Geology of South Korea

with Special Reference to
the Limestone Plateau of Kangweondo

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Introductory Note

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

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

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

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

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

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

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

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

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

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

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

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

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

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

I
A Geological Sketch of Korea and Environs

1. Research in the geology of Korea

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

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

2. Outline of geomorphology of Korea and environs

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

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

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

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

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

3. Tectonic lineament of Korea and environs

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

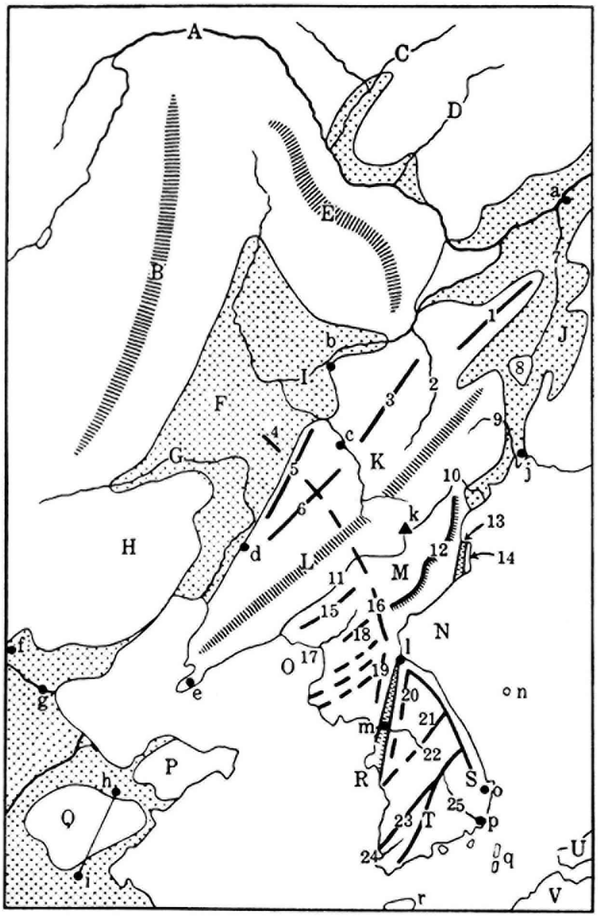
The Pre-Cambrian basement is exposed at some places but none is wide enough to be called a shield.

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

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

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

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



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

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

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

Fig. 1. Orographic Map of Koreo-Manchuria.

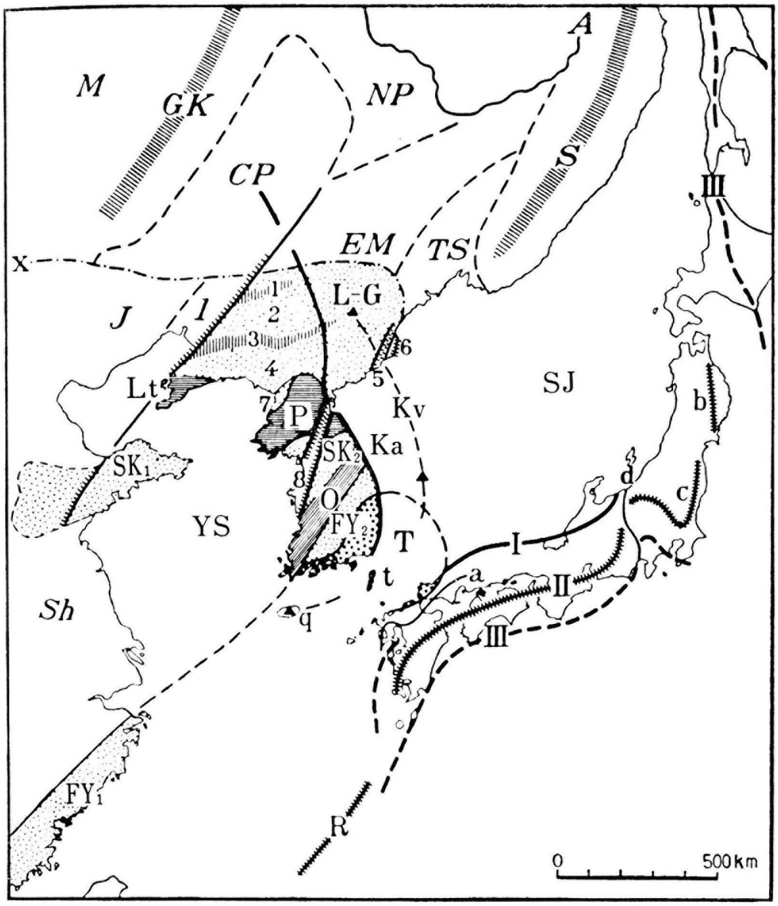
yang (YABE and SUGIYAMA, 1939), but their stratigraphic position is still obscure.

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

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

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

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



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

Fig. 2. Tectonic Map of Korea and Environs.

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

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

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

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

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

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

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

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

4. The Songnim and Taebo disturbances and related granitization

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

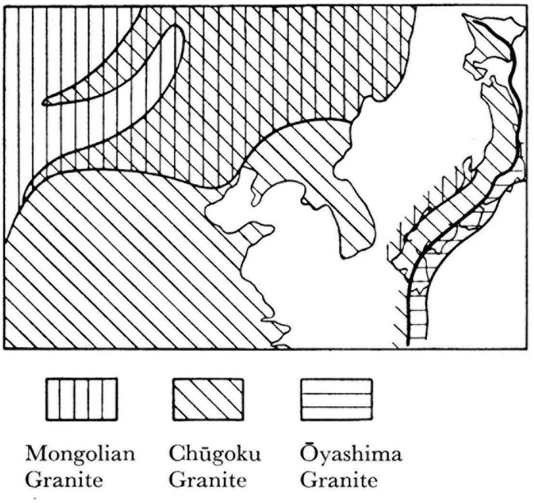


Fig. 3. Granitization of Eastern Asia.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

6. Koreo-Manchuria after the Sakawa orogenic cycle

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

II
Geology of South Korea

1. Outline of South Korea

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

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

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

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

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

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

A P'yeongbuk (Heihoku) Gaima land
B P'yeongnam (Heinan) zone
C Kyeonggi (Keiki) land
D Non-metamorphosed Okch'eon (Yokusen) zone
E Metamorphosed Okch'eon (Yokusen) zone
F Chungbongsan (Chuhosan) block }
G Taebaegsan (Taihakusan) block } Yeongnam (Reinan) land
H Teokyusan (Tokuyusan) block }
I Tsushima basin
White Dots in Black: Basalt
Small Dots: Cretaceous and later sediments
Black: Older Mesozoic formation
White: Massif

Fig. 4. Tectonic Division of South Korea.

