun
16. Tunghaimatou
17. Sanlengshan
18. Panlatao
19. Yuntaishan
20. Taitzushan
21. Nanhaimatou
22. Taoershan

The Chinchou fault extends south of the Chinchou thrust. On its west side are the Taifangshen, Chinchoupeimen, Nankuangling, Leishan and Tayüshan faults. The Kechenpao fault which runs meridionally across the interval between the last two faults is intruded by a diabase dyke. The Liangyenching fault on the west side of Tayüshan describes an arc with convexity to the east and is intruded by diabase at Liangyenching, but cuts a diabase dyke at Nankuangling. Therefore it is presumed that the intrusion of the diabase is nearly simultaneous with the block movement.

Finally the faults of the III group trend in a NNW to NW direction in general, but occasionally run a little west of north. The Chinchou fault is dislocated by faults of this kind, which are evidently the products of the diabase intrusion. The Hsiachiahetzu, Yangchuantzu and Chienkuantun faults in the south belong to group III.

5. **Wuhutsuei Basin** (see Geol. Map III)

On the north side of Yatang bay is a large structural basin. On its northwest side beyond the Fuchouho river is the Fuchou syncline with the Cambrian of Tsianghsingtao island along its axis. At the eastern end of Yatang bay is the ancient gneiss of Tawangshan. Through Tientaishan this is linked to the Taipingkou inlier of the pre-Hsiho metamorphic rocks by the Tiaoyütai quartzite. The Wafangtien and Pulantien basins lie on the east side of this anticlinal ridge.

The anticline stands on the eastern wall of the Wuhutsuei basin which is composed of the Sinian group, about 2,000 m thick; the Korean group, about 1,000 m thick; and the lower P'yeongan group, about 200 m thick. Because the basin structure is asymmetrical, the distribution of the Palaeozoic formations is restricted to the southwestern part of the Chinchia basin. This, too, is asymmetrical as is indicated by the P'yeongan group near the southeastern corner of the Chinchia basin. The Ordovician and Upper Cambrian formations are abruptly bent up along the coast of the south sea or Nanhai.

The east side of the basin is delimited by the Wangpashan thrust. The eastern Chiaotou quartzite is thrust at a low angle upon the western Wuhangshan and Cambrian formations along this tectonic line which rises northward from Paochiatao isle. The coast line has a deep indentation north of this isle, forming an inlet called the Tunghai or east sea. There, the folded belt in front of the Wangpashan thrust is submerged, but it is seen in the hills of Waitoushan that the fold axis of the Lower and Middle Cambrian formations has migrated toward the north. The long Hanchiachuang anticline is on its west side.

Along the west side of the Tunghai through Taishan and Mashan the Ordovician formation forms the eastern wall of the Chinchia basin. At Sanlengshan and Taoershan the Ordovician and lower P'yeongan formations change their strike abruptly to form an acute angle where they are partly overturned. From the apex of this angle the P'yeongan group extends along the bisectrix, forming a low hill where the group lies horizontally.

Although the Chinchia area is cut by numerous faults, it is still a typical basin topographically as well as geologically. The hilly land is surrounded by the ridge-making Ordovician limestone. The Cambrian rocks are distributed on the outer circle. The Wuhangshan series is widely distributed farther northwest, and the Lower Cambrian occurs in the Yuanchiakou basin.

The Chinchia basin and the Pachiashan syncline each measure 6 km in breadth. They are separated by an anticline extending from Laoyufang toward the southeast. A subparallel anticline exists on either side of that anticline. The eastern one is the above mentioned Hanchiachung anticline and the western one is called the Sanchingkung. Both have their axes inclined toward the southeast.

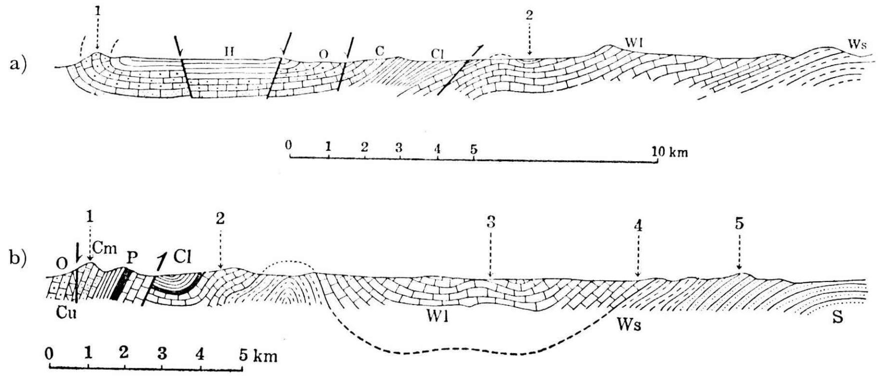


Fig. 18. Profiles of Chinchiachengtzu (a) and Hsitao Area (b) (after NAKAMURA and SOO).

H. Lower P'yeongan Group
O. Ordovician Formation
Cu. Upper Cambrian Formation
C. Upper and Middle Cambrian Formations
Cm. Middle Cambrian Formation
Cl. Lower Cambrian Formation
P. Panlatao Limestone
Wl. Chinchia Black Limestone
Ws. Kaochiatun Shale
S. Chiaotou Quartzite

1. Sanlêngshan
2. Yenchiakou
in the Upper Profile (a)

1. Yuntaishan
2. Hsiaochaochiatun
3. Chientafangshen
4. Chichiafang
5. Taheishan
in the Lower Profile (b)

The Hsitao area is separated from the Chinchia basin by the Sanchingkung anticline, which contains the Panlatao limestone. At Yuntaishan the limestone is overlain disconformably by the Korean group and underlain conformably by the black limestone of Chinchia. They dip to the south and on the north side are thrust upon the Lower Cambrian.

Thus the Hsitao-Chinchia basin suffered thrusting from the south and east sides, with the result that its structure became asymmetrical. While the strata are fluted or steeply inclined near the two margins, they slant gently on the northwest side; there are some broad undulations, as noted already. On the northeast side there is a centrifugal thrust of Sunchiatun along which the Chiaotou quartzite is pushed upon the Lower Cambrian of Hamakou in the east and the Kaochiatun shale at Sunchiatun in the west.

In the Chinchia basin there are numerous faults. One of them is the Chinchia fault, running from NE to SW through the west side of Chinchiachengtzu. It is a large fault along which the southeastern side has sunken. Most other faults trending NE, NNE, NS or NNW, however, are minor. At Lienhuashan in the southeastern part of the Pachiashan syncline are three step faults downthrown on the NW side.

The area between the Wangpashan thrust and the Tientaishan anticline is called here the Lankushan area. This occupies the outer belt of the Chinchia basin where the Wuhangshan and Hsiho series are widely distributed. Some thrusts toward the east or west are generally found within the Nanfen shale and marl formation. The Chiaoyütai quartzite lying on the gneiss of Tawanshan marks the eastern margin of the large Wuhutsuei basin. In the northern part, the Chiaoyütai quartzite is thrust upon the younger members of the Hsiho series at some places.

Though complicated by undulations and low angle dislocations, it is generally accepted in the Lankushan area that the older formations are developed on the east and the younger ones on the west side. Such meridional zones extend southerly as far as the northern coast of the Yatang bay where they are cut by an equatorial tectonic line. Along the eastern part of the coast the Chiaotou quartzite and the younger formation to the south are thrust upon the Nanfen shale along the tectonic line which takes a meandering course. This is the Yatang tectonic line. It is considered to run across Yatang bay diagonally and reach Chientailientao isle where the Chinchia black limestone slips upon the Chaiotou quartzite.

The line is aligned with the Pulantien fault *en échelon*. They indicate the old and young dislocations of the boundary between the peninsula and its neck. Whether the Yuntaishan thrust of Hsitao occupies the western extention of the Yatang tectonic line, or not is difficult to determine but at any rate they are all products of the thrusting of the southern area upon the northern. The northern area can be divided into the Wafangtien-Pulantien area, the Lankushan monoclinal area and the Chinchia-Hsitao basin by the Tientaishan anticline and Wangpashan thrust line.

6. The Wafangtien and Pulantien Basins (see Geol. Map III)

On the east side of the Tientaishan anticline are the Wafangtien and Pulantien basins, and further on an extensive display of the ancient granitized basement. The Pulantien basin of the Cretaceous formation is delimited by the Pulantien fault on the south. Running along the southern coast of the Yatang bay and passing through the southern side of Pulantien, it extends slightly to the north of east. There the Hsiho series is directly overlain by the Cambrian.

In the Wafangtien basin in the north there are patches and strips of the Jurassic Wafangtien formation. The Cretacous Pulantien formation, on the other hand, occupies the large area of the Pulantien basin in the central and southern parts. These Mesozoic formations afford an indispensable key to analyzing the tectonic development.

As mentioned already, the base of the Jurassic is marked by a remarkable discordance. Therefore it can safely be concluded that before Jurassic sedimentation the older formations were folded, most probably by the Songnim disturbance.

The bedrocks on which the Jurassic formation lies belong mostly to the Cambrian formation. Broadly speaking, its upper part is well developed in the central part of the basin, and so is its lower part around the margin. The Hsiho series is distributed in the further outer side, if the secondary dislocation is eliminated. Therefore the depression of the Wafangtien formation also must have been a structural basin of the Cambrian formation. It is noteworthy that the Jurassic lies on the Cambrian with angular unconformity at some places. This fact, together with the variation among the Cambrian rocks, shows that the basin structure was complicated by local folding to some extent.

This structure was later modified considerably by the Taebo disturbance. Among the thrustings in which the Wafangtien formation plays a role, there are three important elements. One is the Yuntaishan *Pseudoklippe*. The second is the Wafangtien thrusting-sheet and the third the thrusts at Chatzuyao and other places within the basin.

The pre-Hsiho phyllites and dolomites near Chinchangtun are intruded by andesite, and are thrust upon the Jurassic north of Hsiaolinchiatun. This thrust is dislocated toward the south and recurs south of Wangchiatun, southeast of Wafangtien. There a small *Klippe* is found on the Jurassic in front of the thrust.

These metamorphic rocks are overlain by the Chiaoyütai quartzite at Yuntaishan. Southwest of Wafangtien, the phyllites are thrust on the Jurassic or the subjacent Cambrian. Because the pre-Hsiho metamorphics are always in thrust contact with the Jurassic or Cambrian formation, there is a theory that they form an exotic mass transported from a remote place, but there is no root for such a thrusting sheet. In my opinion they form a parautochthonous *Pseudoklippe* which was squeezed out by compression of the Taebo movement.

Northeast of Wafangtien there is a chain of *Klippen* composed of the Chiaotou quartzite. They lie on the Lower Cambrian in most places, but on the Jurassic near Lichiayao. On the west side of the railway line is the autochthonous Chiaotou quartzite which is overlain by the Cambrian, which in turn is overlain by the Jurassic formation. This belt must be the root of the Wafangtien thrusting sheet. Due to the difference of competency for lateral pressure, the rigid Chiaotou quartzite presumably was slipped upon the plastic Lower Cambrian shale and was transported tangentially. The dislocation of the thrusting sheet attains about 4 km at the maximum.

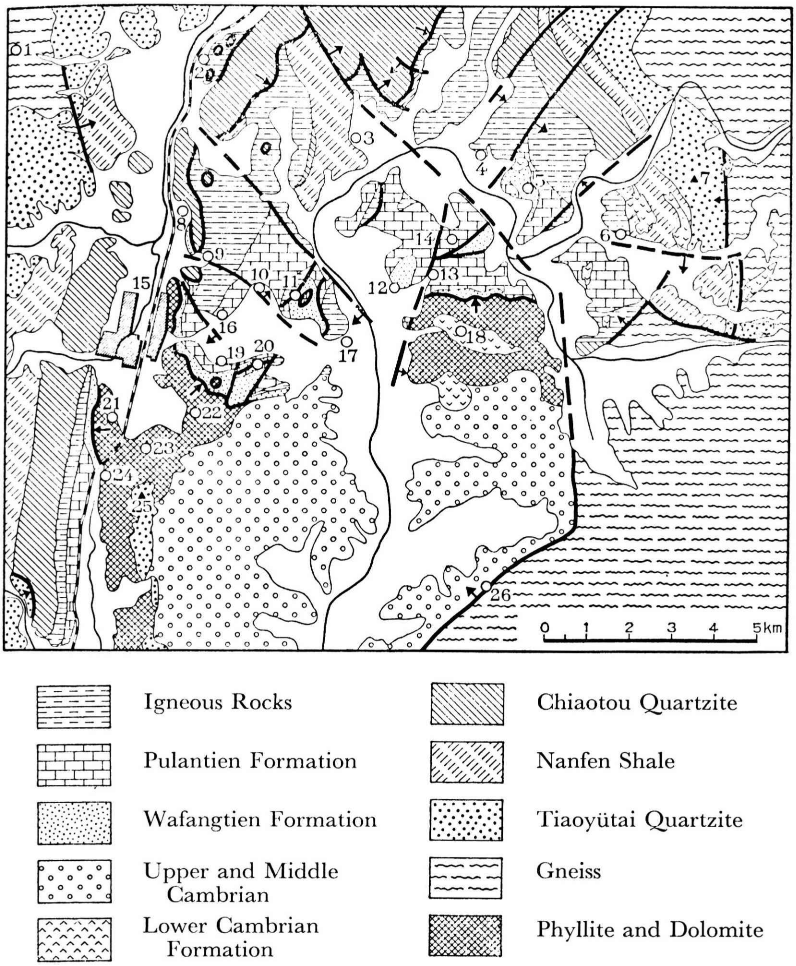


Fig. 19. Geological Map of Wafangtien Basin (after Kobayashi, Horiuchi et al.).

1. Taipingkou	2. Lichiatun	3. Chaochiatun
4. Tailuchiatun	5. Hsiaoyinchiatun	6. Luchiatun
7. Wanchengshan	8. Lichiasueitzu	9. Lichiayao
10. Yangshufang	11. Chatzuyao	12. Takumiao
13. Liuchiatun	14. Hsiaolinchiatun	15. Wafangtien
16. Chuanchüehfang	17. Hsintuntzu	18. Chinchangtun
19. Tangchiatun	20. Wangchiatun	21. Kangtzutien
22. Kanchiatun	23. Chaochiatun	24. Yangshufang
25. Yuntaishan	26. Chunghêtien	

The centripetal thrustings from the northwest and south sides caused the Cambrian and Jurassic formations of the Wafangtien basin to be contorted, yielding some thrusts in themselves. At Chatzuyao the Jurassic formation is thrust by the Cambrian on the east side, strongly disturbing the Cambrian on its west side. There is a thrust in the opposite direction within the Cambrian strata which extend from Kaoshantun to the northeast. It may be an accessory dislocation in front of the Wafangtien thrusting sheet.

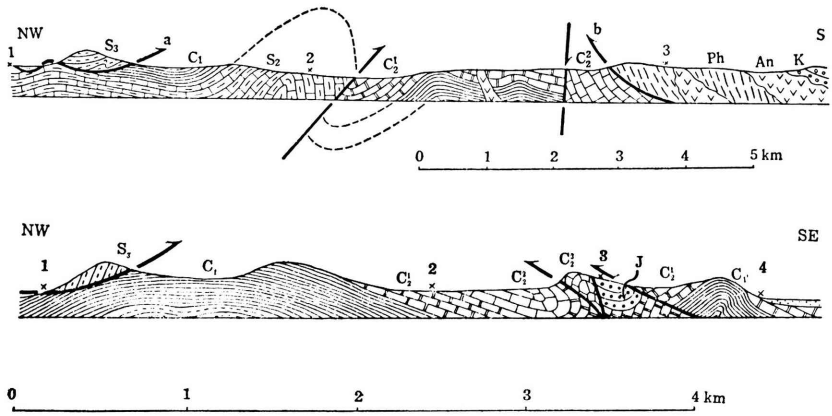


Fig. 20. Two Profiles of the Wafangtien Basin (KOBAYASHI et al.).

K. Pulantien Formation
J. Wafantien Formation
C_2^2. Late Middle Cambrian Formation
C_2^1. Early Middle Cambrian Formation
C_1. Lower Cambrian Formation
S_3. Chiaotou Quartzite
S_2. Nanfen Shale and Marl
Ph. Phyllite and Dolomite
An. Andesite
1. Lichiatun
2. Chaochiatun
3. Chinchangtun
a. Wuchiatun Thrust
b. Chiangchiatun Thrust

in the Upper Profile through the Central Part of the Basin

1. Lichiashueitzu
2. Yangchiafang
3. Chatzuyao
4. Hsinchiatun

in the Lower Profile through the Western Part of the Basin

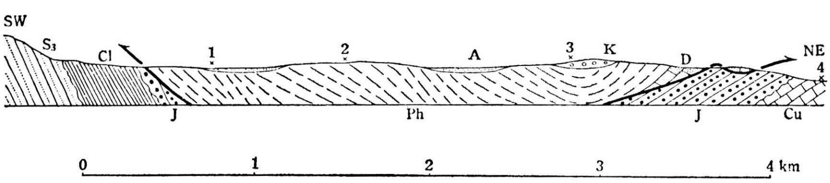


Fig. 21. Profile of the Southwestern Margin of Wafangtien Basin (after SAITO).

A. Alluvium
K. Pulantien Formation
J. Wafangtien Formation
Cu. Upper Cambrian Formation
Cl. Lower Cambrian Formation
S_3. Chiaotou Quartzite
D. Dolomite
Ph. Phyllite
1. Shenyang-Talien Railroad
2. Chaochiatun
3. Kanchiatun
4. Tangchiatun

The basin structure thus intricately disturbed by the Taebo movement was further complicated by vertical dislocations in various directions. The NE to ENE and NW faults are common. They have a tendency to form horsts and grabens. In addition, there is a large meridional fault running from Wafangtien to the south along the railway line.

The Cretaceous formation is a filling of the post-Taebo basin surrounded by rugged mountains. Judging from its lithofacies, it was deposited immediately after the disturbance. Because it is largely cut by faults on the east and south sides, it is certain that a strong block movement has occurred in the late Cretaceous or Tertiary period.

Cut by the NE fault through Tachengchiatun and Tawangchiatun, the Cretaceous is in contact with the gneiss complex. Because of the lack of any gneiss boulders in its conglomerate, it is presumed that the gneiss basement must have been covered by the Hsiho series before the dislocation. The southern boundary fault of the basin belongs to the same system.

7. Discussion and Summary

In the Liaotung peninsula the pre-Songnim sequence differs remarkable in the northern and southern areas, which are bounded by the Yatang tectonic line. As shown in Table 9, the subsidence was three times greater in the southern than in the northern area. Among the three major stratigraphic units the difference in thickness is especially great in the Sinian group, which shows a remarkable difference in the amount of subsidence between the kratonic mass of P'yeongbuk on the north and the geosynclinal zone of P'yeongnam on the south. The Sinian group is not thinner in the Chaeryeonggang belt of North Korea than in the Liaotung peninsula, but is reduced to less than 2,000 m thick in the central and northern parts of the Daedonggang basin. Nevertheless there is no large break between the Sinian and Korean groups. Therefore this difference must indicate differential subsidence among the parts of the geosyncline. It is certainly noteworthy that the stratigraphical break at the base of the Cambrian system becomes larger from south to north in the Liaotung peninsula. Within the northern area it is larger in the Wafangtien area than in the Wuhutsuei basin. In fact the Wuhangshan series is completely missing in the eastern area.

Table 9. Difference in Thickness of the Pre-Song'nim Sediments on the Two Sides of the Yatang Bay Tectonic Line.

Formation	South Area		North Area
P'yeongan group	Ca. 200 m	Yatang Tectonic Line	Ca. 200 m
Korean group	Ca. 1,300 m		Ca. 1,000 m
Sinian group	— 7,000 m		Ca. 2,200 m
Total Sum	Ca. 9,000 m		Ca. 3,000 m

Farther north is the Yungning sandstone, which indicates a fossil delta wedging into the Wuhangshan series and expanding toward the west. These facts indicate that the P'yeongbuk land existed in the middle Sinian period. In the latter half of the Sinian period the northern massif was elevated reciprocally to the subsidence of the geosyncline and underwent erosion. The clastic material thus produced was transported from the land to the geosyncline. During this land period the topographic relief of the massif is thought to have been greatly reduced.

In view of the uniformity of thickness of the Korean group and the preponderance of calcareous rocks, it is understood that the differential movement between the two tectonic units was greatly reduced in the Cambro-Ordovician period. After the prolonged Middle Palaeozoic land period, these areas were submerged and the P'yeongan group was deposited, but the local variation of its facies and thickness between the two areas is slight.

The present geologic structure has resulted through repeated crustal deformations. The Yatang tectonic line is an important boundary between the two tectonic units. Another important boundary is the Chinchou fault. From the tectogenetic point of view the Liaotung peninsula can be classified into four kinds of areas as follows:

—A Strongly Subsided Area: ....Distribution of the P'yeongan-Korean Group.
+B Moderately Subsided Area: ....Distribution of the Middle and Upper Sinian Group.
+B Moderately Elevated Area: ....Distribution of the Middle and Lower Sinian Group.
+A Strongly Elevated Area: ....Distribution of the pre-Sinian Basement.

Table 10. Alternating Disposition of Positive and Negative Elements in the Liaotung Peninsula.

—A	+B	—A
	—A	+A
	—B	—A
+B		

When classified and schematized as in Table 10, it is evident that there was a subsiding NW axis as indicated by three minus As. The elevating NE axis through +A, —B and +B crosses the subsiding axis at right angles. When viewed equatorially or meridionally, the positive and negative elements are found to be arranged alternately. They are combined in a checker pattern. More precisely, the northern area can be divided into the western, middle and eastern areas, or the —A, +B and —A elements, by the Wangpashan thrust and the Tientaishan anticline. West of the Chinchia basin there is a moderately subsided area (—B) of Fengningtao and Hsichungtao, while on the east side of the Wafangtien-Pulantien basin there is gneiss terrain (+A).