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

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

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

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

Table 3. Stratigraphical Sequence of South Korea.

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

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

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

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

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

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

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

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

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

3. Geological sequence of the Kangweondo limestone plateau

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

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

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

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

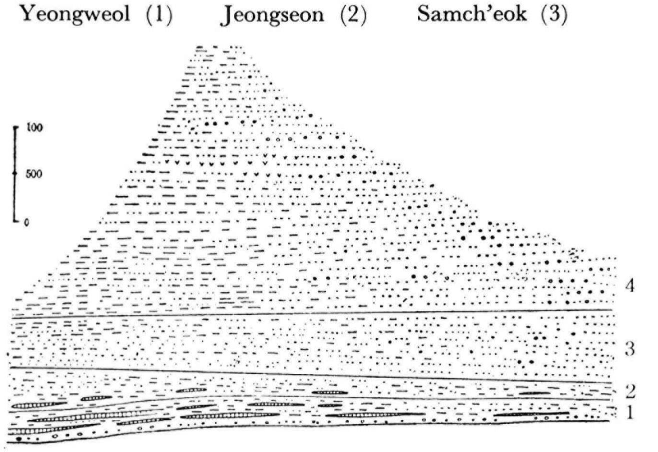
As in the other parts of Korea, the Korean system in the plateau used to be classified into the lower or the Yangdok series and the upper or the great limestone series, but this classification was abandoned and a new classification established in the vicinity of Taepaeksan (Kobayashi, 1930). There the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

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

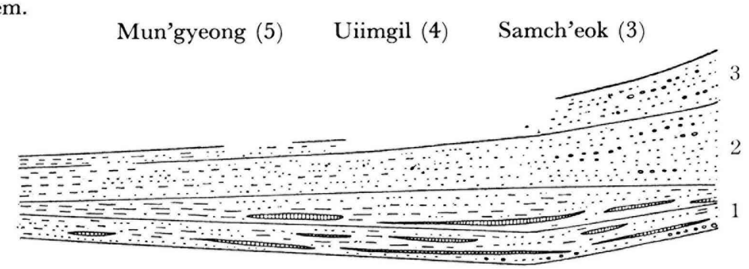
Table 4. Classification and Correlation of the Korean System in the Kangweondo Limestone Plateau (Thickness in meters).

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

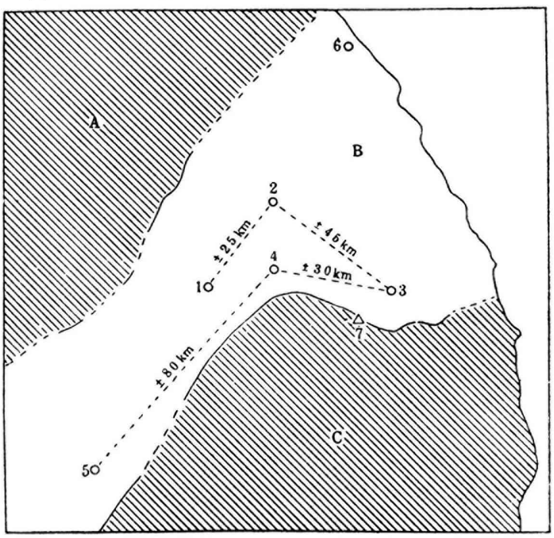
(1) Diagrammatic sections 1–3 showing the variations in facies and thickness of the P'eongan system.



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



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

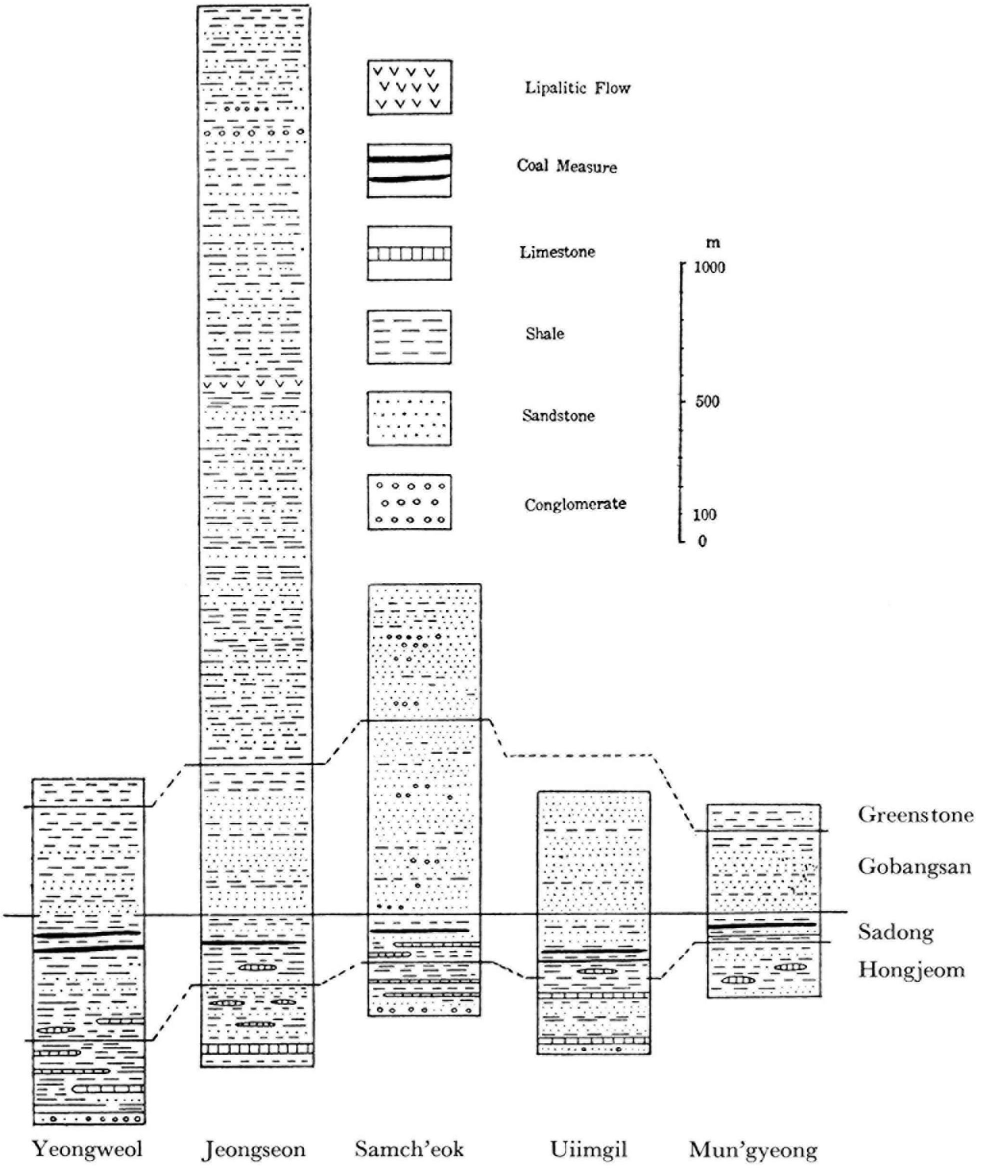


A: Kyeonggi massif
B: Okch'eon Zone
C: Yeongnam massif

4: Greenstone series
3: Gobangsan series
2: Sadong series
1: Hongjeom series

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

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



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

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

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

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

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

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

(1) The Korean and P'yeongan groups were gently warped up and down in the first Songnim phase.

(2) The P'yeongan group and the upper Korean group were extensively eroded, but the Korean group was capped by the P'yeongan at many places.

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

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

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

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

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

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

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

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

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

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

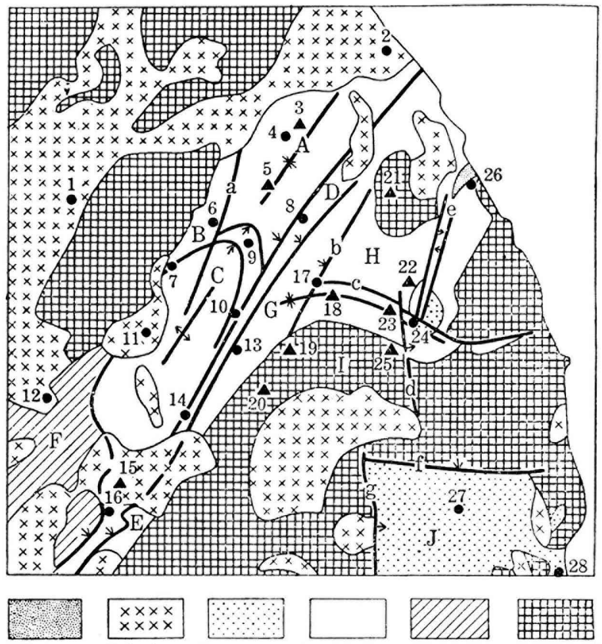
4. Geologic structure of the Kangweondo limestone plateau

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

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

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

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



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

a P'yeongch'ang (Heisho) fault
b Maehwadong (Baikwado) tectonic line
c Chodongni (Chodori) tectonic line
d Hambaeksan (Kanpakusan) fault
A Pongdugonni (Hotokonri) synclinorium
B P'yeongch'ang (Heisho) zone
C Yeongweol (Neietsu) anticlinorium
D Jeongseon (Seizen) zone
E Sin'giri (Shinkiri) zone
e Osipch'eon (Gojusen) shattered zone
f N. Yeongyang upthrust
g W. Yeongyang fault

F Okch'eon (Yokusen) metamorphosed zone
G Paekunsan (Hakunsan) syncline
H Chungbongsan (Chuhosan) block
I Taebaegsan (Taihakusan) block
J Yeongyang (Eiyo) fault angle basin

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

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

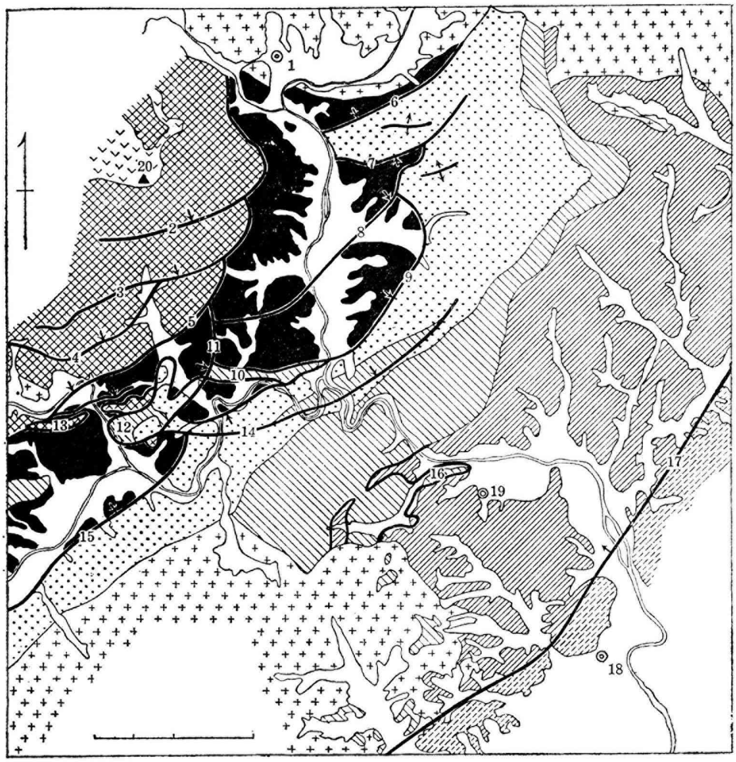
The block movement is very strong on the eastern side of the Hambaeksan fault. In the zone between this fault and the coast of the Japan Sea there are many faults in NE-SW, NNE-SSW, and N-S directions. Some faults run in an ENE-WSW or even E-W direction. The zone to the east of the Hambaeksan fault has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