On the south side of the Yatang line the strongly subsided area (—A) of Chinchou-Sanshihlipu lies in the west and the extensive gneiss terrain (+A) in the east.

Further east is the moderately elevated area (+B) of Pitzuwe-Taichangshantao. On the south side of the above mentioned gneiss terrain there lies the subsided area (−A) of Tangchiakou where the Pyeongan group is encountered. On the south side of the Chinchou-Sanshihlipu area is the Nanshan-Nankuanling area (−B), and to its southwest is the Lüshun or Port Arthur area (+B).

This lineament of the positive and negative elements reveals the total sum of the endogenetic and exogenetic phenomena which have taken place at least since the end of the Palaeozoic era. The amount of erosion differs greatly between the subsided and elevated blocks. Furthermore, the horizontal variation in facies and thickness of the Palaeozoic formation is slight. Therefore it is not difficult to imagine that the Sinian group has been capping the basement to extent, e.g., the gneiss mass east of the Chinchou fault.

It was long thought that the late Mesozoic Taebo disturbance is responsible for the folded structure of the Liaotung peninsula. HORIUCHI, however, pointed out that the base of the Jurassic Wafangtien formation is marked by a strong discordance, where the Jurassic sediments accumulated on the structural basin of the Cambrian formation. It is certain that the quartzites of Tiaoyütai and Chiaotou have resisted against such a compression. In view of the basin structure of these rigid formations on the kratonic mass, it is easy to imagine that the more plastic rocks in the geosynclinal zone have been disturbed more strongly by the same movement.

It is possible that the geosynclinal zone emerged and became a folded mountain range during the Songnim disturbance. The Wafangtien formation is thought to be a lacustrine deposit in the frontal basin of this range. Due to the lack of Mesozoic formations in the peninsular part of Liaotung, the tectonic development of the geosynclinal zone cannot be divided into the Songnim and Taebo phases. The development can be clarified only through the study of tectonics in the Wafangtien basin and by comparison with the geology of the South P'yeongan-do and Hwanghae-do areas in North Korea, which belonged to the same geosyncline. As mentioned earlier, the Songnim disturbance was the principal phase of the crustal movement through which the pre-Songnim formations were strongly folded and thrust. The geologic structure thus produced was further complicated by thrustings and slidings in the Taebo phase.

Judging from the existing structure, a gentle synclinorium and anticlinorium must have been two embryonic folds respectively in the northern and southern parts of the peninsula to the south of the Yatang line. If the southern anticlinorium of the Sinian Sangweon group is compared with that of the Chaeryeong-gang belt, the northern synclinorium corresponds to that comprising the Hwang ju basin and the Chunghwa area in North Korea. In the Liaotung peninsula the synclinorium was asymmetrical, having its subsiding axis in the south upon which the anticlinorium was overturned and developed into a thrusting sheet yielding the Chinchou thrust between them. Later this fundamental structure may have been deformed, yielding upthrustings and slidings of the Taebo phase, but the destruction by still later faulting was greater in this peninsula.

It is interesting to see that the deformation which the Wafangtien basin has suffered is very similar to what has occurred in the western coal-field of P'yeongyang. The Wafangtien thrusting sheet of the former is comparable with the Kŭmche or the Ch'ebong thrusting sheet of the latter. Likewise, the Kiyang thrust of the latter takes a similar position to the northerly thrusting line of the Yuntaishan *Pseudoklippe* in the former area. The Jurassic and Cambrian formations of the Wafangtien basin were thrust in themselves and folded beneath these thrusting sheets from the two sides, as was the Daedong series of P'yeongyang and Kangseo beneath the similar centripetal thrusting sheets. It may, however, be appropriate to compare the Teoksan thrusting sheet near Samdŭng with the Yuntaishan *Pseudoklippe* which is outlined by the centrifugal thrusts on its two sides. Thus the mode of crustal deformation which the Wafangtien formation suffered before the Pulantien period is essentially the same as that of the Taebo phase in the Daedonggang basin in North Korea.

The series of these thrusts in the two regions are not the dislocations developed from the recumbent foldings but a kind of upthrust or intraformational sliding caused by compressive block movement, although they may take the form of low angled thrusts. Slidings of this kind are seen also along the anticline of Tientaishan where the Tiaoyütai quartzite is thrust up toward the east or west. There are also some *Pseudoklippen*. Farther northwest, as far as the Wangpashan thrust, the Sinian group is dislocated in some places by submeridional thrusts. In North Korea there are some thrusts in a similar trend, the Ap'ari or Suip thrust, for example. There is a tendency for the dislocations of these thrusts in the Lankushan area alternate between east and west and for the quartzite formation to shift up. Therefore these dislocations belong to the same system as the thrusting of the Chiaotou quartzite upon the Cambrian in the Wafangtien area. The dislocation lines of the system are cut by the subequatorial Yatang tectonic line.

Thus, on the north side of the Yatang bay, the embryonic basin structure of the Songnim phase in which there were some sharp foldings was later deformed by the compressive block movement of the Taebo phase. It was astonishingly similar to what has been seen in the P'yeongnam orogenic zone of North Korea.

Along the Yatang line the south side was pushed up toward the north. Although the line to the west of Chientalientao lies concealed below sea-level, the push of the southern side toward the north is clearly indicated by the overturned Ordovician at Taoershan and a similar structure at Yuntaishan in the Hsitao area. It is reasonable to consider that such an upheaval has produced an upthrust toward the south within the Lashushan anticline. These series of block foldings were followed by a tension movement through which strike faults are thought to have come into existence.

This block movement was accompanied by volcanic eruption. The pyroclastic materials accumulated in the Pulantien basin. The Pulantien formation consists of two cycles of sedimentation, suggesting the rejuvenation of erosion at their transitional interval when the region suffered folding or even tension faulting caused by excessive compression. Thus the Pulantien formation was probably in the making when the late Mesozoic block movement was still going on. It is cut by faults of later ages. In the eastern part of the Kangweondo limestone plateau in South Korea a block movement and related igneous activity took place near the end of the Cretaceous period. Since the late Mesozoic granite is not extensive in the Liaotung peninsula, the block movement may not have been strong.

Generally speaking, the Palaeogene was a tranquil period for Eastern Asia when erosion advanced in Korea and Manchuria. At length the region was levelled to the Yukpaeksan peneplane. Through the Middle Tertiary block movement this plane was displaced. In the Liaotung peninsula the faults in the Sinian trend are more developed than those in the Korean trend, while the reverse is the case in the Daedonggang basin. The Chinchou or Annak faults are respectively the most significant of the former and latter areas. They differ in direction but agree in the low angles of the dislocation planes.

In short, the folded structure of this region, which used to be considered a product of the Taebo disturbance, is not so simple. The tectonic analysis indicates that the fundamental structure which had been established by the Songnim disturbance was to a great extent secondarily modified by the Taebo disturbance. This fundamental architecture started with embryonic domes and basins which were arranged alternately in a checker pattern. In the geosynclinal zone the embryonic fold developed respectively into an anticlinorium and a synclinorium, till at length they became overturned and cut by thrusts. The Songnim disturbance turned the zone into a quasikraton. Together with the kratonic mass in the north it was later deformed by the block folding of the Taebo phase, causing upthrusting and sliding at places. These dislocations occurred in the northern area along various trends, but south of the Yatang bay the upthrust lines run mostly in a direction concordant with the fundamental structures.

IV
The Taitzuho and Yalu Tributaries in South Manchuria and North Korea

1. Introduction

There are many papers dealing with the stratigraphy of this region, in addition to some discussing its geologic structure. Several geological sheet maps and explanatory texts have also been published, but no tectonic synthesis of this region has as yet been attempted.

I have carried out field work in some detail in the Penhsihu and Niuhsintai basins and the Ch'osan (Sosan) area and have made geologic reconnaissances from Liaotung to Hsiaoshih and from Manp'ojin (Manpochin) to Huch'ang (Kosho). Although these are important areas, my own observations are limited. Moreover, precise descriptions of local geology, published and unpublished, deal only with a small portion of the vast terrain of the two valleys. While the stratigraphy of the Taitzuho or P'yeongan and older formations and rocks is fairly well established, much remains to be studied for the Mesozoic before analyzing this and later movements into phases.

Under these circumstances, the present synthesis cannot help but be preliminary. Nevertheless, intensive studies in some selected areas make it possible to grasp the concept of the regional geology with some accuracy. Therefore it is possible to understand that this geology has characteristics quite distinct from those of the Okch'eon and P'yeongnam zones. The upper Hunchiang and middle Yalu tributaries provide typical examples of kratonic fragmentation, while the Taitzuho river district is an excellent example of quasikratonic deformation.

2. Stratigraphy

From the tectogenetic standpoint the rocks and formations of the Taitzuho zone can be classified into the following three groups:—

A. Pre-Hsiho basement complex.
B. Hsiho series, Korean group and Taitzuho group, all deformed by Mesozoic disturbances.
C. Mesozoic and later sediments and igneous rocks.

a. Pre-Hsiho Basement Complex.

Ancient schists and gneiss are mostly distributed on the north and south sides of basins along the Taitzuho valley. On the south side there is the Liaoho group composed of metamorphic rocks of sedimentary origin. Its sequence with the carbonate facies in the middle part reveals a grand cycle of sedimentation, attaining several thousand meters in total thickness. The Anshan series composed of sericite-schist, quartz-schist, actinolite-schist and so forth, overlies the granites and metamorphics and is intruded by the Kungchangling granite. The field relation between the Anshan and Liaoho formations has not yet been determined. The Shoushan formation, which IMAMURA (1940) considered to occupy the upper part of the Anshan series, consists of tuffaceous sandstone, tuffaceous shale and quartz-trachyte and is overlain unconformably by the Hsiho series.

b. Hsiho Series.

This is divisible into Tiaoyütai quartzite, Nanfen shale and marl and Chiaotou quartzite in ascending order.

(1) The Tiaoyütai quartzite is light brown, gray or white in color and is occasionally conglomeratic near the base. *Dreikanters* are found in the basal conglomerate near Anshan, and hematite layers are contained locally. The thickness of the quartzite varies from 3 to 250 m.

(2) The Nanfen shale and marl formation is 50 to 250 m thick; marl is developed in the lower part whereas shale is common in the upper part.

(3) The Chiaotou quartzite formation comprises some shale and marl and measures more than 250 m at the thickest.

The total thickness of the Hsiho series is 600 m or less in the Taitzuho valley, but the series becomes thicker in the Hunchiang tributary, measuring 1,000 to 2,000 m between the Linchiang and Tzuchengchiang rivers. Near Luohanku, east of Liaoyang, there is a clean-cut river-cliff for a long distance showing that the Chiaotou quartzite is overlain para-unconformably by the Lower Cambrian series. There the contact of the basal conglomeratic sandstone of the Lower Cambrian cuts the banded quartzite beds of the Chiaotou formation with a ratio of 1 to 2 m in a distance of about 1 km.

c. Korean Group.

In the Cambrian system a quartzose sandstone layer of less than 30 meters' thickness is occasionally found near the base. The base is often conglomeratic. Shale, however, is the leading member of the Lower Cambrian series, and limestone is intercalated with it. The Middle Cambrian is built up mostly of limestone, but contains a moderate amount of shale in the lower part; reddish brown sandstone is frequently found in the basal part, and marl occurs occasionally at the top of the series. Platy limestone and intraformational limestone conglomerate are well developed in the Upper Cambrian, but variegated shale or marl is intercalated in its lower and middle parts at places. The thickness of the Cambrian system is about 600 m on the average, but this of course varies to a certain extent.

Table 11. Sequence of the Pre-Song'nim Strata, about 2,000 m thick, in the Taitzuho Valley.

Taitzuho Group About 800 m thick	Permian	Tsaichia Series, 440 m thick
		Lioutang Series, 170 m thick Huangchi Series, 70 m thick
	Moscovian	Penchi Series, 100–120 m thick
Korean Group About 1,000 m thick		Ordovician Formation, 500–700 m thick Cambrian Formation, 600 m thick
Sinian Hsiho Series Less than 600 m		Chiaotou Quartzite, over 250 m thick Nanfen Shale and Marl, 50–250 m thick Tiaoyütai Quartzite, less than 250 m thick

The base of the Ordovician system is marked off by the *Cryptozoon* limestone in many places. Dolomite is common in the lower or Wanwanian series. The larger part of the middle or Wolungian series is occupied by massive limestone, often with patches of chert or flint. Massive limestone is also common in the upper or

Toufangian series, but bedded limestone is not uncommon. Dolomitic spots are frequently seen on them. Limestone conglomerate or so-called *Wurmkalk* is sometimes seen at the base of the Toufangian. The total thickness of the three series is estimated at about 500 to 700 m.

d. Taitzuho Group.

The notable differences between the group in the Taitzuho area and the P'yeongan group of the P'yeongnam and Okch'eon geosynclines are that the limestone occurrences are restricted to the Penchi series and coal measures are intercalated in the Taitzuho area. Fire clay is found in the group at many horizons; the Nogam series is absent. In the Taitzuho area the Taitzuho group is classified into the Penchi, Huangchi, Lioutang and Tsaichia series.

(1) The *Penchi series* lies on the Ordovician, in most places para-unconformably, but in the Hsiaoshih coal-field it is in clino-unconformable relation, indicating the *Hsiaoshih movement*. It is generally 100 to 120 m thick, but attains a thickness of 270 m in the east. It is composed of reddish rocks in the west, but of black shale and gray sandstone in the east; round quartzite pebbles are contained in the basal conglomerate; some limestone lenses or layers and coal measures are found intercalated in most sections.

(2) The base of the *Huangchi series* is generally demarcated by a disconformity, but the clino-unconformity of the *Nanpiao phase* is known in the Hsiaoshih coal-field. This series, about 70 m thick, is the principal coal-bearing series; black and gray colors prevail. It always exists in the western basins, but may be absent in the eastern areas.

(3) The *Lioutang series,* which overlies the preceding conformably, is the upper coal-bearing series, about 170 m thick. In the Hunchiang tributary it is mostly composed of light gray, coarse sandstone.

(4) The *Tsaichia series* is a thicker formation, comprising about 440 m of quartzose sandstone and variegated shale. It appears to lie conformably on the Lioutang, but at some places in the Yentai basin as well as in the Hsiaoshih basin they are in clino-unconformable contact. In the Penhsihu basin the conglomerate of 130 m thickness in the lower part lies disconformably on the Lioutang. In the Hunchang tributary at the top of the series there is false-bedded reddish sandstone, over 300 m thick, a possible equivalent of the Tsaichia series.

In summary it can be said that the Taitzuho group is about 800 m thick in the west, but in the east, where the Huangchi may be missing, it is about 500 m thick.

The Hsiho, Korean and Taitzuho formations altogether give some 2,000 m for the thickness, which is quite thin compared to the pre-Songnim sediments in the P'yeongnam or Okcheon geosyncline.

e. Mesozoic and Later Formations.

A lengthy description of the Mesozoic is given here, because this knowledge is indispensable for any analysis of the tectonic development of this region. According to KOBATAKE (1942), the Mesozoic sequence in the Tienshuaifukou basin is, in descending order, as follows:

(d) Sankeiling cliff-making conglomerate, over 1,000 m thick, containing rounded boulders with diameters averaging 10 cm, or 20 cm at the largest, mostly of quartzite and green siliceous rock, in addition to some black shale, sandstone and quartz-porphyry.

.... Unconformity ....

(c) Tapu coal-bearing formation, over 200 m thick, composed of alternating shale and sandstone in which syenitic porphyrite sheets of various magnitudes are inserted.
(b) Chuanshantzu conglomerate, over 100 m thick, containing unsorted boulders of quartzite and greenish gray siliceous rock; alternation between shale and false-bedded sandstone found in the central and southern parts.
.... Para-unconformity ....
(a) Changliangtzu alternation of black shale and gray micaceous shale, containing subangular pebbles of dark and siliceous rocks; basal sliding often occurs on the Taitzuho or Ordovician formation.

According to SUGAI, the Changliangtzu shale lies on the Ordovician limestone with strong discordance in the eastern part of this basin. All except the Sankeiling conglomerate yield plants. The Chuanshantzu plants and Estherians show some alliance to the Daedong fossils. KOBATAKE collected *Hausmannia* sp. from the Changliangtzu (?) shale west of Yangchikou, 8 km east of Chienchang.

In the Saimaki coal-field the Jurassic coal-bearing formation, more than 1,500 m thick, lies on the Korean group clino-unconformably. According to SUGAI (1942), its sequence is as follows:

I.	Upper coal-bearing formation.	
	Fangniukou sandstone and conglomerate	600 m
	Panchiahsikou coal measures	–650 m
II.	Middle coal-bearing formation	
	Hsinkailing shale	–700 m
	Chuchuankou coal measures	–600 m
	Tientingshan conglomerate	–400 m
III.	Lower coal-bearing formation	
	Hsiaokushantzu coal measures	–200 m
	Changshantzu trachytes	

These conglomerates are all alike; round boulders of fist-size to man's-head-size are most common; some boulders are granitic. The plants which YOKOYAMA (1906) has described were procured from the Hsiaokushantzu coal measures, which are most productive in the southern part of the basin. The three coal measures are all rich in Jurassic plants and common members are *Cladophlebis haiburnensis, Coniopteris burensis, Elatocladus manchuricus,* and *Neocalamites hoerensis.*

The coal-bearing formations constitute an anticline and two synclines, all having equatorial axes and cut by numerous faults. The most important of these are a hinge fault running from NNW to SSE through the center of the basin and a low angle thrust near its northern margin, along which the pre-Cambrian quartzite rides over the Hsiaokushantzu coal-measures, and the Tientingshan conglomerate, as well as the Korean group on the north side.

Subsequent to this disturbance there took place a primary intrusion of granite. This was followed by an eruption of andesite, presumably in the early Cretaceous period, because *Sphenopteris goepperti* (?) was found in greenish gray sandy tuff in the lower part of the andesite series. Finally, an invasion of granitic magma took place on a large scale. This intrusion may be referable to the late Mesozoic Pulguksa igneous activity.

Table 12. Tentative Correlation of the Mesozoic Formations in the Taitzuho and Yalu-Hunchang Tributaries.

Age		Penhsihu	Tienshuaifukou	Saimaki	Sinŭiju	Tunghua	Fusung	Chungangjin	Series
Cretaceous	Upper	Linchia Cg.	Sankeiling Cg.	Andesite		Tuffaceons ss.	Kutsangkou		Pulguksa
	Middle	Tayü							Silla
	Lower	Penhsihu							Naktong
Malm			Tapu	Upper Coal	Ŭiju	Chienshankou			Jehol
Dogger			Chuangshantzu	Middle Coal		Sanchatzu			
Lias-Up. Trias			Changliangtzu	Lower Coal	Ch'eog-seongjin			Chungangjin	Daedong,

In the vicinity of Penhsihu the Mesozoic formations are distributed on the two sides of the Taitzuho river and around Chiashan, east of Penhsihu. The Penhsihu (Honkeiko) and Linchia formations in the west form a gentle structural basin, steeply inclined near the western margin.

The Penhsihu formation overlies the Taitzuho group unconformably. Its lower 69 to 100 meters are represented by red conglomerate containing various rocks derived from the Taitzuho and older sedimentaries and pre-Hsiho metamorphics, in addition to pyroxene andesite, hornblende porphyrite, diabase and other igneous rocks. They vary in rounding and size to a great extent, the largest boulder being 50 cm in diameter; shaly layers are sometimes intercalated in the basal part. The upper Penhsihu, 300 to 500 m thick, consists of red shale and sandstone, partly tuffaceous or conglomeratic; false-bedding is common.

The Linchia formation, about 50 to 80 m thick, lies on the preceding with erosion unconformity; the facies is easily changeable. The lower part is a conglomerate bed containing large boulders of quartzite, 50 cm across; the upper part consists of alternating beds of quartzose conglomerate, sandstone and vari-colored shale; quartzite, gneiss, sandstone and volcanic rocks less than 5 cm in diameter are also contained in the conglomerate.

Cut by a fault in the Chiashan area, the base of the Miyanohara or Tayü formation is unexposed. Its lower part is composed of variegated sandstone, breccia, and conglomerate. Some pebbles resemble the Taling granite and others look like Nanfen marl. In addition, limestone, quartzite, effusive rocks, vein-quartz and others are found. The middle part is mostly yellowish red tuffaceous sandstone. The upper part consists of tuff, tuffaceous conglomerate and some lava flows, the lowest of which is metabasaltic andesite, the next, meta-andesite, and the third, dacite; the uppermost flow is quartz-trachyte. Thus the change from basic to acidic can hardly be overlooked. The formation strikes N 20°–30° E and dips about 50 degrees to the southeast. The other side is brecciated along the boundary fault.

The Tayü formation in the eastern area forms a structural basin with Kaolifenchu at its center. This formation is intruded by liparite and andesite and is thrust by the metamorphic rocks on the south side of the basin. Although the base is unexposed, it is more than 2,500 m in thickness and its facies variation great. The leading component is red or vari-colored tuffaceous shale, but there are numerous intercalations of sandstone conglomerate, limestone conglomerate, breccia and lapilli-tuff.

The mutual relation among the strata in the three areas is at present unclear. Those in the eastern and Chiashan areas, however, are grouped here in the Tayü formation because they are products of violent volcanic eruptions. SHIMAKURA (1937) identified a fossil wood from the western slope of Chiashan with *Pinoxylon dakotensis* KNOWLTON. Because of its occurrence, INAI (1936) emphasized that its age must be somewhere between Lower Cretaceous and Middle Jurassic.