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

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

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

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



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

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

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

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

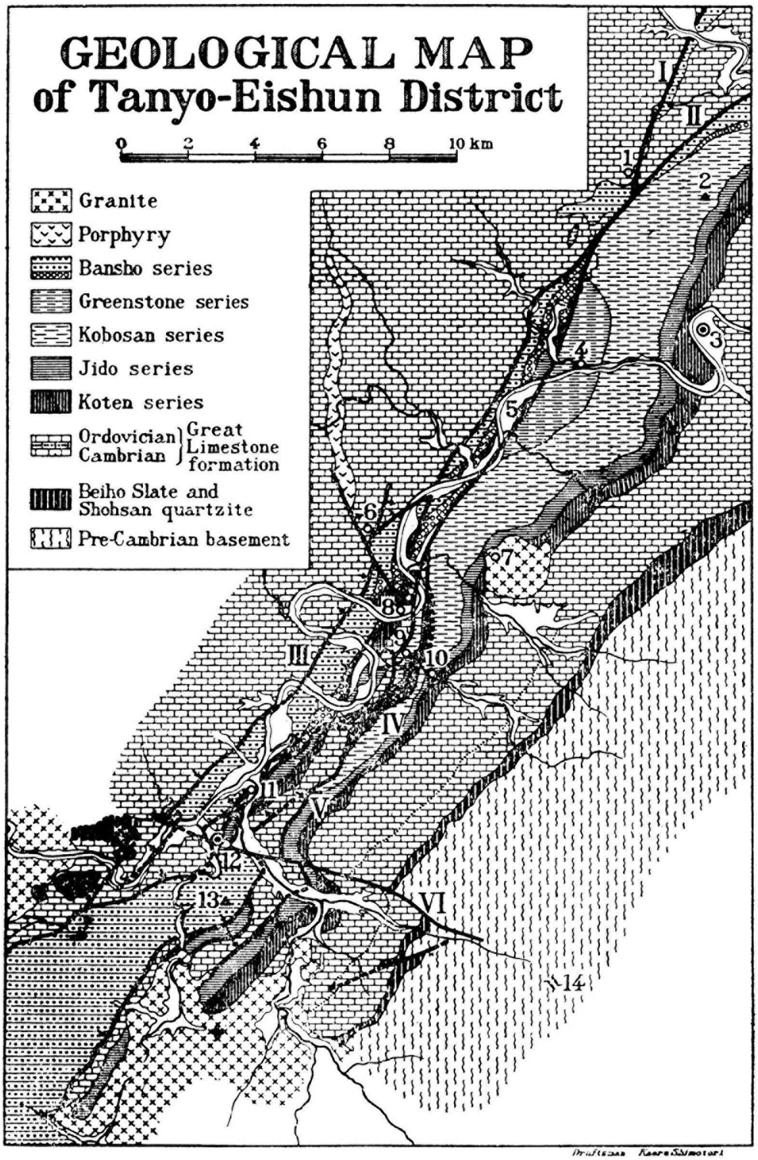
The middle belt is the *Mun'gyeong zone* which is mostly composed of the Korean group, but there are in addition a small brachysyncline of the Bansong, Sadong and Gobangsan series near Tot'amni, a narrow strip of the Greenstone series of Pongsaengdong and a few other strips of the Ongnyeobong formation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

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

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

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

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



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

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

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

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

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

c. Yeongweol (Neietsu) anticlinorium (Map 1)

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

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

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

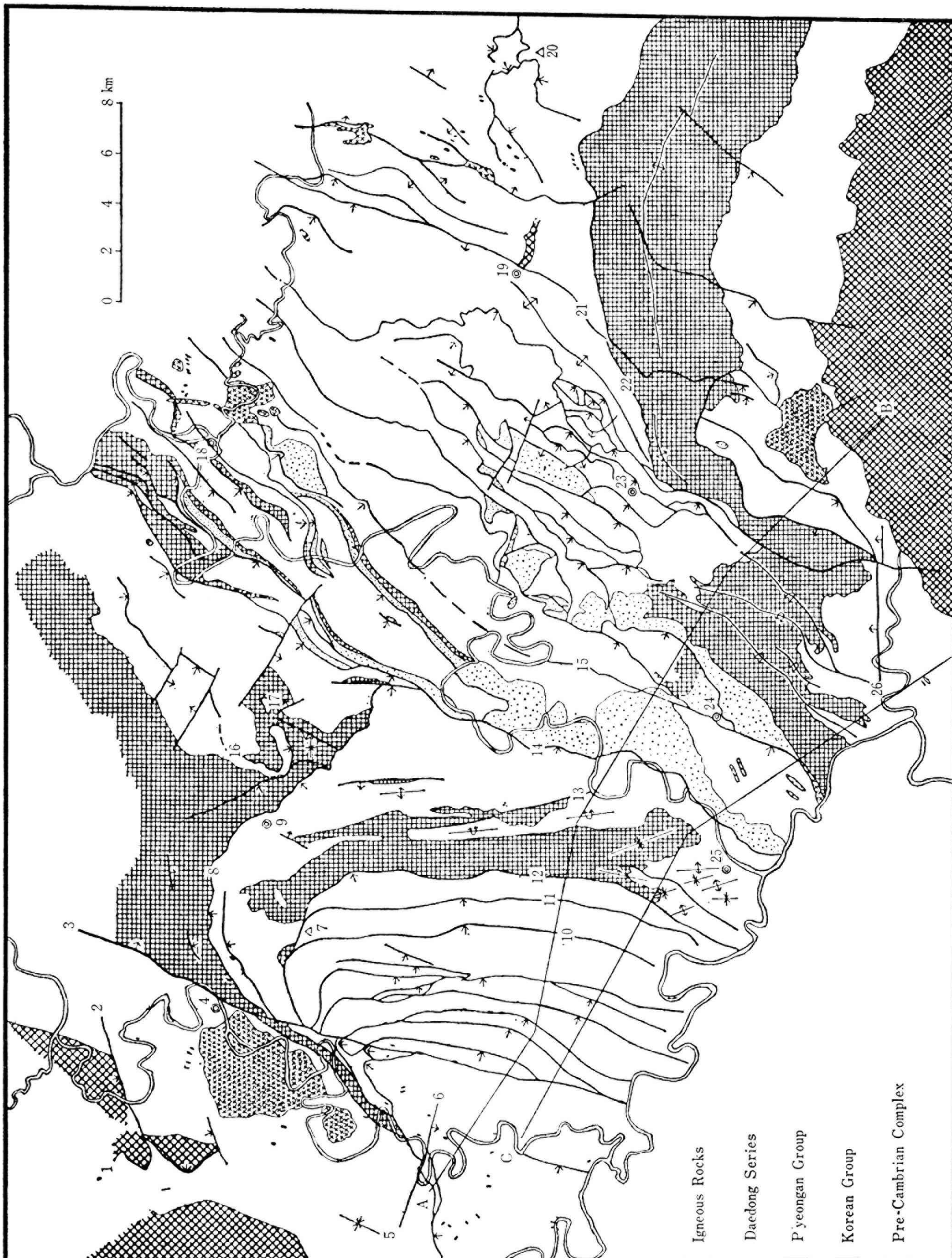


Fig. 9. Tectonic Map of the Western Part of the Kangweondo Limestone Plateau.

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

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

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

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

d. P'yeongch'ang (Heisho) zone

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

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

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

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

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

f. Jeongseon (Seizen) imbricated zone

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

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

g. Paekunsan (Hakuunsan) syncline

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

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

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

h. Chungbongsan (Chuhosan) block

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

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

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

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

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

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

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

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

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

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

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

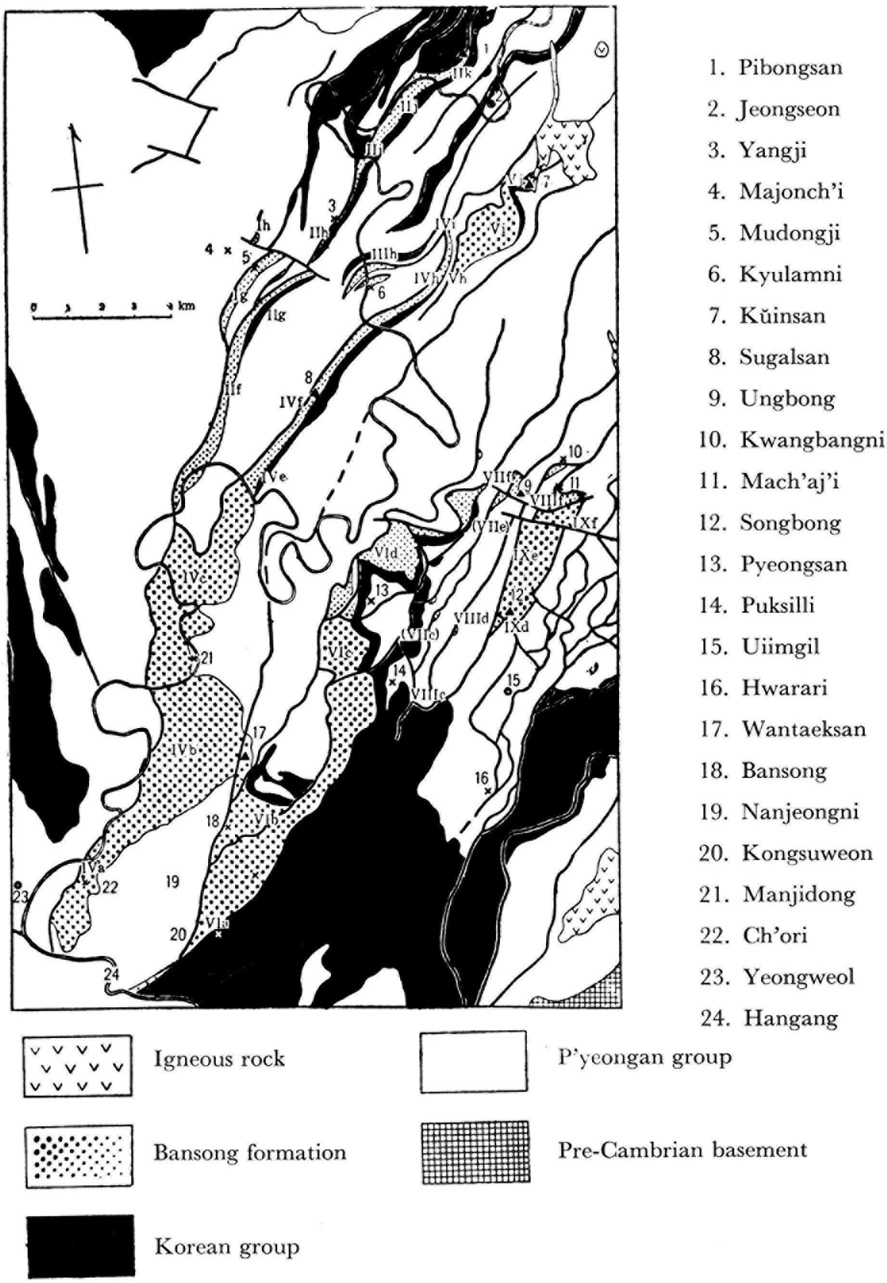


Fig. 10. Tectonic Map of the Jeongseon, Uiimgil and Yeongweol Triangle Showing the Points in Lattice.