According to YABE and S. ENDO (1937), *Salvinia* sp. collected at Tayüpaotzu suggests that the upper Tayü formation is not older than Late Cretaceous. The occurrence of *Plicatounio naktongensis manchuricus* and *Nakamuranaia chinshanensis* in the Mesozoic of Penhsihu has been reported by SUZUKI (1949). Although their exact locality is unknown, it is probable that they were presumably procured from a point 1 km southeast of Hsiwanfen in the Tayü formation. The former pelecypod is known from the Pulantien area and the Yingpan area, east of Fushun. Judging from these fossils the Tayü formation is perhaps Cretaceous in age. The Tayü and Penhsihu formaion represent probably two different parts of the same formation, because they are similar in lithology and structure, although the Tayü contains much more volcanic material than the Penhsihu formation. While the base of the former is unknown, the latter overlies the Taitzuho group unconformably. Therefore it is reasonable to locate the former above the latter.

The change from basic to acidic rock seen in the Chiashan area suggests that the Tayü volcanism corresponds to that of the Silla-Pulguksa series in South Korea. In weighing all of these facts, I am led to the contention that the Penhsihu formation is an approximate correlative of the Naktong series rather than the Jehol series. The Linchia formation lying horizontally on the Penhsihu is the youngest, but still not far removed from the end of the crustal disturbance, as can be judged from its boulder conglomerate. Therefore its age may be late Cretaceous.

At Tungshan, northeast of Hsiaoshih, there is a conglomerate formation, about 50 m thick, in which thin sandstone beds are intercalated. In the conglomerate, rounded or subangular quartzite and other siliceous rocks are cemented by red tuffaceous sandy material; limestone or gneiss pebbles are absent. From its lithology it appears to be a link between the Linchia conglomerate on the west and Sankeiling conglomerate on the east side.

In the upper Hunchiang tributaries east of Huanjen there is a thick vari-colored formation, 1,000 m or thicker, composed of tuffaceous sandstone and shale, tuff agglomerate and breccia containing andesite blocks. Near Pataochiang the Chienshankou coal-bearing strata are unconformably overlain by tuffaceous sandstone and shale. Another formation built up of tuff lies on the Taitzuho group unconformably, but its relation to the coal-bearing strata is undetermined.

Euestheria cfr. *middendorifii* occurs at Huanjen, Yushuchuan near Tunghua and at Sanchatzu, northeast of Tunghua, but the specimens are not preserved well enough to make specific identification. The Mesozoic formation of Kutsangkou can be divided into two parts. Estherians from its lower part bears Neo-Cretaceous aspects (KOBAYASHI and KUSUMI, 1953).

Southwest of Chunggangjin on the middle Yalu river there is a Mesozoic formation, over 1,000 m thick, which overlies the Korean group unconformably. It is composed of conglomerate, sandstone and shale, in addition to coal-seams. Quartzite is common in the conglomerate; its boulders attain a maximum diameter of 60 cm.

Near Sinŭiju on the lower Yalu there is the Cheongseongjin (Seijochin) clayslate formation yielding plants of the Daedong (Daido) flora, but its base is unknown. It is overlain unconformably by another Mesozoic formation which consists of the Cheongjudong (Seishudo) conglomerate (600 m), the Paekt'odong (Hakudodo) tuffaceous shale (420 m), and the Yeondaedong (Yendaido) sandstone and conglomeratic sandstone (170 m) in ascending order. The lower conglomerate is rich in porphyrite boulders, but the largest boulder, 1 m across, is a well rounded granitic gneiss. The middle shale yields Estherians and *Lycoptera* typical of the Jehol fauna. Thin coal seams are interbedded with the upper sandstone.

Overlying the gneiss complex is a monoclinal Mesozoic formation near Kanggye which commences with a basal conglomerate, 150–180 m thick. Above it black shale, 300–500 m thick, white sandstone and conglomerate, 150–250 m thick, and black and green shales, over 100 m thick, are accumulated one after another in the order named. In the northern part there are andesite tuff and lava flows below the basal conglomerate. TAKAHASHI (1953) correlated the sequence with that of the Jehol series near Sinŭiju, but no fossil has been found at Kanggye.

Judging from the plants the Cheongseongjin clayslate of Sinŭiju, the Mesozoic of Chunggangjin, the coal-bearing or the lower sediments of Saimaki, and the Changliangtzu shale of Tienshuaifukou belong to the Daedong series, from Lower Jurassic to Upper Triassic in age.

It is certain that the Jehol series of Sinŭiju is Middle and Upper Jurassic. It is probable that the Chienshankou coal-bearing formation of Pataochiang and the Tapu coal-bearing formation and the Chuanshantzu conglomerate of Tienshuaifukou belong to the Jehol series rather than the Daedong.

There is no Tertiary in the Taitzuho and the Yalu-Hunchiang tributaries, but north of the Taitzuho zone there is the Oligocene Fushun series which is in thrust contact with the basement block on the north northwest side. At Inpan east of Fushun is the Cretaceous formation which yielded *Plicatounio*

f. Igneous Rocks.

Andesite, liparite and granitic rocks which intrude these effusives are widely distributed in the Hunchiang tributary, while the distribution of volcanic rocks is extremely small in the Taitzuho basins. As mentioned earlier, volcanic and pyroclastic rocks are intercalated in certain Mesozoic formations. The change of volcanism from basaltic andesite to acidic rock is shown in the sequence of the Tayü formation.

Granitic rocks intruded south of the Hsiaoshih and Tienshuaifukou coal-fields after the folding but before the faulting. West of Huolienchai the Taling granite is intruded into the Cambrian. It may be a product of the same intrusion as the south Hsiaoshih mass, because no Palaeozoic or older Mesozoic granite is known in South Manchuria.

3. The Taitzuho Valley

In this valley are the Yentai-Liaoyang, Penhsihu-Niuhsintai, Hsiaoshih-Tienshuaifukou and other basins aligned from west to east. They are not only topographical but also structural basins, having the Taitzuho or Mesozoic formation at the center. South of this principal chain of basins are the Saimaki basin and a few other sedimentary patches. The principal and auxiliary zones are set off by late Mesozoic granitic rocks, but some sedimentary roof-pendants show that the two zones belong to the same depression. On the north and south side of the principal zone is an extensive display of the pre-Hsiho gneiss and metamorphic rocks respectively.

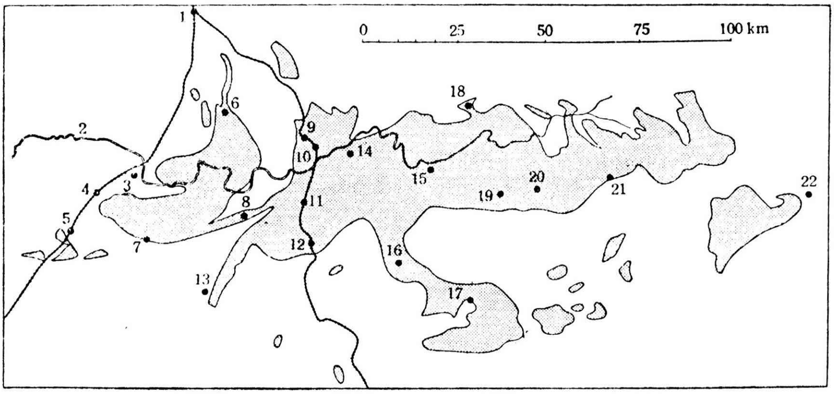


Fig. 22. Distribution of the Hsiho, Korean and Taitzuho Groups in the Taitzuho Valley (after Aoji, Hata et al).

1. Suchiatun
2. Taitzuho
3. Liaoyang
4. Shoushan
5. Anshan
6. Yentai
7. Shangshantzu
8. Hanpeling
9. Huolienchai
10. Penhsihu
11. Chiaotou
12. Nanfen
13. Helankou
14. Niuhsintai
15. Hsiaoshih
16. Tsaohetang
17. Saimaki
18. Chinghecheng
19. Tienshuaifukou
20. Chienchang
21. Szupingkai
22. Huanjen

These basins are not simple basins, however, because their original structure was considerably modified by later movements. The rigid basement was broken into pieces by compression, and the pieces were in turn wedged into the chain of sedimentary basins from the north or south. Further complications were made by the faulting and granitic invasion.

a. Penhsihu-Niuhsintai Basin (see Geological Map IV, Profiles Vb. 5–10). This area is bisected into the Penhsihu and Niuhsintai basins by the northwest trending Shihchiaotzu fault (e in Fig. 23). The Penhsihu basin has a triangular outline. It is cut by a series of thrusts of Hsintungkou on the west side and by the Pingtingshan upthrust on the south side. In its northern part there is a monocline of the Hsiho series, 230 m thick, which strikes in the NW direction. It is overlain by the Cambrian system, 200 m thick, but syenite dykes or sheets are frequently encountered near the base. The Taling granite intrudes the Middle Cambrian and older formations in the northernmost part. The Ordovician is gently folded and overlain disconformably by the Taitzuho group. Both are sharply bent toward the southwest at the western end. The Honkeiko (Penhsihu) formation on the Taitzuho is also steeply inclined to the east along its western margin, and near Linchiasueitzu is overlain by the horizontal Linchia formation.

This flexure develops into the pre-Hsintungkou upthrust. Behind it is the Hsintungkou thrust (g in Fig. 23), west of which gneiss and granite are exposed extensively. In addition there are some patches of the Anshan series, and also the Hsiho series and the Korean group on the basement complex. The main Hsintungkou thrust along the eastern margin of this rigid mass runs slightly east of north and its branches cut into the mass. As a whole they form a series of imbricated scales. The Hsiho and Korean formations on the basement complex of these scales still maintain the original NW strike on the northern side, but become parallel to the principal thrust on the other side.

Yoshimura (1941) noted that the primary tectonic line was a simple thrust which developed secondarily into a series of scales, yielding cracks in the mass. In the course of this imbrication the flexure of the Taitzuho and older formations had increased along the line till at length their strike became parallel to it. In the southern part the Cambrian is thrust upon the Taitzuho group. The western block was later elevated again and pushed upon the basin on the east side, yielding the pre-Hsintungkou upthrust. As a result the Taitzuho group became vertical or even overturned.

Near this upthrust the Penhsihu formation dips 60 to 80 degrees to the east, but soon becomes as gentle as 10 to 15 degrees near the center of the basin.

The Linchia formation lies on the eroded surface of the Penhsihu formation. The leading component of its basal conglomerate is large boulders of quartzite which were evidently derived immediately after the upthrusting from the Tiaoyütai quartzite and Chiaotou quartzite of the western block. The conglomerate is a kind of fanglomerate or deltaic sediment which expanded eastward into the lake. The lacustrine sediment on the conglomerate contains various kinds of rocks, supplied from a greater drainage in mountains of lessened relief and altitude.

The pre-Hsintungkou upthrust is cut at right angles by some faults. The Penhsihu basin is cut diagonally by the Minshankou fault (f in Fig. 23), the downthrow of which is on the southeast side. There the Tayü formation is distributed and is delimited by the Pingtingshan upthrust (h in Fig. 23) from the south. The fault plane dips about 50 degrees toward the southeast and the formation is intruded by quartz-trachyte and quartz-porphyry of the Chiashan area.

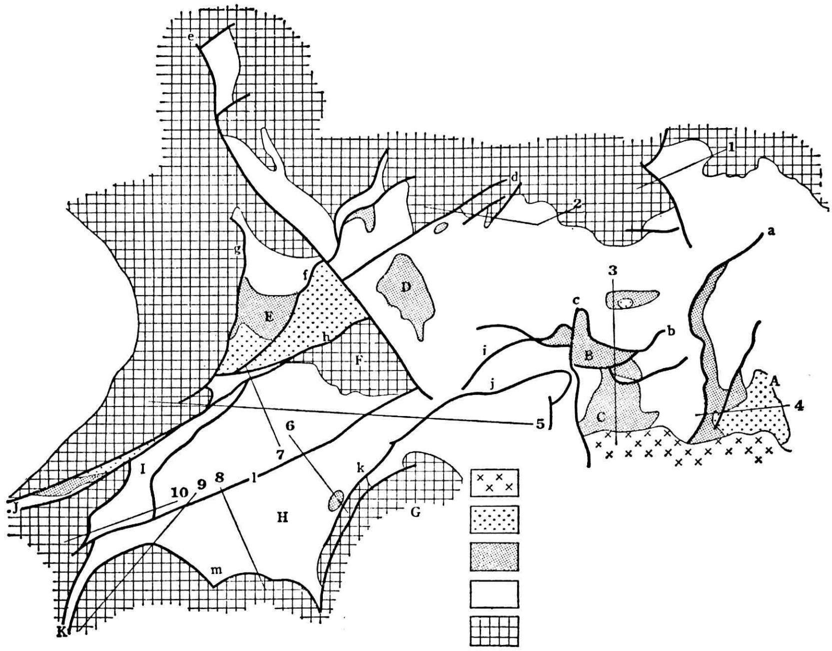


Fig. 23. Tectonic Map of the Middle Taitzuho Valley. See Figs. 24, 25, 29, and 30 for Profiles 7, 6, 3 and 4 and Geol. Map IV and Profile Vb for Profiles 1, 2, 5, 8, 9 and 10 (Kobayashi, Kobatake, Morishita, Yoshimura, et al).

A. Tienshuaifukou Basin
B. Hsiaoshih Basin
C. Shanchengkou Basin
D. Niuhsintai Basin
E. Penhsihu Basin
F. Pingtingshan Block
G. Miaoerkou Block
H. Nanfen Area
I. Achiakou Graben
J. Hanpeling Graben
K. Helankou Graben.

a. Papanling Thrust.
b. Yaopao Thrust
c. Hsiaoshih Fault
d. Pienlingpaotzu Thrust
e. Shihchiaotzu Fault
f. Minshankou Fault
g. Hsintungkou Thrust
h. Pingtingshan Thrust
i. Pichiakou Thrust
j. Linchiapaotzu Thrust
k. Miaoerkou Thrust
l. Tiaoyütai Thrust
m. Nanfen Thrust.

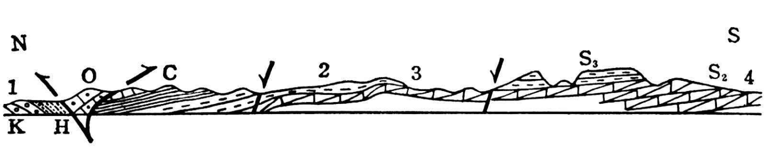


Fig. 24. Profile through the Pingtingshan Block (after Morishita), (7 in Fig. 23).

K. Tayii Formation
H. Taitzuho Group
O. Ordovician Formation
C. Cambrian Formation
S_2. Chiaotou Quartzite

S_3. Nanfen Shale and Marl
1. Taitzuho River
2. Fuchinling
3. Chiachiakou
4. Hsiho River

There are strips of the Huangchi series at Tuanshantzu and between Chinfukou and Yaopao along the southern periphery of the Penhsihu basin. It is thrust by the Toufangian series on the south side and the Toufangian in turn is thrust again by the southern mass along the Pingtingshan tectonic line. In the eastern part of this shattered zone there are also the Huangchi and Cambrian rocks, between the Tayü formation and the metamorphic rocks of Pingtingshan. These strips are all by-products of the Pingtingshan upthrust by which the Taitzuho and Korean groups of the Penhsihu basin were sharply bent up and broken.

The Niuhsintai basin northeast of the Shihchiaotzu fault is divided into two parts by the Pienlingpaotzu tectonic line along the Taitzuho river. The southern half-basin is not much deformed, while the destruction of its counterpart is great.

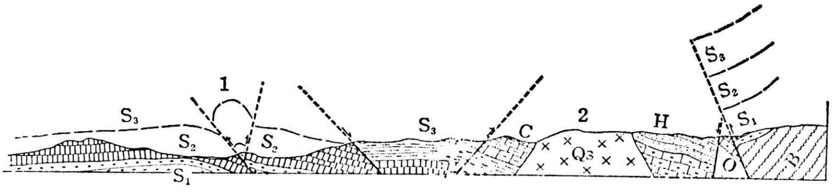


Fig. 25. Profile of the Nanfen Area (after YOSHIKAWA), (6 in Fig. 23).

Qs.	Quartz Syenite	S_2.	Nanfen Shale and Marl
H.	Taitzuho Group	S_1.	Tiaoyütai Quartzite
O.	Ordvician Formation	B.	Basement Complex
C.	Cambrian Formation	1.	Santaohetzu
S_3.	Chiaotou Quartzite	2.	Shanchengtzu

In the southern half the major axis of the Niuhsintai brachy-syncline is represented by the hills south of Hunglienkou. Its southwest side is undulating and is inclined steeply, but the other limb is inclined gently. Thus the structure is asymmetrical, and cut by faults in the NW, NE and other directions. The Tsaichia series lies near Shangniuhsintai. The southern margin of the basin is marked by thrusts from the south.

On the north side of the Taitzuho river, the original basin is strongly deformed by thrusting and faulting. Starting from the north, there is a tectonic line extending northeast from Lichiawepeng along which the gneiss complex, capped by the Hsiho series, is thrust toward the southeast. In front of it is a parallel thrust. The thrust sheet in this interval is composed of the Hsiho and younger formations, the youngest of which is the Taitzuho group at Hueishan at the southwestern terminus. On the southeast side is a broad syncline, which is, however, bisected by a tectonic line through Shueiyükou, and the west side is the Taitzuho group which forms a wedge near Yaotzuyü.

Starting from the west end of this northern basin a long syncline of the Hsiho and Korean formations extends to the northwest along the Shihchiaotzu fault as far as Kantaijentun, although it is cut by some NE faults. The Pingtingshan block wedges in between the Niuhsintai and Penhsihu basins from the south side. The basement complex is exposed extensively in its northern part where the Pingtingshan upthrust and the Shihchiaotzu fault meet at right angles. Because this is a tilted block, it is covered by the blanket formations in the west. The Hsiho series is a gentle monocline, but the Cambrian is moderately undulating with the axes varying from N to NW. Further west the Ordovician is folded to form the graben of Achiakou extending from NE to SW.

The southeast side of the block is limited by the Tiaoyütai upthrust (1 in Fig. 23), which is parallel to the Pingtingshan upthrust. The Nanfen area on the south side is largely occupied by the Hsiho series. There the Taitzuho group is restricted to a small area of Tahuangpaiyü in the east where it lies on the Ordovician. The basement complex in the southeast is pushed up at a steep angle toward the north along the Miaoerkou upthrust. The Hsiho and later formations between this and the Tiaoyütai tectonic line are complicated by thrusts of various directions. Some of them having a WNW trend as well as some others having a NE trend are thrust also toward the south; others having a NE strike are thrusts toward the north. The three kinds of thrusts are each represented by 3 or 4 thrust lines.

In the western part of this area, the southern basement complex is thrust up toward the north. This is the Nanfen upthrust (m in Fig. 23) which describes two large arcs.

The structure at the southwest corner of the Penhsihu basin is rather perplexing.

The granite gneiss of Peitaikou, capped by the Tiaoyütai quartzite, rides over the Cambrian with a low angle at the corner and a *Klippe* lies in front of the thrust. The Achiakou graben is sunken between this granitized mass and the Pingtingshan block. It is occupied by the Ordovician as far as the Hsiho river, but the Cambrian is exposed farther west and at length the Lower Cambrian is thrust by the Hsiho series. This tectonic line extends to the south from Huangchiapaotzu, taking an undulating course.

The Hsiho and the Middle and Lower Cambrian occupy a trapezoidal area which is delimited by the Tiaoyütai thrust on the south side and the Chioukeyü thrust on the northwest. The Chioukeyü thrust is indicated by a thrusting of the granitic block upon this folded area. The granite is covered by the Tiaoyütai quartzite near the eastern margin of the block. Besides the main Chioukeyü thrust there is an auxiliary one on each side. At the northeast corner black schists of the Liaoho group are thrust toward the southwest.

The Chioukeyü thrust, though displaced by the Tiaoyütai thrust, extends southwestward for about 20 km. A narrow straight graben of the Hsiho series between this and the arcuate Nanfen thrust is traceable through the metamorphosed region as far as Helankou (13 in Fig. 22).

Another remarkable graben runs between the granitized masses from ENE to WSW through Hanpeling (8 in Fig. 22). The Ordovician and Taitzuho formations are exposed respectively in its western and eastern part. Also in the eastern part there are porphyrite and tuff which from their lithic aspect may be referred to the Tayü formation. Near the western end, the northern granite mass is overlain by the Tiaoyütai quartzite of the large Liaoyang-Yentai basin. The Hanpeling shattered zone between the basin and the southern block describes an arc convex to the southeast. Combined with the Hsintungkou tectonic line this zone outlines the large basin and its eastern block.

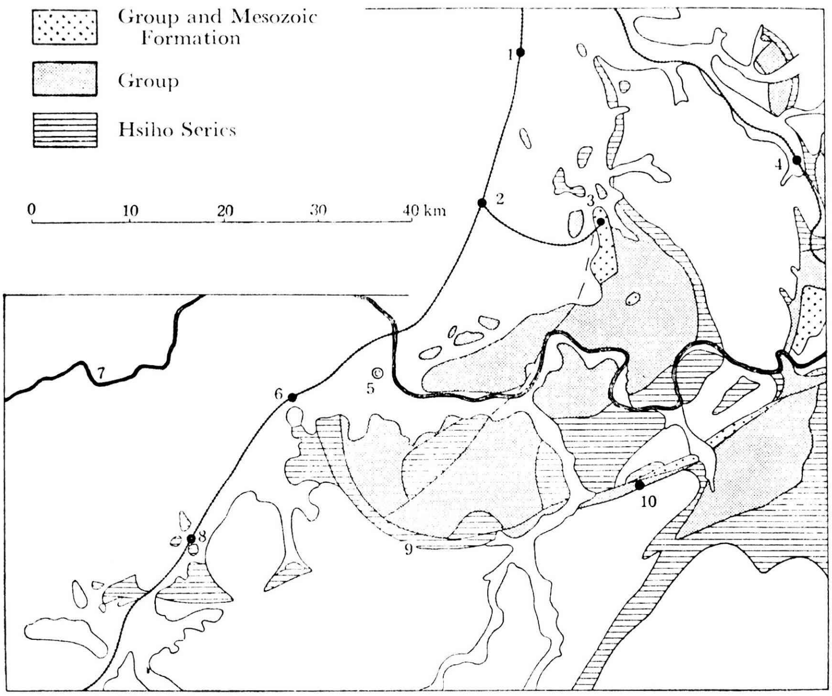


Fig. 26. Distribution of the Rakuroan Complex and Taitzuho Group in the Yentai Basin and its Vicinities (after Aoji and Hata).