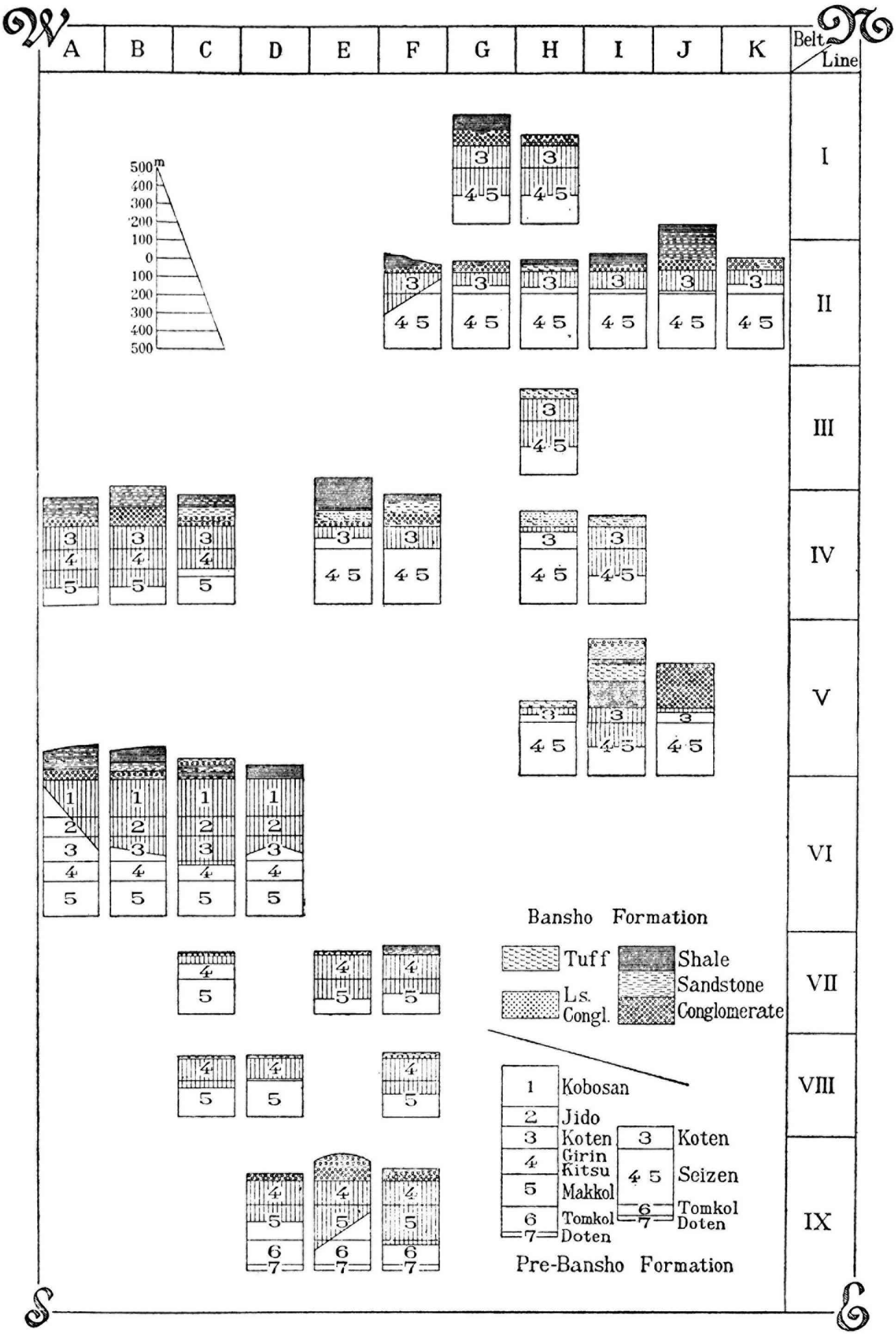


Fig. 11. Stratigraphic Sequences at the Points of the Lattice in Figure 10.

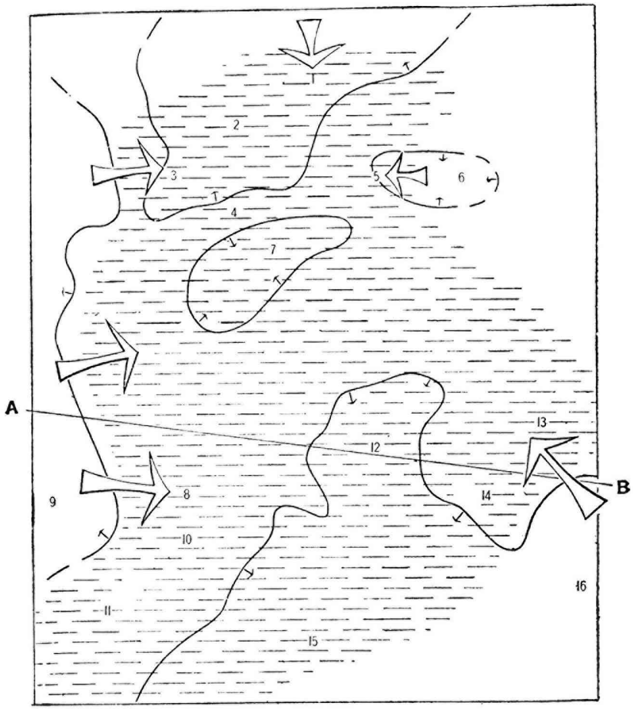
cycle of sedimentation, although it is difficult to say whether the coarse rocks were accumulated in the final stage or whether they were eroded out.

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

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

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

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



Structural basin of the P'yeongan (Heian) group

Bansong (Bansho) lake

Bansong sediment of the deltic facies and its source

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

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

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

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

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

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

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

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

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

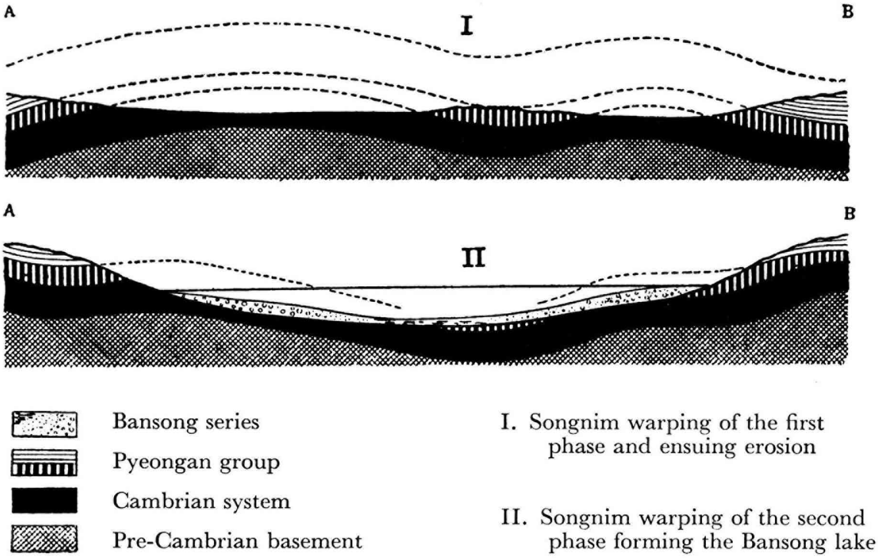


Fig. 13. Songnim Disturbance in the Western Part of the K·ngweondo Limestone Plateau Analyzed into the Early and Middle Phases.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

6. Kyeonggi (Keiki) land

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

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

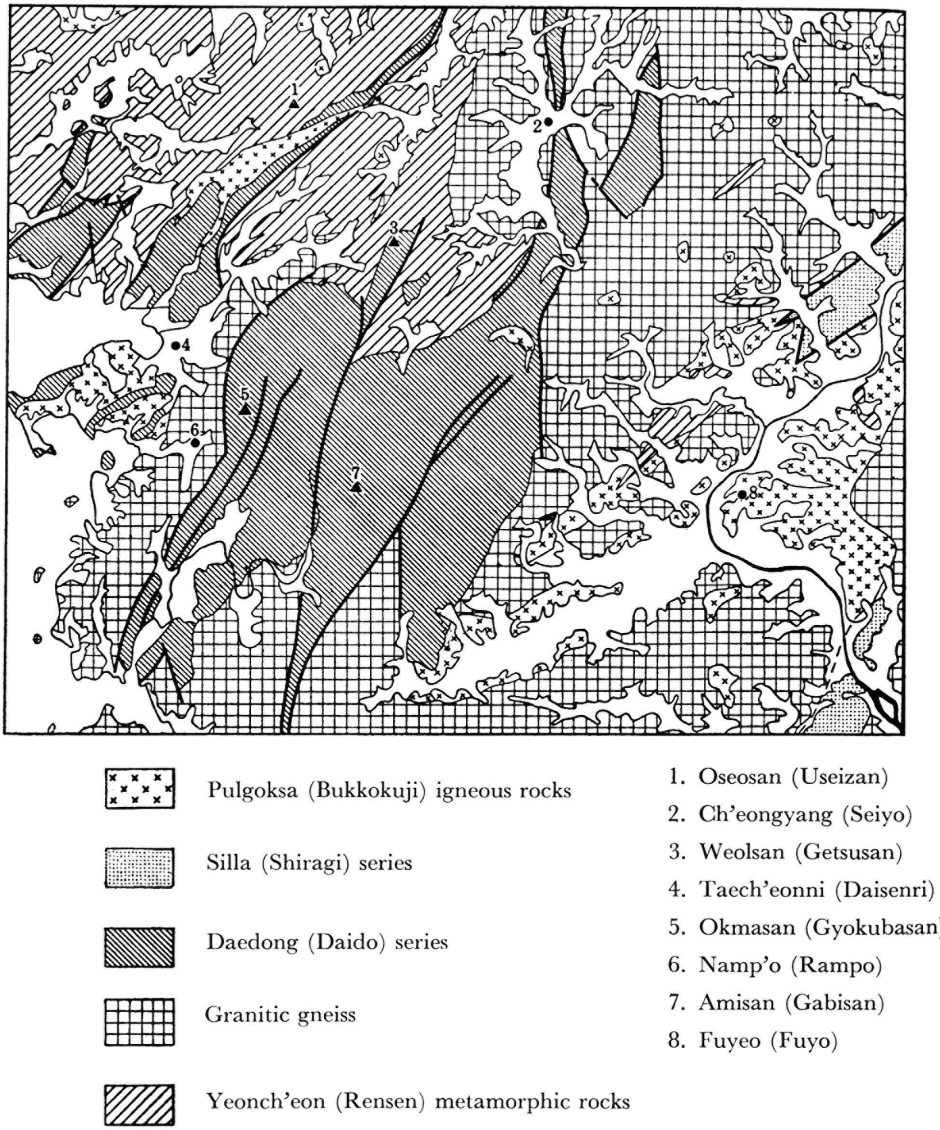


Fig. 15. Geological Map of Namp'o District.

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

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

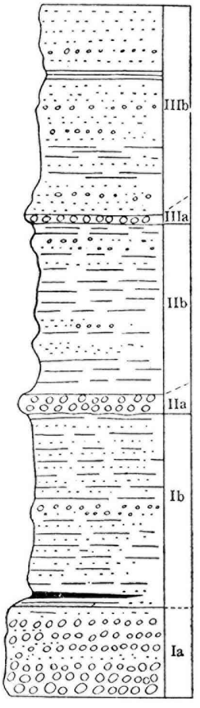


Fig. 16. Three Cycles of Sedimentation in the Daedong Formation in the Namp'o District.

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

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

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

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

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

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

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

7. Taebo (Taiho) disturbance

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

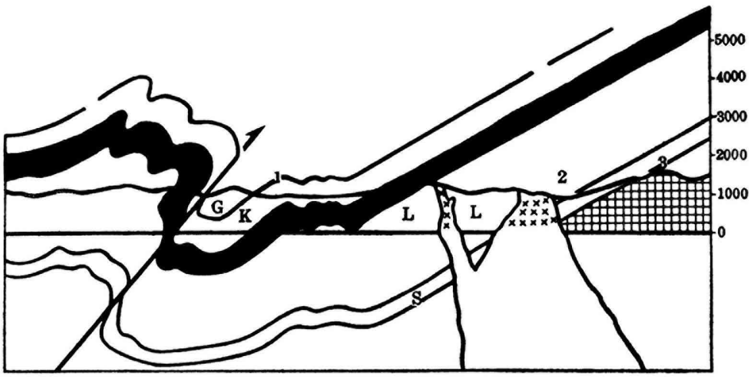
In the Mun'gyeong district farther to the southwest the middle or Mun'gyeong zone corresponds to the Jeongseon zone. In the northern part of the district the Sin'giri zone is protruded to the west and several thrusts run across the Mun'gyeong zone obliquely. Further tectonic complexity is revealed by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

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

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

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

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



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

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

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

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

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

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

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

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

8. Kyeongsang group in the Tsushima basin

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

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

Table 5. Stratigraphical Sequence of the Tsushima Basin.