1. Shahe,
3. Yentai Station
3. Yentai Coal-Field
4. Shihchiaotzu
5. Liaoyang
6. Shoushan
7. Taitzuho
8. Anshan
9. Shangshantzu
10. Hanpeling

b. Liaoyang-Yentai Basin.

This basin is not as deformed as the preceding. The unconformity between the horizontal Tiaoyütai quartzite and the steeply inclined Liaoho schists seen at Shenwe on the Taitzuho river is such a significant aspect that *Shenwe* was proposed for the pre-Tiaoyütai disturbance. The sequence above the quartzite is simple and regular. The Hsiho series is followed by the Cambrian, and then comes the Ordovician. At length one reaches the Taitzuho group of Yentai.

Near the Yentai coal-field there are some faults with different trends. The southern boundary of the Yentai coal basin is drawn by a ENE fault. At Kangyao, to the southeast beyond the fault, there is a small basin of the Taitzuho group.

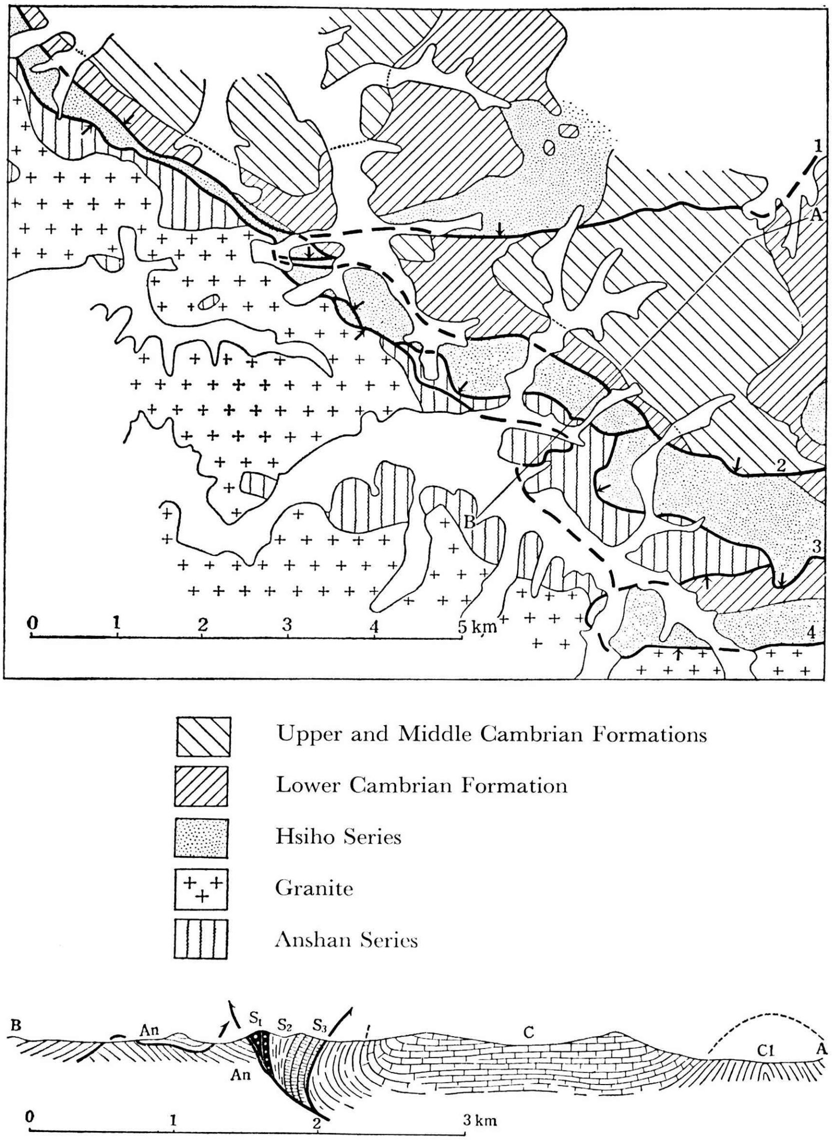


Fig. 27. Geological Map and Profile of the Shangshantzu Area (after SAWATA).

1. Shueichuanstzu Thrust
2. Yatzukou Thrust
3. Weichiakou Thrust
4. Shangshantzu Thrust

C. Upper and Middle Cambrian Formations

Cl. Lower Cambrian Formation

S_3. Chaiotou Quartzite

S_2. Nanfen Shale and Marl

S_1. Taioyütai Quartzite

An. Anshan Series

Most important is the median tectonic line which bisects the Liaoyang-Yentai basin. It runs through the lowland west of Yentai toward Shangshantzu (9 in Fig. 26). To the east of Shahe station on the Shenyang-Talien railway line is a narrow hill of gneiss. This, together with the eastern gneiss, forms an acute angle where the Yentai-Liaoyang basin is pointed. The southeastern outline of the basin, on the other hand, is broadly arcuate, but as mentioned earlier, there is a shattered peripheral zone due to the Hsintungkou thrust and the Hanpeling graben, which are aligned en échelon. The Ordovician formation in the graben is traceable westward as far as Tangheyen.

Near Shangshantzu in the southwestern part of the basin (SAWATA, 1942) the concentric disposition of the Cambrian and Hsiho formations is strongly disturbed by the Shueichüantzu, Yatzukou and Weichiakou thrusts, which diverge eastward. The north side is repeatedly thrust upon the other along these tectonic lines. The Anshan series and Kungchangling granite on the southern block resisted this movement, but at length they were thrust northward along the Shangshantzu tectonic line, which is generally high-angled, but is low-angled near Shangshantzu. The Shueichüantzu thrust appears to be a part of the median tectonic line diagonally across the Yentai basin, although its whole length has not yet been traced.

The Yatzukou and Shangshantzu thrusts face each other. The graben between them indicates the western extension of the Hanpeling graben. The Hsiho series is strongly contorted in the graben, yielding some diagonal thrustings. A shattered zone lies between the northern basin and the southern block. The Korean group is extensive on the northeast side, whereas the Hsiho series is exposed only along saddles of anticlines.

West of Shangshantzu is an unsurveyed area. In the Anshan-Shoushan area further west (IMAMURA, 1941), the Cambrian, Hsiho and Shoushan-Anshan formations are distributed around the eastern granitic mass. On the south side these formations imbricate toward the southern granite mass.

c. Hsiaoshih-Tienshuaifukou Basin (see Geol. Map IV and Profile Vb 1–4)

To the northwest of the aforementioned Pienling thrust is an extensive display of granite or gneiss. On the other side there are also some thrusts. It is a common habit for the northern mass to thrust upon the south side. Some additional faults have a NW or other trend. At Pienlingpaotzu at the western end of this imbrication is a small Taitzuho exposure.

With respect to the geology of Chinghecheng, YOSHIMURA (1941) mentions that "the Hsiho series and the Cambrian system form a syncline with a NW trending axis, having Tungtataishan, south of Chinghecheng, at its center. Thrust by a granite mass, its western limb is steeply inclined, whereas the eastern one dips gently at 30 degrees or so. Its northern margin is also limited by a thrust. Near Machiakou in the south, the Hsiho series strikes almost equatorially and dips southerly. It is cut by two strike faults. The western end of this faulted zone is cut by a thrust which runs through the west side of Tungtataishan. Cut by equatorial thrusts, the Tiaoyütai quartzite near Mengchiapaotzu, southwest of Chinghecheng, forms narrow belts which are truncated at the western end by a fault in the NNW to SSE direction. Another fault in a similar trend is found in the west of

Hsikou. The Hsiho and Lower Cambrian formations are strongly disturbed in a wedge between these two faults."

South of this area is the Tungshan basin, through which the Taitzuho river flows. The Taitzuho group is at its center, and the main synclinal axis runs from NE to SW. The Tungshan thrust lies on the southeast side, along which the Ordovician and Taitzuho formations are thrust upon the Ordovician. In the west the Taitzuho group slips upon the Ordovician. They are dislocated further by minor NW faults. The Taitzuho group is capped by the Linchia conglomerate in the eastern sunken block.

Southwest of Tungshan there is the Hsiaoshih basin, where the Taitzuho group forms a synclinal basin with its main axis trending WNW. In the Shanchengkou basin to the south, however, the axis of folding is equatorial. In addition to this principal folding there are some rectangular undulations. Between the two basins there is a moderate exposure of Ordovician formation. With respect to the geologic structure, there is some disagreement among YOSHIMURA (1941), SUGAI (1948) and KOBATAKE (1949), but here the description follows the opinion of KOBATAKE.

On the northeastern side of the Hsiaoshih basin, the brachysyncline of the Taitzuho group is thrust by the Mapichiangkou thrusting sheet of the Korean group, and the latter in turn by the Yaopao thrusting sheet of the Upper Cambrian and Ordovician formations. West of the meridional Hsiaoshih fault (IX in Geol. Map IV), a sheet of the Nanfen shale which is considered by KOBATAKE (1949) to be the extension of the Yaopao thrusting sheet is thrust on the Taitzuho group. This Taitzuho syncline is thrust on the south side by the Ordovician of the Pichiakou thrusting sheet (X in Map IV) and this in turn is thrust by the Cambrian of the Niangniangkou thrusting sheet (XI in Map IV). Because the latter is low-angled, its thrust line is noticeably curved. Further south is the Linchiapaotzu thrusting sheet (XII in Map IV), where the Nanfen shale has ridden upon the Niangniangkou thrusting sheet. These thrusts describe arcs convex to the southeast.

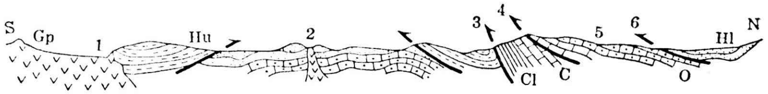


Fig. 28. Profile of the Hsiaoshih Coal-Field (After KOBATAKE), (3 in Fig. 23).

Gp.	Granite Porphyry	1.	Yenchiapaotzu
Hu.	Upper Taitzuho Group	2.	Shanchengkou
Hl.	Lower Taitzuho Group	3.	Mapichiangkou Thrust
O.	Ordovician Formation	4.	Yaopao Thrust
C.	Upper and Middle Cambrian Formations	5.	Taitzuho
Cl.	Lower Cambrian Formation	6.	Tungshan Thrust

Within the Shanchengkou basin is the Lishantaokou thrust, along which the lower Taitzuho group overrides the middle Taitzuho. To the north, the Ordovician of the Pichiakou thrusting sheet is thrust upon the Taitzuho group. On the east side of the basin is an Ordovician dome. Farther east the Taitzuho group, which forms a basin, is shifted upon the Ordovician along the periphery.

After the thrusting, granite porphyry intruded on the south side. Still later the area was cut by a few faults trending the direction slightly east or west of north.

According to KOBATAKE (1942), the Papanling thrust on the western border of the Tienshuaifukou basin represents double and partly triple thrusts. Near Papanling the Lower Cambrian is thrust upon the Ordovician and the latter on the Taitzuho group. In the northern part, however, an accessory thrust appears in this interval, where the Ordovician is thrust upon the lower Taitzuho or the Ordovician. In addition, in the southern part there is the pre-Papanling thrust along which the Taitzuho group is thrust on the Mesozoic formation or on the Taitzuho group below it. In the eastern part of the Tienshuaifukou basin there is the Kuchiakou thrust from which the Tiehtzushan thrust branches off.

These thrusts toward the east cut the plane along which the Changliangtzu black shale slipped over its basement. This and the later Mesozoic formations are cut by NW and NE trending faults, but the Sankeiling conglomerate is not displaced.

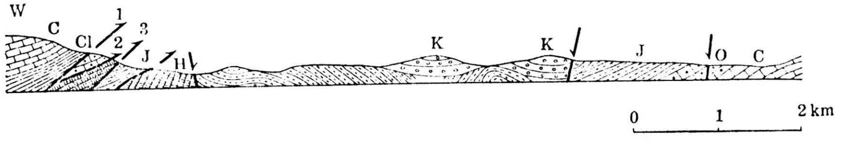


Fig. 29. Profile of the Tienshuaifukou Coal-Field (after KOBATAKE), (4 in Fig. 23).

K. Sankeiling Conglomerate
J. Changliangtzu Shale and Chuanshantzu Conglomerate
H. Taitzuho Group
O. Ordovician Formation
C. Upper and Middle Cambrian Formations
Cl. Lower Cambrian Formation
1. West Papanling Thrust
2. East papanling Thrust
3. Pre-Papanling Thrust

The Mesozoic formation lies on the Taitzuho group in the west, but on the Ordovician in the east, although its base has slipped to some extent. In my opinion it is probable that the incipient basin was a little modified before the deposition of the Changliangtzu black shale. According to SUGAI the black shale overlies the Ordovician in the eastern part with angular discordance. The significance of the Chuanshantzu conglomerate on the tectonic development is not yet well deciphered. It is, however, fairly certain that the deformation of the basin had been almost completed before the Sankeiling conglomerate was laid down.

In short, the deformation of the original basin commenced with the basal sliding of the Mesozoic formation. Subsequently a series of thrustings were repeated toward the east, and the pre-Papaling thrust indicates the final phase of lateral compression. Later block movement dissected the terrain into blocks. Monzonitic porphyry was intruded in the southern part after these structural developments.

4. The Yalu and Hunchiang Tributaries

In the Yalu tributary including the Hunchiang, its branch on the Manchurian side, the ancient gneiss complex is widely exposed. The Mach'ollyong metamorphic group is found as patches near Linchiang, Ŭiju and other places. East of Tienshuaifukou there are still a few other basins, but the chain of basins along the Taitzuho terminates in the vicinity of Huanjen. South of this chain are the Tsaohetang and Saimaki basins. The Santaoyangcha and Putaochiolingtzu coalfields are located in the same zone, but far to the east. Further eastward, beyond the main stream of the Yalu, are the Ch'osan area and several others where the

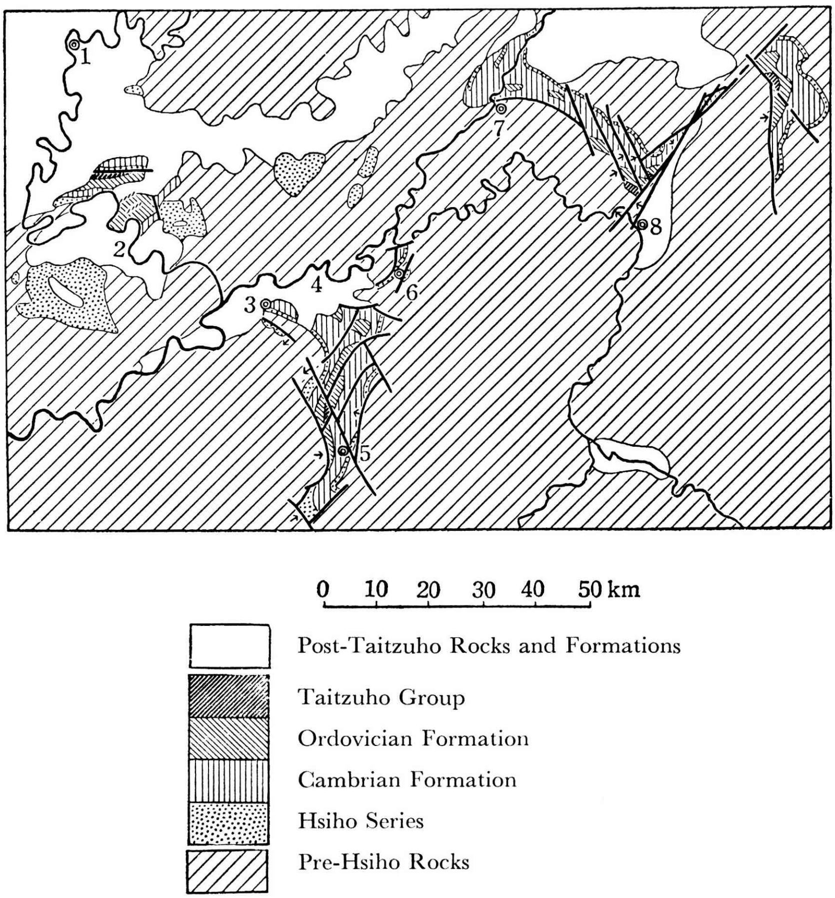


Fig. 30. Distribution of the Rakuroan Complex and Taitzuho Group in the Middle Yalu Valley (After NAKAMURA, AOJI, KOBAYASHI et al.)

1. Huanjen
2. Hunchiang River
3. Ch'osan, (Sosan)
4. Yalu River
5. Kojang, (Kojo)
6. Wiweon, (Igen)
7. Manp'ojin, (Manpochin)
8. Kanggye, (Kokai)

Taitzuho, Korean and Hsiho formations form basins or zones of depression. In the upper Hunchiang there is the so-called Pataochiang *Fenster*, which is actually a narrow graben extending from NE to SW.

In 1884, GOTTSCHE discovered some Cambrian fossils en route from Wiweon to Kojang. Jointly with KIM (1930, 31) and NONAKA (1943) I have investigated the Korean group in the Ch'osan-Wiweon-Kojang area, Kanggye-Manp'ojin area and the Huch'ang area. In the Ch'osan area the group is underlain disconformably by the Hsiho series. The lower part of this series is built up of quartzite, but the basal part is conglomerate; the upper part is composed chiefly of variegated clayslate, which is interbedded with quartzite or alternating marl and limestone at places. The Hsiho series is separated from the *Redlichia*-bearing Lower Cambrian by a wavy erosion surface.

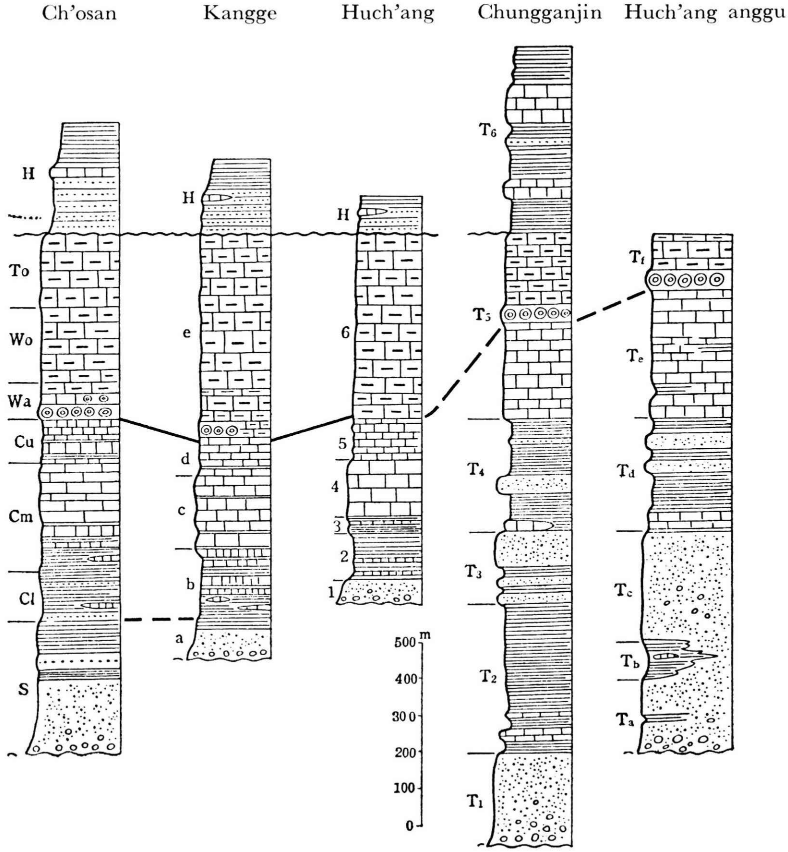


Fig. 31. Columnar Sections of the Rakuroan Complex in the Middle Yalu Valley (after NAKAMURA, KIM and NAKANO, compiled by KOBAYASHI).

H. Taitzuho Group
To. Toufangian Series
Wo. Wolungian Series
Wa. Wanwanian Series
Cu. Upper Cambrian Formation
Cm. Middle Cambrian Formation
Cl. Lower Cambrian Formation
S. Hsiho Series

Redlichia and other Lower Cambrian fossils are unknown from the Kanggye and Huch'ang areas. Whether the quartzite and slate beds in the basal 70 to 100 meters in these areas belong wholly to the Lower Cambrian or the Hsiho series, or whether the boundary between the two formations exists within the basal part is still questionable. It is quite certain, however, that the total thickness of the Palaeozoic and Proterozoic sediments is gradually reduced toward the east through these three areas, as shown in Table 13.

Table 13. Variation of Thickness of the Pre-Song'nim Sediments on the South Side of the Middle Yule Valley.

Thickness in m	Ch'osan (Sosan)	Kanggye (Kokai)	Huch'ang (Kosho)
Taitzuho Group	300	200	100
Ordovician Formation	500	550	500
Cambrian Formation	550	500	450
Korean Group	1,050	1,050	950
Hsiho Series	350	100 (?)	70 (?)
Naknang Complex	1,500	1,250	1,020

Farther northeast are the Linchiang-Chaseong-ganggu, Huch'ang-ganggu and Changpai-Hyesanjin areas. K. NAKAMURA (1942) has referred a formation near Chaseong-ganggu on the Korean side to the Korean group, but judging from the lithology, it seems reasonable to refer the larger part of the lower quartzite and clayslate of the formation to the Hsiho series, as is done for the same formation on the Manchurian side. Taking the *Cryptozoon* limestone as the key to the base of the Ordovician, a tentative correlation is shown in the diagrammatic sections in Fig. 31. Because no Cambrian fossil is known in the Chaseong-ganggu and Huch'ang-ganggu sections, it is difficult to point out the base of the Cambrian, but presumably it lies somewhere within the T_4 beds.

The Hsiho series thus outlined is thicker than 500 meters. The quartzite, especially the basal one, is often conglomeratic, containing quartz and clayslate pebbles, 2 to 3 cm across. In this part of the Yalu valley the clastic facies, especially conglomerate, appears more developed in the southeast than on the other side.

On the Manchurian side of the Yalu river between Changpai and Linchiang SAITO observed that the Cambrian overlies the gneiss and schists directly. The Hsiho series, however, is well developed west of Linchiang. It consists of the Chiaoyütai quartzite and the Nanfen shale and marl and measures 1,000 to 2,000 m in total thickness. In this area as well as in the region east of Tunghua the Chiaotou quartzite is absent. Between Tunghua and Wutaochiang the Nanfen shale and marl formation is seen to be overlain disconformably by the basal quartzite of the Cambrian formation, which contains the Nanfen marl as boulders.

The local variation in facies and thickness suggests that there were lands on the

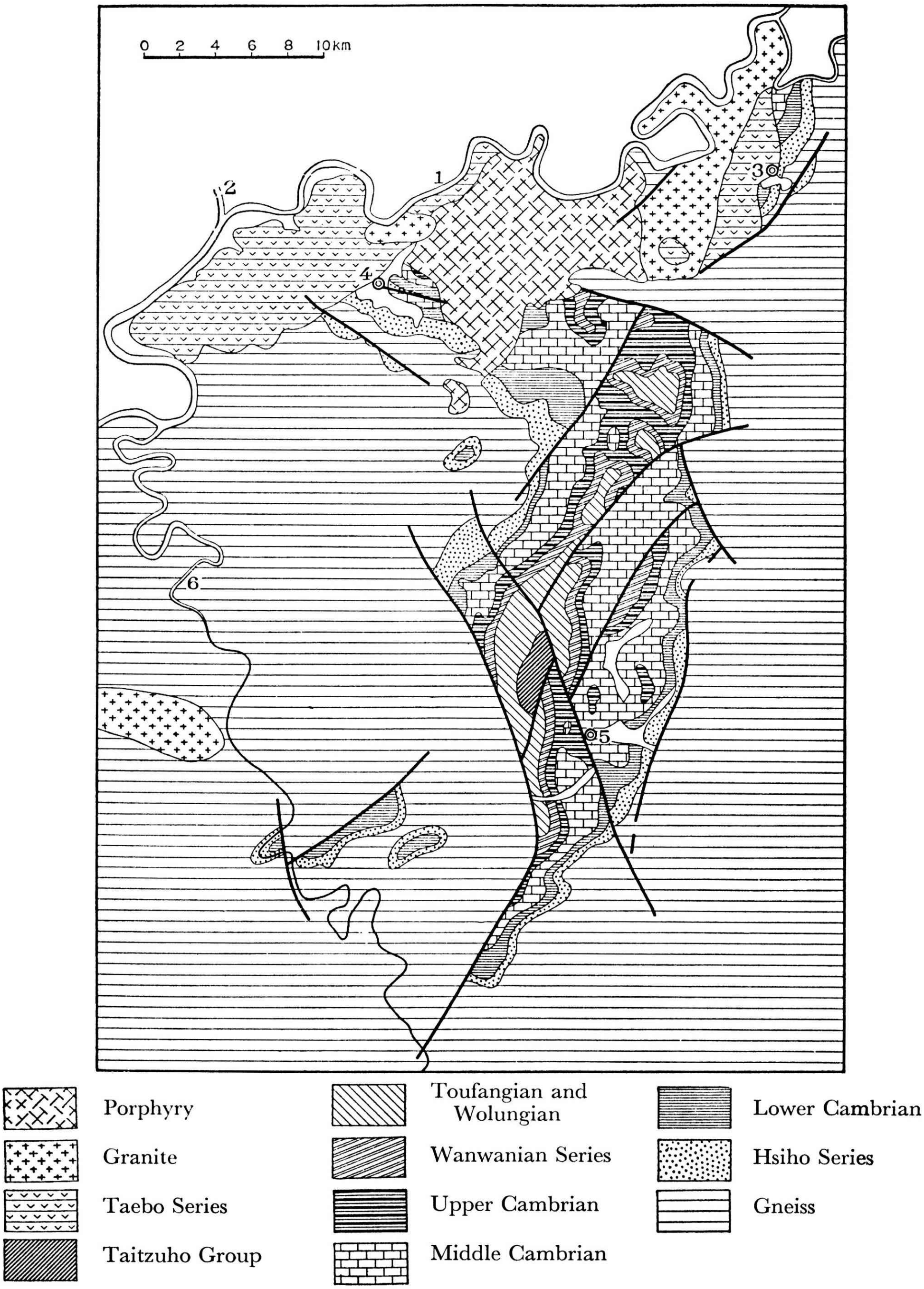


Fig. 32. Geological Map of the Ch'osan (Sosan) Area (after KOBAYASHI, KIM and TAKAHASHI).

1. Yalu River
2. Hunchiang
3. Wiweon, (Igen)
4. Ch'osan, (Sosan)
5. Kojang, (Kojo)
6. Ch'unggang, (Chuko)

east and south sides in the Hsiho period. The conglomeratic facies between the Huch'ang-ganggu and Hyesanjin shows that there was a trough bordered by high lands.

According to Inai and Shikama (1940), the Cambrian and Ordovician formations east of Tunghua are respectively 500 m or less and 600 to 800 m in thickness. They are in discordant relation, as manifested by the fact that the *Cryptozoon* limestone of the latter lies on various horizons of the former.

The Taitzuho group is found in the Tiehchengtzu, Wutaochiang, Pataochiang and other coal-fields. Its basal conglomerate on the eroded surface of the Ordovician limestone is 2 to 5 m thick and contains quartzite boulders of frst-size, or rarely, the size of a man's head. The lower coal-bearing formation consists of shales and sandy shales in addition to Moscovian fusulinid limestone. The upper coal-bearing formation begins with well stratified sandstone succeeded by coal-bearing shale beds, quartzose and partly conglomeratic sandstone beds, and black shale beds.

On the Korean side of the Yalu river a similar limestone containing Moscovian fusulinids (Toriyama, 1941) is known to exist at Sinmakdong, Nanmyeon, in the Ch'osan area. Some brachiopods, naiads and plants occur near Kanggye and also in the Huch'ang basin, showing the existence of the Hongjeom and probably the lower Sadong series.

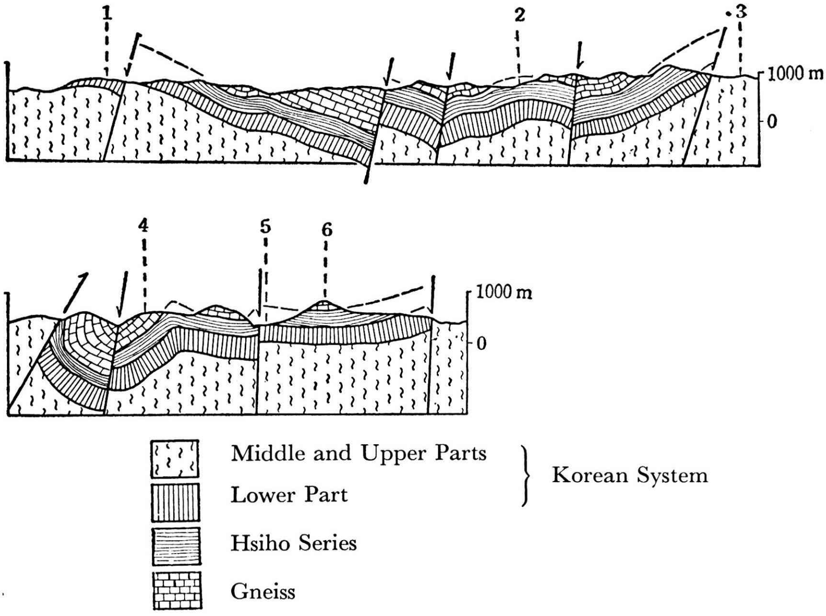


Fig. 33. Two Profiles of the Ch'osan Area (after Kim)

1. Nanhach'ang
2. Ohwadong
3. Mundok-tong
4. Yongdong-dong
5. Kojang, (Kojo)
6. Yondu-bong

In the Ch'osan area the Taitzuho, Korean and Hsiho formations form a synclinorium, the principal axis of which is subvertical and takes a NE trend, but in the northern part an auxiliary axis branches off at right angles and extends to the northwest. This T-shaped zone of folding is cut by NE and NW trending faults, some of which are high angle thrusts placing gneiss upon the sedimentary formations as shown in the profiles in Fig. 33. In addition to the main distribution, there are a few patches still remaining in the gneiss terrain on the west side.

In the Kanggye area these formations form a syncline or monocline, the strike of which takes a U-shaped course. That is, it runs from NW to SE in the middle sector, but at the two ends it is bent at right angles and extends to the northeast. Kanggye and Manp'ojin are located near the two angles. North of Kanggye the gneiss on the south side is thrust upon the lower Taitzuho group at the top of the monocline. The gneiss block is capped by quartzite and clayslate in the northwestern part, which must be a relic of the southern limb of the original syncline. This structure is further complicated by a thrust within the monocline and by NW and NE trending faults.

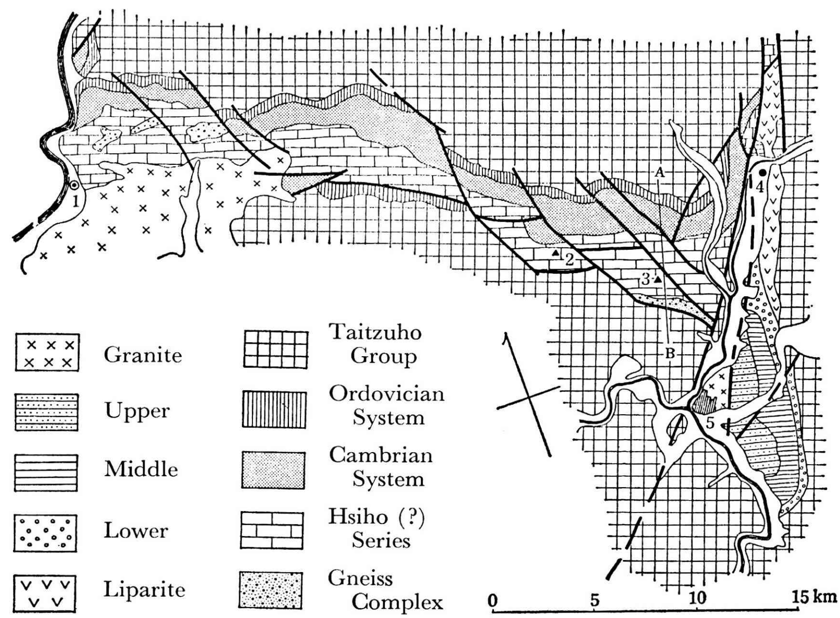


Fig. 34. Geological Map of the Kanggye (Kokai) Area (after Kobayashi, Nakano, et al.), (see Fig. 35 for Profile A–B).

1. Manp'o-jin
2. Sipijup-san
3. Choidok-san
4. Hanjon-dong
5. Kanggye

East of Kanggye there is the subtriangular Huch'ang basin. Quartzite and clayslate of the Hsiho (?) series overlie the gneiss basement on the northeast and southeast sides. It is supposed to have been a quadrate basin with the Hong'jeom series near the center, but it is cut by faults on the west side.

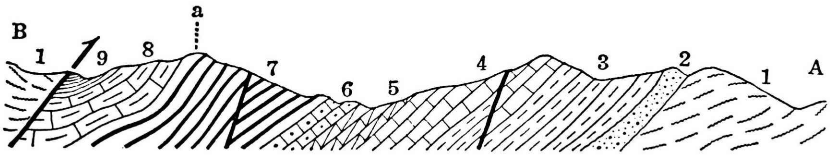


Fig. 35. Profile of the Kanggye Area (after NONAKA), (see Fig. 34 for Points A and B).

1. Paragneiss
2. Quartzite
3. Slate, variegate shale, marl and limestone
4. Purple shale and black limestone
5. White massive limestone
6. Gray limestone and purplish black shale
7. Slabbly limestone and Wurmkalk
8. Dark gray massive limestone
9. Taitzuho Group

a. Choidok-san

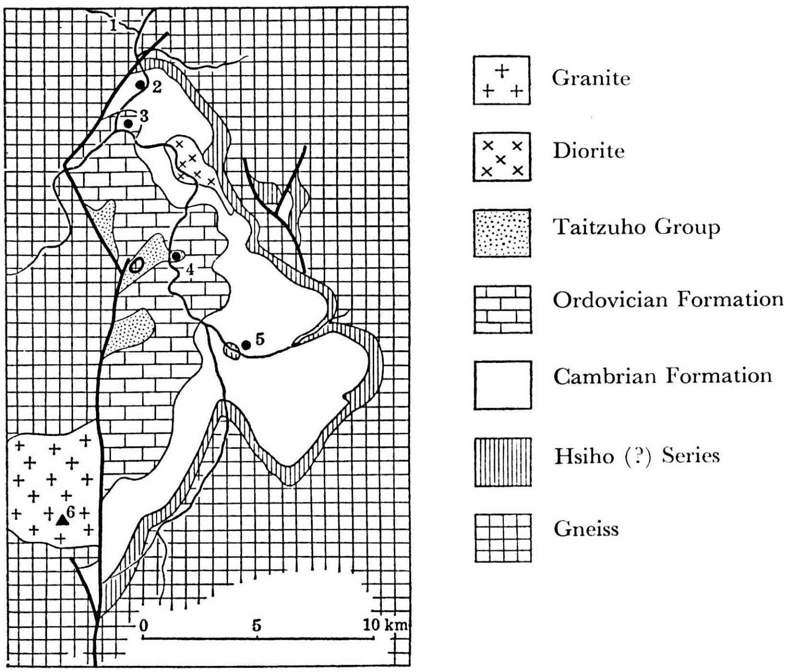


Fig. 36. Geological Map of the Huch'ang (Kosho) Area (after YAMANARI, KOBAYASHI, et al.)

1. Chasoeng-gang, (Jijoko)
2. Uhwa-dong
3. Hwap'yoeng
4. Puhŭng-dong
5. Sobuk-tong
6. Paeksam-bong

The so-called Pataochiang *Fenster* extends from NE to SW along the upper Hunchiang river for about 40 km with a breadth of less than 6 km. This is a *Pseudofenster*, or a kind of graben which consists of Mesozoic, Taitzuho and older formations. The boundary faults on its sides are thrusts of the Korean and Hsiho formations toward the graben. The Palaeozoic formations were folded in by compression between the thrusting blocks and were diagonally folded and faulted. These Palaeozoic formations are overlain by a Mesozoic formation which is not disturbed as much. Nevertheless, the Mesozoic is capped by several *Klippen* which were probably transported from the two sides. Judging from these facts, it is certain that there were two or more phases of movement. The Mesozoic formation is a filling of the graben produced by the early movement, but it was thrust from the two sides by the later one.

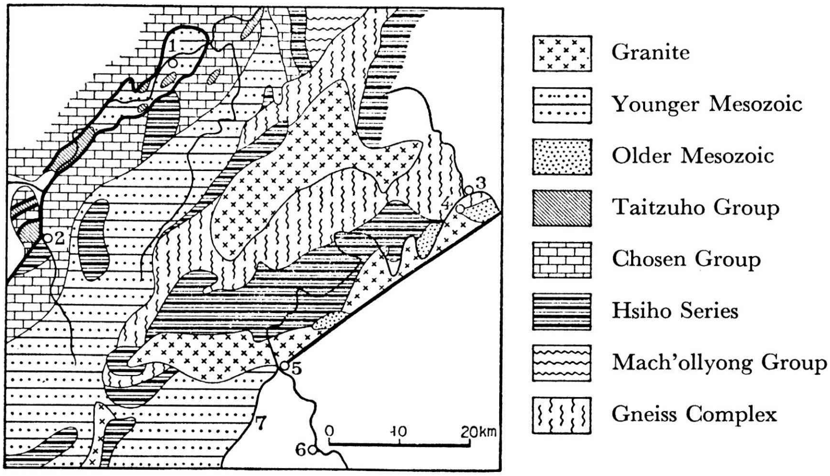


Fig. 37. Geological Map of the Upper Hunchiang Valley.

1. Pataochiang
2. Tiehchengtzu
3. Linchiang
4. Chunggang-jin
5. Chaseong-ganggu
6. Chaseong
7. Yalu River

The sequence of the Mesozoic formations in the Pataochiang graben is as follows:

c. Tuffaceous sandstone and shale formation, 120 m thick.
Alternating sandy shale, sandstone and shale.
Tuffaceous conglomerate, tuffaceous sandstone and tuff, 5–15 m thick.
Sandstone and conglomeratic sandstone, 30 m thick.

.... Unconformity ....

b. Chienshankou coal-bearing formation.
Alternating shale and marl.
Tuffaceous sandstone and coal seams.
Greenish tuffaceous shale.
Tuffaceous sandstone.

.... Base unknown ....

a. Tuff with a small amount of reddish tuffaceous sandy shale and bluish green tuffaceous sandstone, unconformably overlying the Taitzuho group.

Euestheria cfr. *middendorfii* from Sanchiatzu, northeast of Tunghua (Kobayashi and Kusumi, 1953), judging from its locality, is thought to have been collected from one of these formations in the graben. At Kutsangkou further northeast near Fusung are two formations separated by a disconformity. The lower one, 350 m thick, overlies the Ordovician and older formations unconformably and contains volcanic flows and tuffs. Several species of Estherians collected near the top bear some similarities to the Silla, Laotzukou and Sungari faunas. Therefore the age of the Estherians is considered to be Lower or Middle Cretaceous (KOBAYASHI and KUSUMI, 1953). The upper formation, comprising oil shales and coal seams, may be either Upper Cretaceous or Palaeogene. Thus there are at least two Estherian horizons in this region. Assuming that the Kutsangkou Estherian beds can be correlated with the c formation of the Pataochiang graben, the Estherians of Sanchiatzu were probably contained somewhere in the a–b formations which are the Jehol members.

If this interpretation is correct, the primary phase of the movement must be Liassic or older and the final one Middle Cretaceous or younger.

North of Chaseong the folded Korean group is overlain clino-unconformably by the Daedong series containing plant beds and coal seams. Because its basal conglomerate varies in thickness and contains boulders of up to 60 cm in diameter, it is probably an orogenic sediment. Therefore the movement by which the underlying Korean group was folded is referable to the Songnim disturbance.

Near Sinŭiju the Daedong series is overlain unconformably by the Jehol series. TAKAHASHI (1953) proposed *Gishu* or Ŭiju for the movement indicated by this discordance and referred the Mesozoic formation near Kanggye to the Jehol series, but its reference to the Silla series is no less probable. As mentioned earlier, the Mesozoic formation of Kanggye is monoclinal and cut by a fault at the northeast margin. The Jehol near Sinŭiju, on the other hand, is moderately folded and cut by a mesh of NE and NW trending faults.

The Mesozoic formation near Ch'osan is more than 1,000 m thick. It is composed of porphyrite in the lower, tuff, tuffaceous sandstone and shale in the middle, and an alternation of porphyrite and tuff in the upper part. Conglomerates are found near the base of the middle part. This formation is similar to the Silla series in South Korea. It is intruded by granite and quartz porphyry which belong to the Pulguksa igneous group. In the P'yeongbuk massif there are normal faults of various trends among which NW and NE are more common than the equatorial and meridional trends. The western boundary of the Huch'ang half-basin looks as though it were meridional. Close examination reveals, however, that it consists of a combination of NW and NE trending faults, where the latter faults are penetrated by porphyrite dikes.

In the Kanggye area there are diagonal faults which cut the Mesozoic formation and granite porphyry. In the Ch'osan and Huch'ang-ganggu areas, on the other hand, granite and quartz-porphyry are seldom faulted. Thus there are local differences in the age of faulting with regard to igneous activity.

In the Pukchin area southwest of Ch'osan the Pre-Cambrian gray gneiss is intruded by the Pulguksa igneous rocks. According to KINOSAKI (1933), the succession of their intrusions and block movements can be analyzed as follows:

1. Pukchin spotted granite laccolith and Ich'eondong (Risendo) granite batholith.
2. Northeast faults.
3. Quartz-porphyry dikes.
4. Meridional faults.
5. Northwest faults.
6. Gold quartz veins and dikes of pegmatite and aplite.
7. Dikes of porphyrite and lamprophyre.

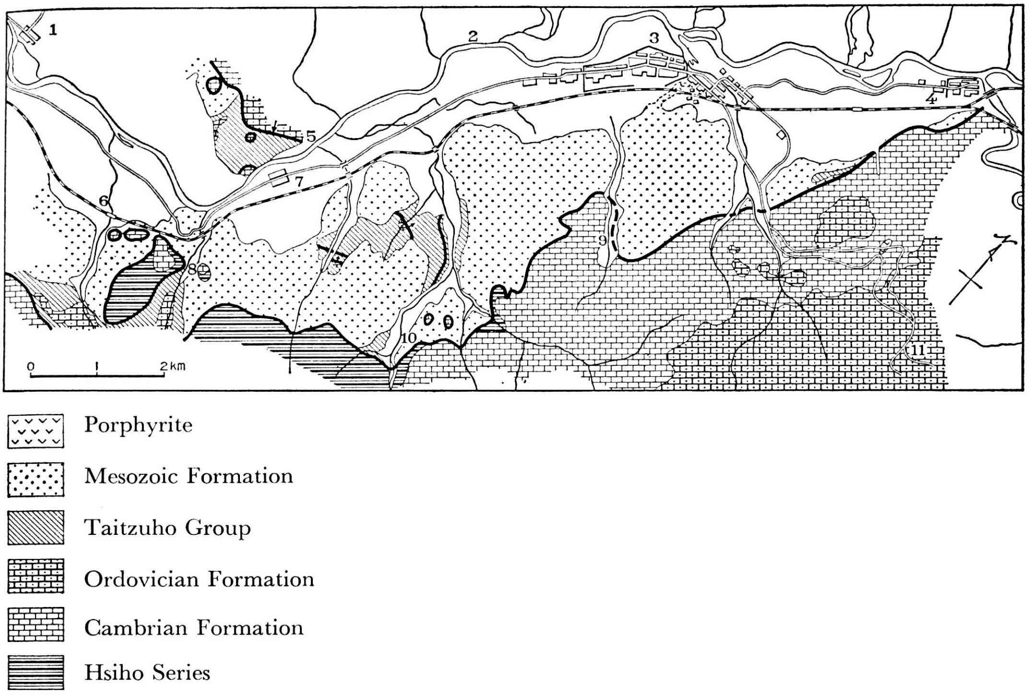


Fig. 38. Geological Map of the Pataochiang Graben (after INAI and SHIKAMA).

1. Heihsiatzukou 2. Hunchiang 3. Pataokou
4. Hungtuya Hekoukai 5. Yenchiapaotzu 6. Toukoutzu
7. Chitaokou 8. Yehchihpei 9. Chienshankou
10. Tatungkou 11. Laoyehling

Although much remains to be settled with respect to the chronology of the Mesozoic formations, on the basis of the known facts the history of the Mesozoic movements may be analyzed into the following phases:

V. Block movements and Pulguksa igneous activity.
Silla series in Ch'osan and Kanggye areas.
IV. Upthrusting: Late Taebo disturbance.
c formation of Pataochiang; Kutsangkou Estherian beds.
III. Gentle folding: early Taebo disturbance.
b and a formations of Pataochiang; Sanchiatzu Estherian beds; Jehol series of Sinŭiju.

II. Gentle folding of Ŭiju phase.
  Daedong series of Ŭiju and Chaseong.
I. Songnim disturbance.

The boulder conglomerate at the base of the Daedong series near Chaseong may be an orogenic sediment deposited immediately after the Songnim disturbance. The distribution of the above mentioned Mesozoic formations appears to be mostly related to the Palaeozoic basins in some way but the sequences in these Mesozoic areas differ greatly. The Pataochiang depression which was brought about by the Songnim or Ŭiju movement was filled with Mesozoic formations (a–c). Later this region was compressed, resulting in the upthrusting of the neighboring blocks toward the depression. As a result, the Pataochiang graben was almost completed.

The Kanggye-Manp'ojin zone was primarily a synclinal depression, but later the southern block was thrust upon the northern limb of the syncline. The monocline thus introduced, however, was faulted probably more than once. The Kanggye Mesozoic was tilted and cut by a strike fault of the block movement in a later phase. In the Ch'osan area there are also some thrusts along which the southwestern block is pushed up. Some others are tension faults. Thus there were tension movements from which the Kanggye Mesozoic suffered, and compressive movements which preceded its deposition. The Jehol series of Ŭiju was gently folded by an earlier movement and cut by the fault mesh of a later movement. In the Pukchin area the faultings are known to have been repeated during the Pulguksa igneous activity.

Because there is no Tertiary, nothing definite can be said of the later modification of the Mesozoic structure. Since there was no strong crustal deformation in the Palaeozoic era, the present structure of the Palaeozoic and Proterozoic formations of 1,000 to 2,000 meters' thickness is the product of a series of Mesozoic and later movements.

The structure in this region is quite different from the preceding tectonic regions. There is no chain of basins as seen in the Taitzuho valley. The structure in the P'yeongnam-Liaotung orogenic zone differs even more. Here these Palaeozoic and Proterozoic formations are much thinner than in other regions. They are folded in between the basement blocks. Their structure may be a monocline, syncline or a synclinorium. Whichever of these three it is, such a depression is often thrust from one or two sides, as exemplified by the Kanggye-Manp'ojin zone or the so-called Pataochiang *Fenster*. The most remarkable tectonic feature of the region is the rectangular bending or branching of such a depressed zone. The Kanggye-Manp'ojin zone is U-shaped and the Ch'osan area T-shaped. They are similar to each other in that the prolongation of the depression is in the NE or NW trend. The Pataochiang *Fenster* as well as the Linchiang-Chaseong zone are elongated in the NE trend.

The syncline of Huch'ang-ganggu extends from east to northwest for 20 km. In the western part it is expanded to a breadth of more than 10 km and intruded by granite and quartz porphyry. The Huch'ang basin is no less wide. It appears to be cut by a meridional fault on the west side. This boundary, however, is partly composed of NE and NW trending faults. Thus, the diagonal trends are predominant but the equatorial and meridional trends can hardly be overlooked.

The diagonal cracks were brought to being in the rigid basement by the compression from north to south which produced the equatorial chain of basins in the Taitzuho valley. The Palaeozoic and Proterozoic strata which mantled the basement were warped down into the depression or folded in between the blocks. Later they were cut by normal faults. The structure one sees here now is a typical example, though on a small scale, of the kraton fragmentation.

5. Discussion and Summary

The Taitzuho, Korean and Hsiho formations are three major units of blanket strata which constitute the basins and grabens in the Yalu-Taitzuho region. The base of the Hsiho series is marked clearly by the discordance of the Shengwe phase, where the Tiaoyütai quartzite overlies the Anshan series, Liaoho-Mach'bllyong metamorphic rocks or ancient gneiss.

I have noted already that the Yungning sandstone is a deltaic sediment which was accumulated on the western margin of the P'yeongbuk land. The Nanfen marl thins and the clastic sediment increases from the Taitzuho and Hunchiang valleys to the Korean side of the middle Yalu. The conglomeratic facies is well developed in the lower Hsiho series between Hyesanjin and Huch'ang-ganggu. If the source of these terrigenous material is considered, the Taitzuho depression must have been a separate embayment, instead of a marginal part of the P'yeongnam geosyncline.

Assuming that the Hsiho series of the Taitzuho valley can safely be correlated with the so-called Hsiho series at the neck of the Liaotung peninsula, the thickness does not differ greatly between the two areas where it is generally 500 to 700 m, but attains 2,000 m at the maximum. There is, however, a large stratigraphic break in the former which involves the middle and late Sinian periods, while there is a Wuhangshan series in the latter area. The break is indicated by the disconformity at Luohanku and other places. The base of the Korean group cuts the Hsiho series with such a small angle that 1 or 2 meters per kilometer of the Chiaotou quartzite are truncated. In the distance of some 200 km from Liaoyang to the upper Hunchiang valley the dissection reaches the Nanfen shale and marl formation through the Chiaotou quartzite, about 250 m thick. This is proven by the inclusion of the Nanfen marl in the basal quartzite of the Cambrian formation northeast of Tunghua.

In the Korean group, the variations in facies and thickness are quite reduced compared to the Hsiho. It measures 1,100 to 1,300 m in the Taitzuho valley and 950 to 1,150 m on the Korean side of the middle Yalu valley. Not only is the difference in thickness slight, but the lithological sequence is very similar through-out the whole region. It is mainly a great limestone formation, although shales and sandstones are common in its lower part. As it is a monotonous formation, the Cambro-Ordovician topography is thought to have been simple and flat.

There is a general tendency in this region for the stratigraphic breaks to become large or numerous toward the east. The Redlichian sea, for example, did not flood any further beyond the Ch'osan area (KOBAYASHI, 1966). In the Pataochiang graben, INAI and SHIKAMA noted that the base of the Lower Ordovician formation lies disconformably on various parts of the Cambrian formation.

After a prolonged Middle Palaeozoic land period, the Taitzuho group was deposited on the Ordovician para-unconformably in most places. In the Hsiaoshih coal-field and a few other places, however, a clino-unconformity is observed at the base of the Penchi, Huangchi or Lioutang series. Though it is local, it is noteworthy that the Akiyoshi prorogeny in the Mongolian geosyncline was a stronger influence on this zone than the P'yeongnam geosyncline.

The thickness of the group is some 800 m in the Taitzuho, but diminishes to about 500 m in the Hunchiang and less than 300 m in the middle Yalu valley. The Penchi or Hongjeom series containing the Moscovian limestones and coal seams is distributed extensively. The Huangchi series, which is the main coal-bearing series in the Taitzuho valley, may be absent in the Hunchiang tributary. The Tsaichia and probably the Lioutang formation are apparently absent in the Ch'osan, Kanggye and Huch'ang areas. In the Taitzuho tributary the Lioutang is the upper coal-bearing unit which lies conformably on the Huangchi series in most places. In the Hunchiang region it is represented by a coarse sandstone formation with a disconformity at the base. The Tsaichia formation is a thick variegated formation or a red sandstone formation in the Taitzuho or Hunchiang valleys respectively. KONNO (1949) noted that there is a thick basal conglomerate of the Tsaichia series in the Penhsihu coal-field lying on the Lioutang series. Through the *Gigantopteris* flora the Tsaichia is correlated to the Gobangsan series in Korea. Therefore there is no equivalent of the Nogam series in this region.

The Penchi sea was flooded in the Moscovian epoch as far as Huch'ang and Pataochiang, but the Permian formations are mostly non-marine and the depression was reduced successively through the Chiaotsuo and Tungwu phases of movements, which correspond respectively to the Kanokura and Usuginu phases in Japan.

It was turned completely to land by the Ssuwan or Tate movement. It is interesting to see that the Usuginu phase is indicated by a great increase of coarse detrital sediments, because this reveals the growth of the embryonic geanticline.

The Hshiho, Korean and Taitzuho formations are respectively about 500–600 m, 1,100–1,300 m and 500–800 m in thickness, or a total of about 2,000–2,500 m. This amount does not differ greatly from the 3,000 m in the northern area of the Liaotung peninsula, but corresponds to only about one-fourth of about 9,000 m in the geosynclinal part of the peninsula. The total thickness of the geosynclinal sediments attains more than 10,000 m in North Korea.

Table 14. Stratigraphic Sequence of the P'yeongan Group and Its Relation to the Phases of Crustal Movements.

Age	Korea (P'yeongan Group)	South Manchuria (Taitzuho Group)		Japan	China
Middle Trias			Songnim	Akiyoshi	Weiyang
Early Trias	Nogam				
	Gobangsan	Tsaichia		Tate	Ssuwan
Permian	Sadong	Lioutang		Usuginu	Tungwu
		Huangchi		Kanokura	Chiaotsuo
Uralian Moscovian	Hongjeom	Penchi	Nanpiao	Sakamoto	Kunming
			Hsiaoshih		
	Stratigraphic Sequence		Phase of Crustal Movement		

Because the Mesozoic stratigraphy has not as yet been thoroughly established and because the Tertiary formation is absent in this region, the tectonic analysis cannot be quite conclusive. A tentative correlation on the basis of the present knowledge, however, allows one to distinguish five or more phases of Mesozoic movements. The Triassic Songnim disturbance was very important to the destruction of the previous depression. The Changliangtzu shale formation in the Tienshuaifukou basin is a member of the Daedong series. It appears disconformable with the Taitzuho or Ordovician formation, but the relation becomes an angular unconformity in the eastern part. This probably means the dip of these formations increases from the center to the margin of the embryonic basin. The Daedong series near Chunggang-jin begins with a thick boulder conglomerate bed which is suggestive of an orogenic sediment.

Near Ŭiju are the Daedong series containing plants and the Jehol series yielding Estherians and *Lycoptera*. The movement which occurred between them is called the Ŭiju phase. The Jehol series, starting with the boulder conglomerate, attains over 1,000 m in thickness. It was folded by the Taebo disturbance.

In the Penhsihu basin the Penhsihu and Tayü formations were deposited and volcanic eruptions repeated in the Cretaceous period. They were folded gently except along the south and west margins where they are sharply folded, yielding upthrusts.

At Pataochiang the Chienshankou coal-bearing formation, which is probably Upper Jurassic, appears to be separated from the Cretaceous pyroclastic formation by the unconformity of the Taebo phase. The latter, which suffered from the upthrusting of the Sakawa phase, may be correlated with the Tayü formation.

The Linchia formation may have been deposited immediately after this movement. The structure was further complicated by faulting related with the Pulguksa igneous activity.

In looking through the stratigraphic sequence, it is certain that the Palaeozoic and Mesozoic were respectively the ages of crustal stability and mobility for this region. Due to the lack of Tertiary sediments, little is known of the movement of this period. It is, however, certain that the Mesozoic movements were compressive, but became the tension type in the Late Cretaceous and probably in the Tertiary period. The batholithic intrusion of the granitic magma may be most responsible for the change in this tectonic habit.

Although the original structure was later modified to a great extent, the chain of basins is still maintained in the Taitzuho valley. These basins are separated from one another by wedges of the basement complex, the aspect being shown more clearly in the northern than in the southern margin. The ancient gneiss or the Liaoho metamorphic group is well developed respectively on the north and south side of the chain. The Saimaki and other coal basins are aligned further south. Judging from the disposition of the basement complex and blanket formation, the incipient structure produced by the Songnim disturbance is thought to have been composed of the following four elements, listed from north to south:

1. The northern anticline of the ancient gneiss.
2. The principal syncline of the blanket formation.
3. The southern anticline of the Liaoho metamorphic group.
4. The auxiliary syncline of the blanket formation.

As clearly shown by the first and second elements, the anticlines and synclines were the chains of domes and basins which were aligned alternately in a checker pattern.

Compressed repeatedly by the later movements, such positive or negative elements were further elevated or depressed. As a result the plastic blanket was folded and the rigid basement cracked along the boundary between two units of opposing tendencies. Such folds developed into thrusts by further compression. Therefore it is a general tendency for blanket formations to be more strongly deformed from center to margin of a basin. If it is delimited by a thrust, the strata are abruptly bent and even overturned in its vicinity. As noted by YOSHIMURA, it is a general feature of deformation here that the structure is more complicated on the thrust side than on the thrusting side.

Among blanket formations, the Tiaoyütai quartzite is most rigid and resistant to erosion. Therefore it often forms *Pingtingshan,* which means a flat topped mountain like a basaltic mesa. Limestones are on the contrary easily folded. The differential deformation among them is well exemplified on the Pingtinghan block where the Hsiho series is gently inclined, but the Korean group is repeatedly folded.

The Liaoyang-Yentai basin is bisected by a median tectonic line which is a thrust at least near Shangshantzu. Its basin structure is, however, not much destroyed, probably because the compression was released by the dislocation along the Shangshantzu-Hanpeling shattered zone. The Hsiho and Korean formations are more compressed near Anshan beyond the Chienshan granite mass where they form an imbricated structure.

The middle Taitzuho region is strongly disturbed by thrusts in various directions. Thrusting of the northwestern, western or northern block toward the other side is, however, seen more commonly than the opposite thrust; the latter is found mostly in the southern part.

The Hsintungkou thrust provides an interesting example of fracturing of a rigid block along a boundary tectonic line. The Penhsihu basin was compressed from the west and south sides and the thrust-plane so low-angled at the corner where a *Klippe* is seen. In these aspects, this basin agrees with the Wafangtien basin. Is it accidental that each of these two has a large and simple basin on its west side? The large Wuhutsuei basin is, however, different from the Liaoyang-Yentai basin in the common occurrence of intraformational slidings. The *Klippen* of the Chiaotou quartzite capping the Lower Cambrian of the Wafangtien basin are also relics of the same kind of dislocation.

The differential movement between the two sides recurred along the Hsintungkou thrust as well as the Papanling thrust, yielding an upthrusing toward the east side which incorperated the filling of the Mesozoic basin. This is a kind of *Doppelüberschiebung*, bearing certain characteristics in common with the famous pre-Alpine *Doppelüberschiebung*.

There are many basins of various sizes that are commonly asymmetrical in outline and structure, but most of them are not so compressed as to be called brachysynclines. The outline may be elongated, but there is no definite trend for their major diameters or axes. In these respects this structure is quite different from the basins in the P'yeongnam orogenic zone in North Korea.

The Shihchiaotzu fault appears to be a long normal fault, but it needs further confirmation, because the Pingtingshan, Tiaoyütai and Pienlingpaotzu thrusts are also straight. Tension movement is, however, not well illustrated in this area.

As the Taitzuho zone is similar to the Wuhutsuei-Wafangtien area in the materials which constitute these terrains, their geologic structures have features in common. The basin, composed of relatively thin blanket formations, was later destroyed under the strong influence of the compressive block movements of the rigid basement. In short, it was the destruction of a quasikraton composed of a thin plastic veneer capping a rigid basement.

The structure visible in the Yalu-Hunchiang tributaries is an example of kraton fragmentation and is different from the preceding. Because it is the marginal part of the Taitzuho depression, the blanket formations were not well developed. Their basement is mostly composed of granitic gneiss. This well granitized part of the P'yeongbuk massif was broken into pieces by compression. As it is rigid and homogeneous, cracks were more commonly diagonal than parallel or at right angles to the direction of compression.

If a quadrate block is gradually sunken, a rectangular basin like the one of Huch'ang appears from the down -warping of its veneer, but it is easily eroded because it is thin. The veneer is better preserved along the boundaries, among blocks. It is thought that it was formed originally in a gentle syncline, but was later deformed in various ways.

If the boundary between the basement blocks is linear and simple, the veneer may become a monocline by the thrusting of one block upon another and by losing a limb of the syncline on the thrusting block. This is the case of the Kanggye area.

If it is a relatively broad zone, a syncline may develop into a synclinorium by further compression, as in the Ch'osan area.

If it is a narrow trough in which later sediments accumulated on the veneer, they may be folded in together between the blocks and suffer from the thrusting up of the neighboring blocks. The so-called Pataochiang *Fenster* is a typical example of such a closed graben.

Though the last one is a narrow zone of infolding, it is quite distinct from the arcuate shattered zone of Hanpeling-Shangshantzu. The Helankou graben and the monocline along the Shihchiaotzu tectonic line, which is partly synclinal, bear greater similarities to the third and first types of structures respectively. They are two exceptional off-shoots from the chain of basins into the areas of the basement complex.

These remnants of the veneer along the boundaries are always straight or nearly straight, as they are controlled by the fragmentation of the P'yeongbuk massif. It may happen that a zone of blanket formations issues an off-shoot or is bent by itself. Then it is expected to form an angle of about 90 degrees, or less commonly 45 degrees, at the point of branching or bending. The T-shaped branching of Ch'osan and the U-shaped bending of Kanggye and Manp'ojin are excellent examples of such deformations.

V
Comparative Tectonics

1. Different Types of Geologic Structures

In discussing the orogenic cycles in Japan in 1941, I pointed out the coincidence in the fundamental design of the architecture between the Sakawa folded mountains and the Alps. Each is an anticlinorium of grand scale having a metamorphosed core. In other words, each of them is a long uniaxial folded zone of high amplitude. They differ, however, in that the tangential dislocation in the Alps is much longer than that of the Sakawa mountains. Overthrusting of the *Oga Decke* for a distance of over 40 km was one of the two interpretations which I have previously suggested; the other explanation of the *autochthonous Pseudoklippe* now seems no less probable.

The *Decken* in the Alps are very complicated in comparison with the structure of Japan. In the history of tectonic development, however, Japan is more intricate than the Alps, because here the orogenic cycles were repeated three times. More precisely, similar mountains were successively built in Japan through the cycles of orogeny, causing a migration of the geosyncline, as shown in Table 15. The Akiyoshi mountains were built on the continental side before the Sakawa mountains, and as discussed in my recent paper (1955), the Oyashima mountains on the Pacific side are still in the making. The Ryukyu, Mariana and Chishima arcs which are intimately related to the Japanese arc are also folded mountains in different stages of growth. All are arcuate and each has a large hinter basin and a narrow deep trench in front.

As noted in my 1941 paper, the folded mountains in the Okch'eon as well as the P'yeongnam zone in Korea are very different from the Japanese type of folded mountains, as the metamorphosed axis is absent. I have already given a detailed description of the Okch'eon type of structure seen in the western part of the Kwangweondo limestone plateau. Between P'yeongchang and Mun'gyong it is a large straight anticlinorium with a small synclinorium on each side. These triaxial folds developed into an imbricated structure, yielding thrust lines which show a remarkable parallelism for a long distance. This aspect reminded me of the imbrication of the ridge and valley zone in the Appalachian mountains. This part is, however, considered at present the frontal nonmetamorphosed zone of the mountain system, instead of the system itself.

The Okch'eon folded zone is about 40 to 60 km in breadth, the P'yeongnam zone is much broader, measuring about 200 km wide in North Korea. No long or persistent axis of folding exists and the zone consists of many brachysynclines and brachyanticlines which are mostly composed of the P'yeongan and Sangweon groups respectively. The Korean group between them often forms disturbed zones, and the basement complex is exposed in some places as domes. The alternate arrangement of positive and negative elements in the P'yeongnam zone corresponds to the Taitzuho type of structure, but is distinct from that type in the presence of short and parallel or subparallel folded axes. The zone bears some features of the Taitzuho zone whereas the structure of the Okch'eon zone is similar to the Chichibu zone of the Sakawa mountains. However, the two zones in Korea are folded zones developed from the geosyncline-like troughs or parageosynclines, while the folded mountains of the Japanese type have grown up from the true geosyncline or orthogeosyncline.

The geologic structure produced in the Yalu region and the Taitzuho zone during Mesozoic disturbances are something other than folded mountains. They belong to kratonic or quasikratonic terrains, and their structures were produced by fragmentation of such rigid terrains. A chain of basins is aligned from west to east along the Taitzuho river. These basins are arranged alternately, with the domes on the two sides. Among them the major axis of the brachysyncline has no definite trend, but the chain of basins as a whole forms an equatorial zone. There

Table 15. Tectonic Lineaments of the Folded Mountains in Japan.

Tectonic Elements		Akiyoshi Mountains	Sakawa Mountains	Yezo Mountains
Hinter Basin		(Monguagai Basin in Ussuri)	Tsushima Basin, etc.	Tokaichi Basin, etc.
Axial Zone	Granitized Zone	Hida Gneiss Zone	Ryoke Gneiss Zone	Hidaka Mountains
	Metamorphosed Zone	Sangun Metamorphosed Zone	Nagatoro Metamorphosed Zone	
Frontal Deformation Zone		Yamaguchi folded Zone	Chichibu Folded Zone	Ishikari Coal-Field, etc.
New Geosyncline		Shimanto Geosyncline	Nakamura Geosyncline	Ishikari Plain

are thrusts, many of which are diagonal to the zone. Thus the basins are nonaxial whereas the whole depression forms a zone.

The Yalu-Hunchiang tributaries which occupy the marginal part of the P'yeongbuk land are not zonal. This massif, chiefly composed of granitic gneiss, suffered from the Mesozoic movements simultaneously with the depressions or troughs. Judging from the equatorial zones of the Taitzuho and P'yeongnam, it is evident that the P'yeongbuk massif was compressed meridionally. As a result it was broken into blocks along straight cracks which were more commonly diagonal than equatorial or meridional. The thin veneer of Palaeozoic and Proterozoic sediments which covered the basement complex was tilted up or folded down between the blocks. Such grabens are narrow and straight, and if branching or bent, often form right angles. This is a typical example of kraton fragmentation caused by compressive block movements.

Thus there are five distinct types of structures in Japan and Koreo-Manchuria, called the Japan, Yokusen (Okch'eon), Heinan (P'yeongnam), Taitzuho and Yalu types for the sake of convenience. *Because these structures were produced by the same Mesozoic orogenies or disturbances, their differences must depend upon the terrain.* The relation of these structures to the original terrains are as follows:

1.	Japan type of uniaxial arcuate mountains	Orthogeosyncline
2.	Okcheon type of a triaxial folded zone	Parageosyncline
3.	P'yeongan type of a polyaxial folded zone	
4.	Taitzuho type of block folding	Quasikraton
5.	Yalu type of kratonic fragmentation	Kratonic massif

The following gradations can be observed in these structures:

1. From uniaxial through polyaxial folding to non-axial structure.
2. From zonal or parallel structure to areal or diagonal structure.

2. Kraton Fragmentation

Starting with kraton fragmentation, we can compare the characteristics of the geologic structure. The P'yeong'buk massif provides an excellent example of fragmentation. It was broken into minor blocks along straight cracks which were more commonly diagonal than parallel or perpendicular to the direction of compression. Because of this habit of fragmentation the isolated microkratons are often subquadrate in outline. The Colorado plateau, Texas basin, Bohemian massif, blocks of Podolia and Woronez, the Kuznetsk basin, and the sunken block of the Kara sea are similar examples.

The cracks in the Pyeongbuk massif were nearly straight and its veneer, which is relatively thin, suffered from the compressive block movement. This is seen in the *Pseudofenster* of Pataochiang, the U-shaped monocline of the Kanggye-Manp'ojin area and the T-shaped synclinorium of the Ch'osan-Wiweon-Kojang area.

Because of the right angle at the junction or beding point, these T- and Ushapes are related to the L-shape described by the Red Sea and Gulf of Aden or a part of the zig-zag course of the Great Rift Valley in Africa.

The Huch'ang basin is remarkably truncated by a long meridional fault. This basin is not as compressed as the Eo-Palaeozoic formation near Prag in the Bohemian massif. Its triangular outline consists of two edges of discordance and one of dislocation. Near Huch'ang-ganggu there is a syncline having an equatorial axis. Judging from the facies and thickness of sediments it is probable that there was a narrow Proterozoic trough between blocks. The Arbuckle mountains have also developed from a narrow trough between kratonic masses.

Thus there are more than two kinds of troughs. One is a simple graben or zone of depression in which the blanket formation sank after a movement, and the other has developed from a trough or an embryonic syncline. The latter can be further subdivided into two kinds. One is an old trough like the Arbuckle trough which was primarily brought to being by kratonic fragmentation. The other is the case of the Pataochiang *Pseudofenster*. It was not a trough in the Palaeozoic or Proterozoic period, but must have been some kind of a depression in the Mesozoic period. Such a Mesozoic depression was later thrust from the two sides into the form of a graben.

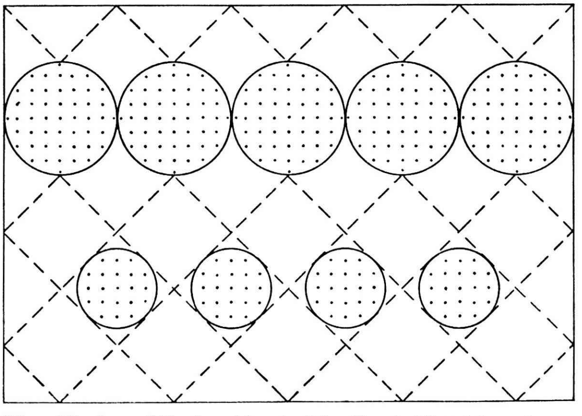


Fig. 39. Chains of Basins (dots), Idealized. Hatching shows the basement block, diagonally cracked.

There is no sharp boundary between the Yalu and Taitzuho types or between the latter and the P'yeongnam type of geologic structure, but there is a great difference in the thickness of the sediments. Accordingly, the differential deformation between these sediments and their basement reveals a remarkable tectonic feature.

In the Taitzuho zone, positive and negative elements which were arranged alternately in a checker pattern can be recognized fairly well. The embryonic folding must have involved the doming up of positive elements and the subsidence of negative ones. At the side of the Taitzuho valley and its neighborhood there were rows of such domes and basins which were arranged parallel to the Mongolian geosyncline.

It is interesting to see that the arrangement is more or less allied to that of tectonic elements in the Mid-Continent and their relation to the Appalachian geosyncline. In eastern North America the Adirondack dome, Cincinnati arch and Nashville dome correspond to the three arcs of the Appalachian mountains. Beyond the lower Mississippi valley are the Ouachita mountains and the Ozark dome. Northwest of this chain of positive elements are the Michigan, Illinois and other basins, which form a row of depressions. The Sioux quartzite area represents the elevation lying farther from the mountain system. Needless to say, these domes and basins in central North America are incomparably larger and much less deformed than those of the Taitzuho valley. Nevertheless they alternate in a similar manner.

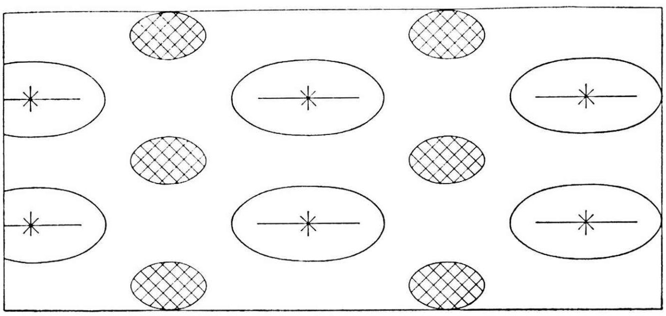


Fig. 40. Brachysynclines Alternating with Domes (crosses).

It is a remarkable fact that the domes and basins in North America bear positive and negative tendencies respectively and grew step by step through the Palaeozoic era. Such tendencies of embryonic folds cannot yet be recognized in the stratigraphic sequence of the Taitzuho region, if each basin is taken as a unit, but it is evident that the region as well as the P'yeongnam geosyncline were two zones of subsiding tendency which were separated by the P'yeongbuk land.

It is interesting that part of Eastern Asia, as exemplified above, reveals various features comparable to those of Laurentia and other megakratons, though on a miniature scale. Therefore it is noteworthy that, insofar as these common features are concerned, *there is no essential difference in the kratonic fragmentation between the mega-and micro-kratons.*

3. Deformation of the Quasikraton

The basins in the Taitzuho tributary are composed of the Mesozoic or P'yeongan formation in the central part, surrounded by the Korean group and then by the Hsiho series. There is a general tendency for their dip to become steeper distally.

Commonly a northern or southern block wedges in between two basins. These blocks and basins are mostly separated from one another by tectonic lines. Among such boundaries the northeastern and northwestern trends are more prominent than the equatorial or meridional ones. Some of the lines are indicated by normal faults, but many others are thrusts, upthrusts or disturbed zones.

Basin structures complicated by thrusts from two or more sides are not uncommon. Such basins may be called *closed basins*. They are caused by centripetal thrusting. The Wafangtien basin, bounded by low angle thrusts from the south and west, is an excellent example of such a basin. It may be said to be doubly closed, seeing that the Wafangtien coal-bearing sediments of Chaotzuyao are folded in between the Korean group on the east and west. The Shanchengkou basin of Hsiaoshih is thrust from the north and west; the Penhsihu basin is thrust from the west and south, but with high angles.

Due to the differential movement among basin sediments, some of them have also slipped outward relative to the underlying part. This type of centrifugal dislocation is sometimes seen within the Sangweon group in the Wuhutsuei basin. Such a basin may be called an *open basin*. The Hwangju basin in North Korea reveals this kind of structure (see Fig. 9). On the south side of the north P'yeongnamdo coal-basin centrifugal dislocations are repeated in the Imcheon shale, forming the Seongch'eon imbricated zone (see Fig. 6). The western borders of the Penhsihu as well as the Tienshuaifukou basin are defined by thrusts which are close-set and nearly parallel to one another. Through Papanling on the western margin of the latter basin there are parallel thrusts along which the Korean and P'yeongan groups are repeatedly thrust two or three times toward the east. The pre-Papanling thrust is a secondary dislocation along which Palaeozoic formations are pushed upon the Mesozoic. It is noteworthy that all of these dislocation lines among the middle and upper parts of the blanket formations are concave toward the basin.

The pre-Papanling upthrust is a product of a secondary dislocation similar to that of the pre-Alpine *Doppelüberschiebung*. The pre-Alpine *Überschiebung* took place in the culmination phase of the Alpine orogeny. There is some question, however, whether the primary thrusting was soon followed by a secondary one in the Taitzuho valley. In the outer zone of western Japan old and new tectonic lines trending parallel to each other near an important tectonic boundary are not uncommon. In western Shikoku there are the Butsuzo and pre-Butsuzo lines. The former is the boundary thrust between the Chichibu imbricated zone and the Shimanto folded zone in the Sakawa folded mountains. The latter marks the northern boundary of the Neo-Cretaceous formation in the Uwajima basin and must be a secondary tectonic line produced by the Middle Tertiary Oyashima disturbance. Along the eastern margin of the Akaishi mountains, as I pointed out earlier (Kobayashi, 1941), there are some parallel tectonic lines which were produced one after another by a similar mechanism.

The amount of dislocation is much larger along the Hsintungkou thrust than along the Papanling thrust, because the pre-Hsiho basement complex is widely exposed on the west side of the former thrust. Another difference is that the former is convex toward the basin, but the latter somewhat concave. In the course of the thrusting of the western block upon the Penhsihu basin on the east side, the pre-Hsiho basement was cracked and these cracks issued as branches from the main thrust. The pre-Hsintungkou thrust is the secondary product of the repetition of a movement similar to that along the pre-Papanling thrust. I am particularly interested in the peripheral destruction of the western block by branches of the Hsintungkou thrust, because it appears to exhibit a stage earlier than the development into the *Schuppenstruktur* as seen at the two angles of the Chungbongsan block in South Korea.

The Hanpeling-Shangshantzu zone in the Taitzuho valley is a remarkable disturbed zone. It is narrow, long and arcuate, but fairly discordant with the structure of the Yentai basin. The strata in the zone are strongly disturbed, having a strike diagonal to the zone, an aspect which is suggestive of the rotation of the strata within the zone. The Tanagura disturbed zone in the Kwanto region in Japan is straight. Its nature is not yet well known, and its relation to neighboring blocks differs from that of the Hanpeling zone. In the central and western part of the Hida plateau in Japan there is a disturbed zone along the periphery of the Hida gneiss complex. The upper Palaeozoic formations are strongly disturbed and the Middle Palaeozoic formations and metamorphic rocks are wedged into the zone, but it is straight rather than arcuate. Furthermore, the southern boundary of the zone is obscure; I cannot find any example in Japan which is comparable to the Hanpeling-Shangshantzu zone.

4. Grade of Oronization

The mode of deformation of a given orogeny differs in various rocks, formations and terrains. As a rule, the finer the grains of a sediment or the more homogeneous a formation, the easier it is to change the relative position of the grains by compression. Therefore deformation by a crustal movement is stronger for shale than conglomerate, sandstone being intermediate between them.

The sedimentary rocks, when once folded intensely, are not as easily folded or thrust as before, though this is still feasible. The secondary thrusting or the B-type of thrust can clearly be distinguished in North Korea from the primary or A-type of thrust. The former is concordant with folding, while the latter is discordant with the folded structure.

The rocks and formations may be further consolidated by regional metamorphism, but the terrain may not be completely solidified until it is granitized. In other words the oronization, i.e., the consolidation and stabilization of a terrain, can be subdivided into three major grades—deformed, metamorphosed and granitized grades.

The Koreo-Chinese heterogen was largely oronized by the batholithic invasion of granitic magma in the late Mesozoic period. Because Korea and South Manchuria were granitized almost completely, their subsequent development was unrelated to the previous tectonic lineament. Growth of the Korean peninsula since the latter part of the granitization truncates the P'yeongnam and Okch'eon zones almost at right angles. Such a discordance between the new and old tectonic elements is comparable to that between the Caledonian mountains and the Kareliden in Europe.

5. From Oronization to Anoronization

In looking through the various types of crustal deformations, it can generally be accepted that *the thinner the blanket formation, the greater the influence of its basement upon the deformation of the blanket.* The Yalu, Taitzuho and P'yeongnam types reveal deformation respectively of thin, intermediate and thick blanket formations caused by the same orogeny. These are all compressive deformations and their characteristics have already been pointed out.

The movements which took place in Koreo-Manchuria since the late Cretaceous period were mostly tension rather than compression. I shall not examine this trend of research very deeply here, but the following types of movements are significant:

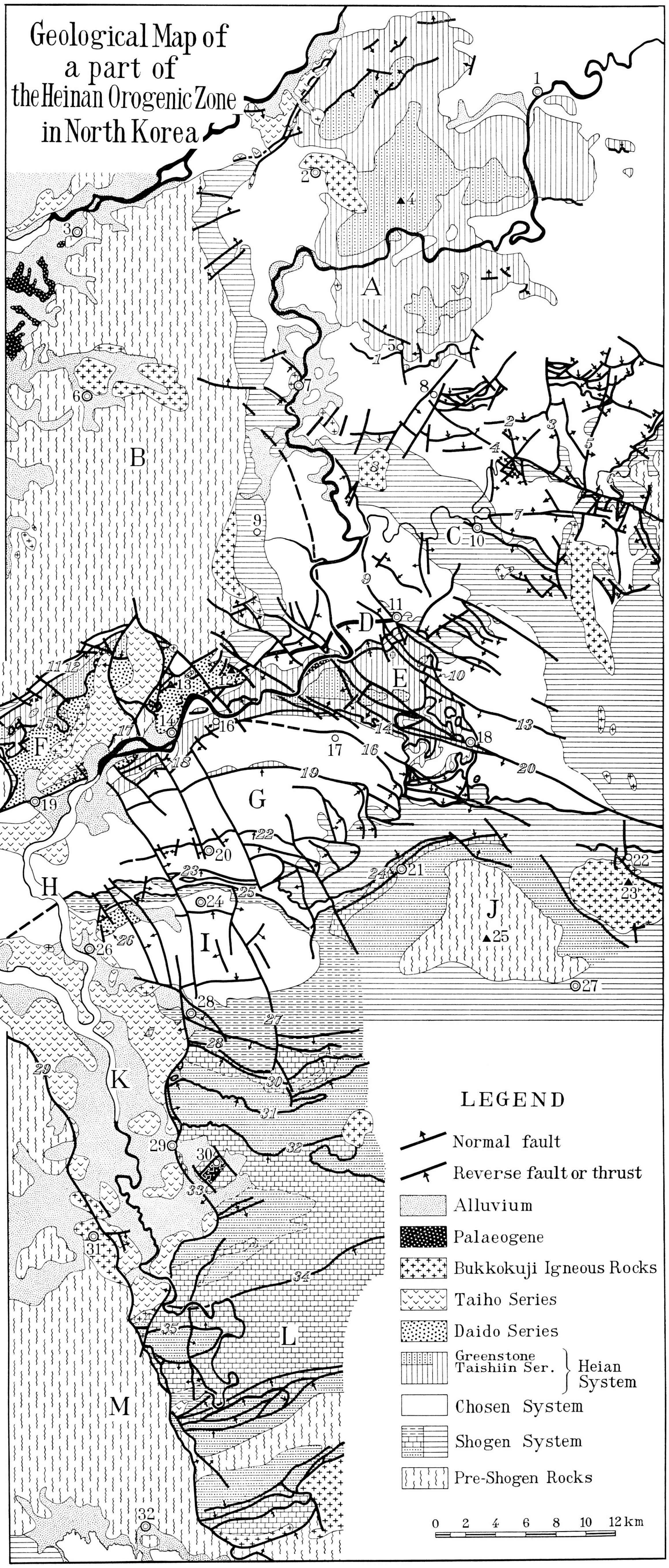
1) The Taebaegsan dislocation zone in Central Korea.
2) The Annak and Chinchou faults.
3) Upheaval of the asymmetrical geanticline indicated by the Yukpaiksan peneplane in Central Korea.
4) Tilting of the Kaema plateau and its peripheral destruction by the Hamgyeong fault system.

The first of these is a zone of faults intimately related to the Pulguksa igneous activity. Although it is difficult to date the faulting, the Annak and Chinchou faults are boundary faults of tilted blocks. They are both long and low angled faults along which the neighboring blocks slipped down. In these characteristics the dislocations are comparable with the sliding of the inner zone along the Median Tectonic Line in the Ichinokawa phase.

The Hamgyeong system is represented by a series of parallel or subparallel faults and the upheaval of the Kaema plateau must have been related in some way to the effusion of basalts or alkaline rocks which occurred before as well as after the principal tilting and faulting.

The geanticlinal upheaval of the Korean backbone appears to be unrelated to either the faulting or the volcanism, but this is not entirely true. It is cut diagonally by the Weonsan-Seoul tectonic valley, which is filled with basalt flows. Furthermore the volcanic rocks are distributed from Mt. Paektu-san to Cheju island through Ullŭng isle, describing an outer circle alone the Korean peninsula. It is clearly seen in Korea that *granitization was followed by culmination or Grossfaltung and volcanism of anorogenic type.*

I. Geological Map of a Part of the P'yeongnam (Heinan) Orogenic Zone in North Korea. (After S. NAKAMURA, I. TATEIWA, S. SHIMAMURA, T. SHIRAKI, E. KONNO, S. MATSUSHITA, T. KOBAYASHI, N. KOBATAKE, K. SAITO, T. WATANABE, N. IKEBE, et al.)

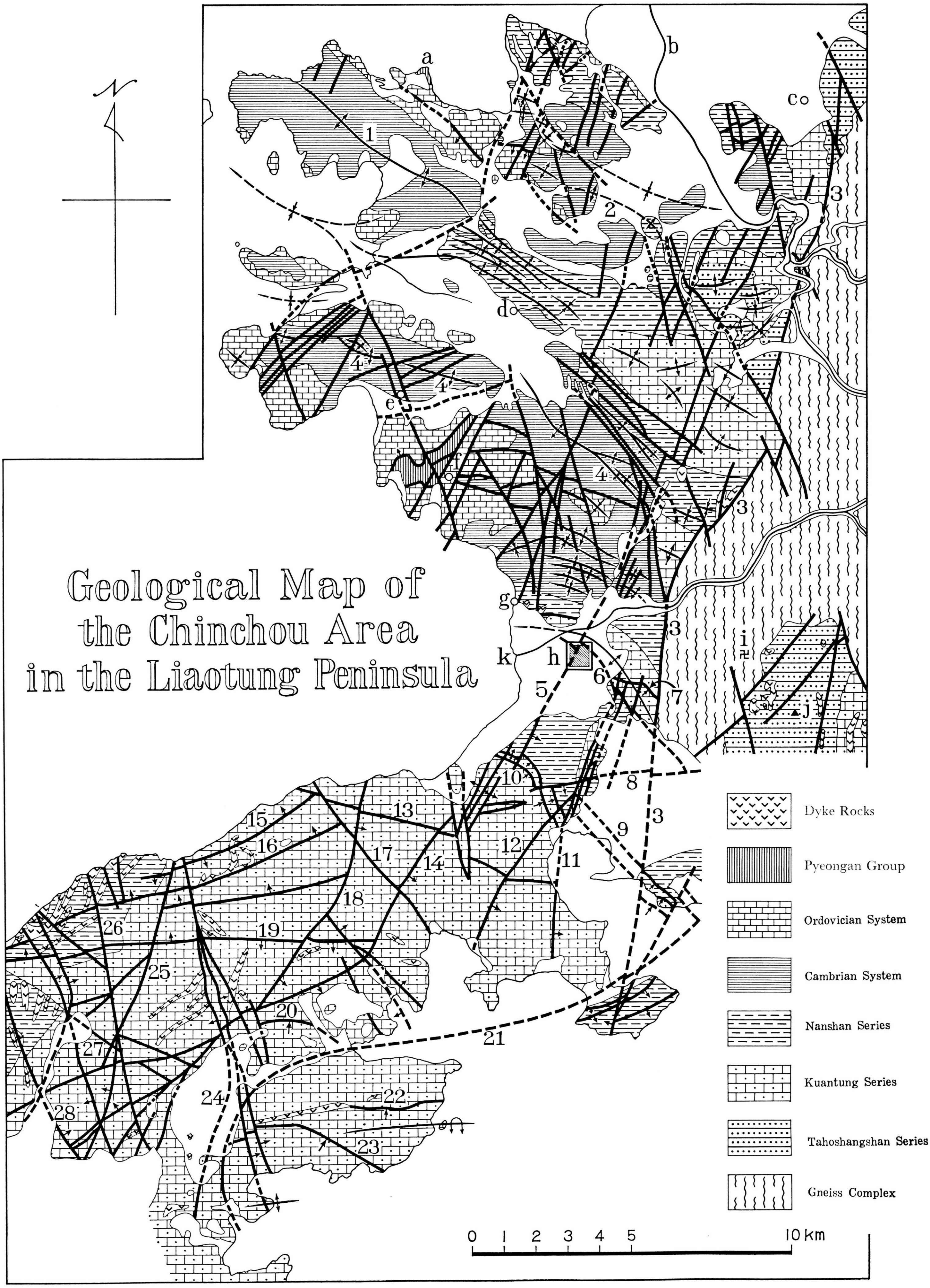


A. North P'eongnam Coal-field
B. P'yeongweon Massif
C. Seongch'eon Disturbed Zone
D. Boundary Tectonic Line between the Northern and Middle Parts
E. Kangtong Coal-field
F. Kangseo Coal-field
G. Chunghwa Disturbed Zone
H. Daedong-gang River
I. Hwangju Basin
J. Chŭngbong-san Dome
K. Chaeryeong-gang River
L. Chaeryeong-gang Disturbed Zone
M. Sinju Massif

1. Teok'cheon
2. Kaech ton
3. Anju
4. Maninbong
5. Ch'eongseong-ni
6. Sukch'eon
7. Sunch'eon
8. Sinch'ang-ni
9. Sainjang
10. Seongch'eon
11. Kangtong
12. Taeseong-san
13. Kambuk-san
14. P'yeongyang
15. Muhak-san
16. Sadong
17. Mandal-san
18. Samdŭng
19. Kiyang
20. Chunghwa
21. Sangweon
22. Holgol
23. Onjin-san
24. Hukkyo
25. Chŭngbong-san
26. Kyeomip'o
27. Suan
28. Hwangju
29. Sariweon
30. Pongsan
31. Chaeryeong
32. Haeju

1. Yeongdaeni Thrust
2. Sadosan Thrust
3. Sakch'ang-ni Fault
4. Changnim Fault
5. Hoeeomsan Fault
6. Pyeolch'angni Thrust
7. Hyangp'ungsan Fault
8. S'ungasan Granitic Mass
9. Ap'ari Thrust
10. Suip Thrust
11. Kŭmche Thrust
12. Changsan Thrust
13. Pongnaeni Fault
14. Teoksan Thrust
15. Taebo Thrust
16. Koyeongsan Thrust
17. Kiyang Thrust
18. Sadong Thrust
19. Post-Sadong Thrust
20. North Samdŭng Fault
21. Muhaksan Fault
22. Chunghwa Thrust
23. Chuyeomjong Thrust
24. Sangweon Thrust
25. Kuhyeonch'i Thrust
26. Songnimni Discordance
27. Tohyeon Fault
28. Toch'i Fault
29. Annak Fault
30. Teongmor Thrust
31. Cheongbangsan Thrust
32. Pongsan Thrust
33. Sariweon Fault
34. Ŭllyong Fault
35. Changsusan Fault

II. Geological Map of the Chinchou Area in the Liaotung Peninsula. (After S. MATSUSHITA)



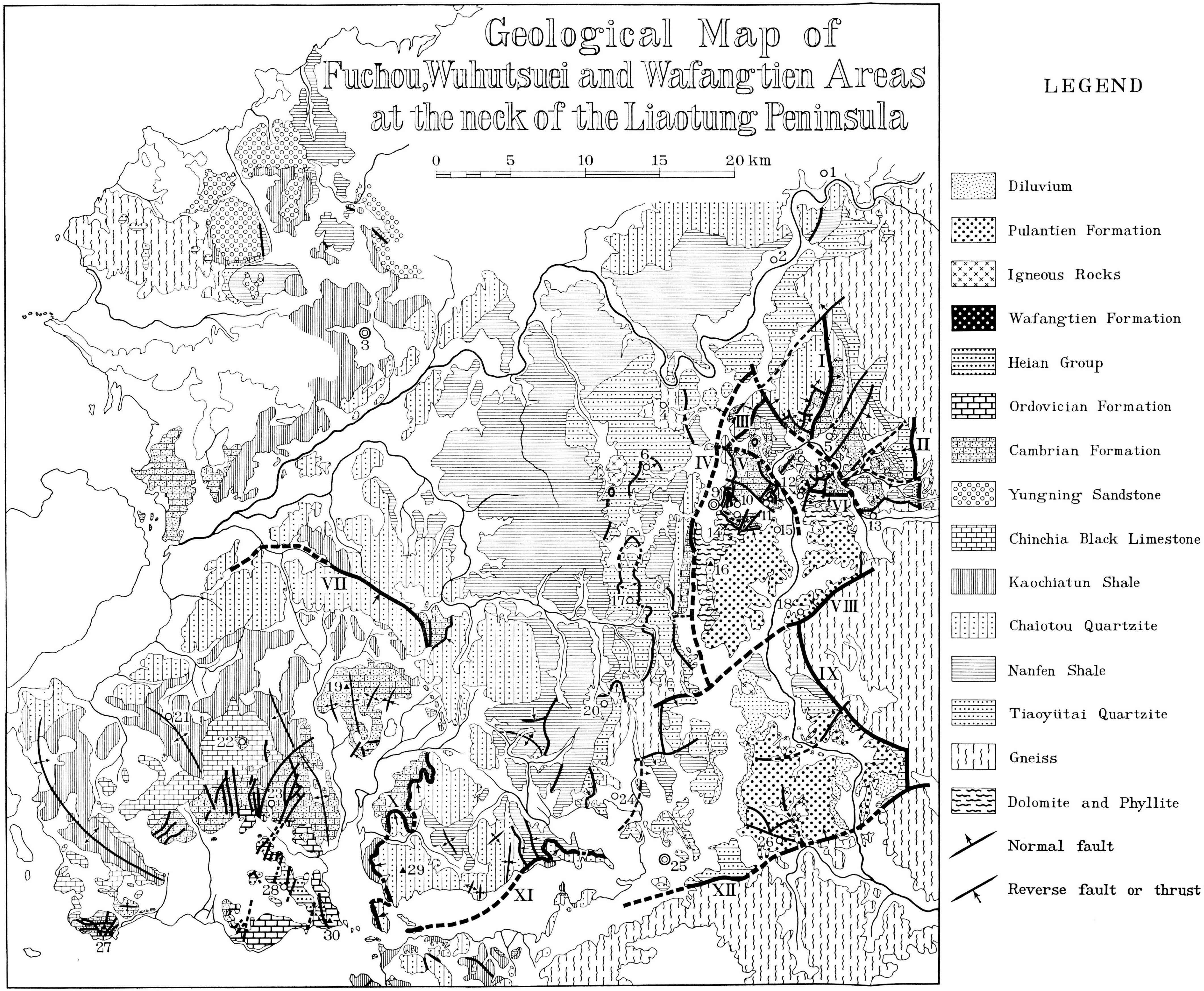
1. Lashushan Anticline
2. Chitingshan Anticline
3. Chinchou Fault
4. Houshihhueiyaotun Anticline
5. Chinchou-peimen Fault
6. Chinchou-tungmen Fault
7. Chinchou Thrust
8. Tahoshangshan Fault
9. Pre-Nanshan Thrust
10. Nanshan Thrust
11. East Tafangshen Fault
12. West Tafangshen Fault
13. Tamaoyingtzu Fault
14. Nankuanling Fault
15. Lashufang Fault
16. Chipanmê Fault
17. Chienkuantun Fault
18. Leishan Fault
19. Luotuoshan Fault
20. Chuanshueiyentzu Thrust
21. Lioushutun Fault
22. Haimiaotuotzu Thrust
23. Kanchingtzu Thrust
24. Liangyenching Fault
25. Tayüshan Fault
26. Panchüantzu Fault
27. Chungkechenpao Fault
28. Hsiachiahetzu Fault

a. Tiaohutzu
b. Sanshihlipu River
c. Sanshihlipu
d. Taweichiatunhuei
e. Houshihhueiyaotun
f. Chienshihhueiyaotzu
g. Lungwangmiao
h. Chinchou
i. Hsiangshueiszu
j. Tahoshangshan
k. Peitaiho

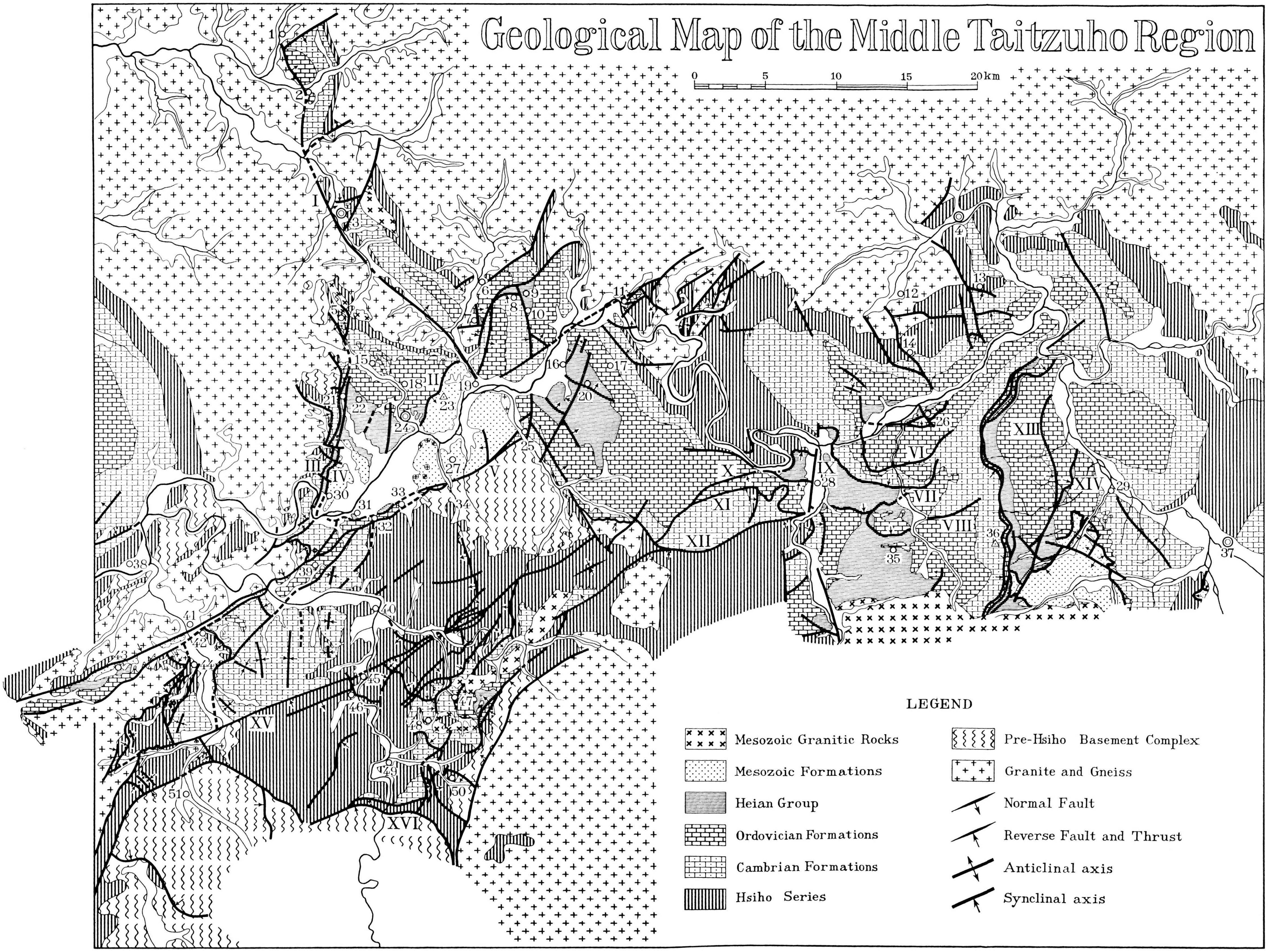
III. Geological Map of the Fuchou, Wuhutsuei and Wafangtien Areas at the Neck of the Liaotung Peninsula. (After O. Aoji, T. Kobayashi, K. Horiuchi, M. Nakamura, M. S. Soo, R. Saito, M. Noda, et al.)

I. Sungchiatun Fault
II. Wangchengshan Fault
III. Wuchiatun Thrust
IV. Wafangtien Fault
V. Kaochiatun Fault
VI. Chiangchiatun Thrust
VII. Lüchiatun Thrust
VIII. Tawangchiatun Fault
IX. Feichiatun Fault
X. Wangpashan Thrust
XI. Yatang Bay Thrust
XII. Pulantien Fault

1. Sungshu
2. Teiliszu
3. Fuchou
4. Taipingkou
5. Luchiatun
6. Yinchiatun
7. Talinchiatun
8. Hsiaolinchiatun
9. Wafangtien
10. Chuanchüehfang
11. Chatzuyao
12. Takumiao
13. Tachengchiatun
14. Tangchiatun
15. Sunchiatun
16. Yuntaishan
17. Hêhuawan
18. Tawangchiatun
19. Waitoushan
20. Tsungwangmiao
21. Laoyufang
22. Yuanchiakou
23. Chinchiachengtzu
24. Sankuanmiao
25. Pulantien
26. Pipuhsien, Hifumi Pass
27. Yuntaishan
28. Feichiatun
29. Wangpashan
30. Sanlengshan



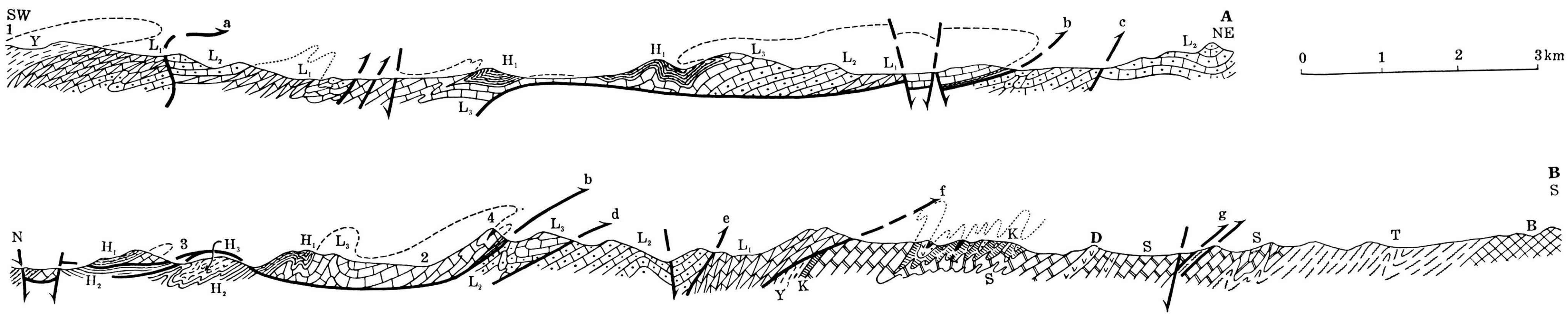
IV. Geological Map of the Middle Taitzuho Region. (After O. AOJI, J. HATA, R. ENDO, T. KOBAYASHI, N. KOBATAKE, M. MORISHITA, Y. YOSHIKAWA, I. YOSHIMURA, et al.)



1. Paihsingchai
2. Kantaijentun
3. Shihchiaotzu
4. Chinghecheng
5. Taling
6. Lichiawepeng
7. Hueishan
8. Houti
9. Yaotzuyü
10. Shueiyaokou
11. Pienlingpaotzu
12. Hsichiapaotzu
13. Machiakou
14. Hsikou
15. Huolienchai
16. Shangniuhsintai
17. Wanwankou
18. Santaokangtzu
19. Weiningcheng
20. Hunglienkou
21. Hsintungkou
22. Toufangkou
23. Chiashan
24. Penhsihu
25. Wolung
26. Tungshan
27. Kaolifenchü
28. Hsiaoshih
29. Tienshuaifukou
30. Linchiasueitzu
31. Tungshantzu
32. Chinfukou
33. Yaopao
34. Pingtingshan
35. Shanchengkou
36. Papanling
37. Chienchang
38. Shenwe
39. Achiakou
40. Chiaotou
41. Kuchiatzu
42. Huangchiapaotzu
43. Hanpeling
44. Chioukeyü
45. Puchiszu
46. Tiaoyütai
47. Taihungpaiyü
48. Hsiaomiaokou
49. Nanfen
50. Miaoerkou
51. Wangchiapaotzu

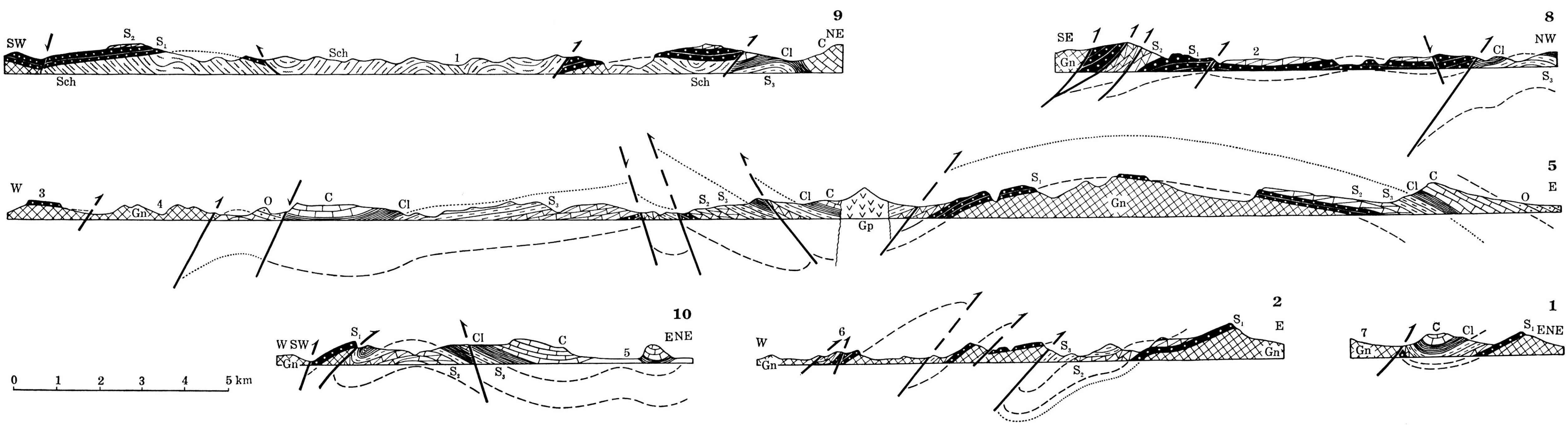
I. Shihchiaotzu Fault
II. Minshankou Fault
III. Hsintungkou Thrust
IV. Pre-Hsintungkou Upthrust
V. Pingtingshan Upthrust
VI. Yaopao Thrust
VII. Mapichiangkou Thrust
VIII. Lishantaokou Thrust
IX. Hsiaoshih Fault
X. Pichiakou Thrust
XI. Niangniangkou Thrust
XII. Linchiapaotzu Thrust
XIII. Kuchiakou Thrust
XIV. Tiehtzushan Thrust
XV. Tiaoyütai Thrust
XVI. Nanfen Thrust

Va. Two Profiles of the Samdŭng-Sangweon Area in North Korea. (After N. IKEBE)



H_3.	Gobangsan Series	a.	Koyeongsan Thrust
H_2.	Sadong Series	b.	Teoksan Thrust
H_1.	Hongjeom Series	c.	Suip Thrust
L_3.	Upper Great Limestone Series	d.	Taeyeonni Thrust
L_2.	Middle Great Limestone Series	e.	Sinmadong Thrust
L_1.	Lower Great Lime stone Series	f.	Kojeongsan Thrust
Y.	Yangdeok Series	g.	Sangweon Thrust
K.	Kuhyeon Series	h.	Chŭngbongsan Dome
S.	Sadongmor Series	1.	Koyeongsan
T.	Chikhyeon Series	2.	Namgang
B.	Basement Complex	3.	Teoksan
D.	Dyke Rocks	4.	Kanjinsan
		5.	Kojeongsan

Vb. Six Profiles of the Middle Taitzuho Valley (After I. YOSHIMURA)



Gp.	Granite Porphyry	1.	Lanhe
H.	P'yeongan Group	2.	Chinghecheng
O.	Ordovician System	3.	Peitaiping
C.	Middle and Upper Cambrian Formations	4.	Nanfen
C_1.	Lower Cambrian Formation	5.	P'ienlingpaoyzu
S_3.	Chiaotou Quartzite	6.	Pingtingshan
S_1.	Nanfen Shale and Marl	7.	Wangchiatun
S_1.	Tiaoyütai Quartzite		
Gn.	Gneiss		
Sch.	Schists		

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