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

II. Silla (Shiragi) series

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

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

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

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

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

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

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

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

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

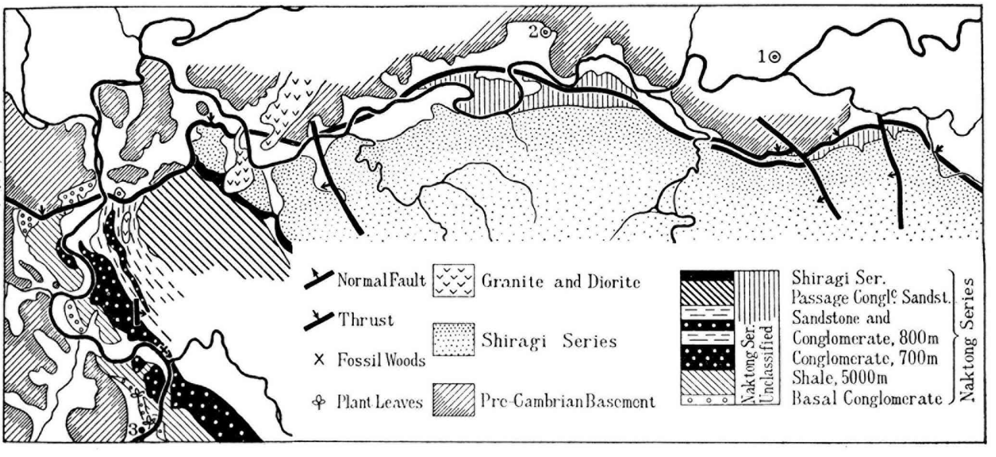
The group's correlation to the Mesozoic formations in Japan, has long been undetermined. I (1926) ascertained in Yamaguchi Prefecture that the Jurassic Toyora series is overlain by the Inkstone discordantly. Subsequently the Wakino series was discovered to lie beneath the Inkstone in northern Kyushu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

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

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

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

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



1. Antong 2. Pungsan 3. Naktong

Fig. 18. Uisong Wedge and Andong Upthrust.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

9. Metamorphosed Okch'eon (Yokusen) zone

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

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

(3) Lower Okch'eon formation chiefly made up of quartzite, sandstone and metamorphosed clayslate.

(2) Middle Okch'eon formation comprising hornblende schist, limestone, mica schist and phyllite besides some sandstone intercalations.

(1) Upper Okch'eon formation composed mostly of biotite schist and phyllite, though thin layers of conglomerate, sandstone, limestone, hornblendite and quartzite are intercalated in it.

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

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

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

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

(3) Kirinbong (Kirinho) formation: biotite schist, phyllite and tremolite schist.

(2) Sindong (Shindo) formation: limestone, phyllite, biotite schist and quartz schist.

(1) Sadaeri (Shidairi) formation: sericite schist and quartzite.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

10. Taebaegsan (Taihakusan) dislocation zone

(See Geological Map II)

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

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

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

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

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

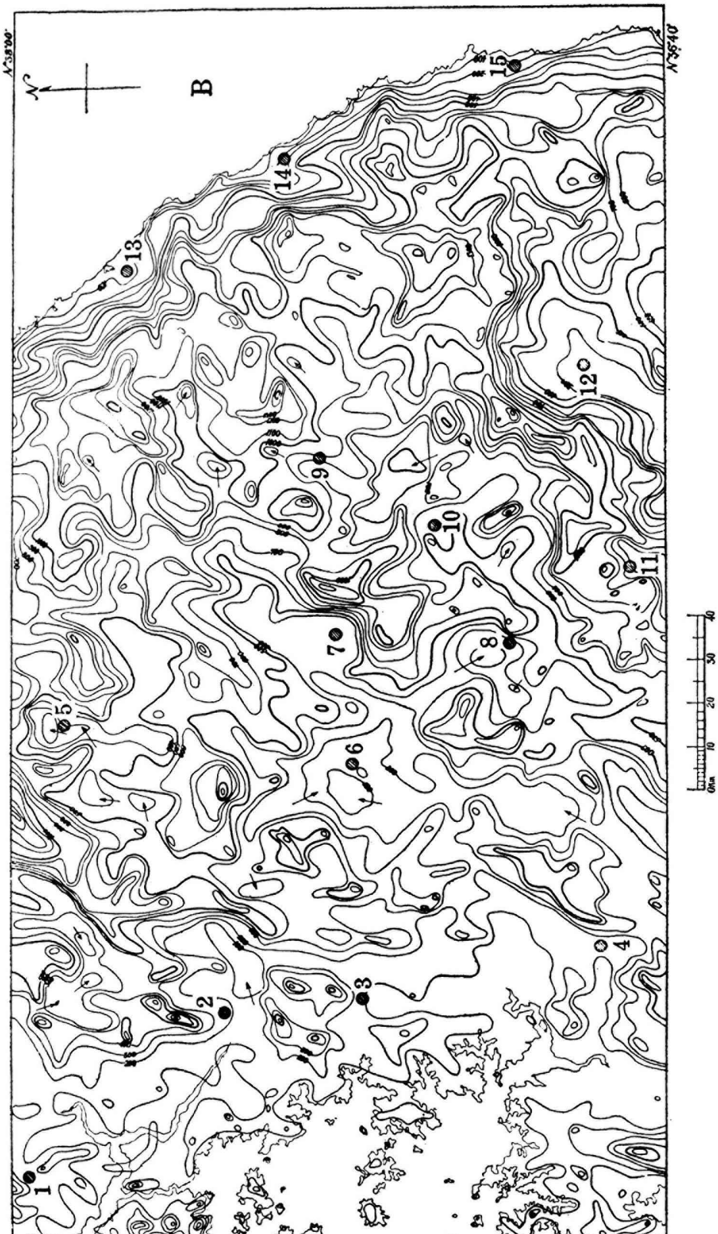
In the Ungbongsan structural basin to the west of the Sandgeongni fault the Korean system is overlain by the P'yeongan system. As mentioned already, the *Schuppenstruktur* of this basin is developed toward the Osipch'eon. Judging from this feature, the Wap'yeongni tectonic line must be one of the old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

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

11. Geomorphological history of Central Korea

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

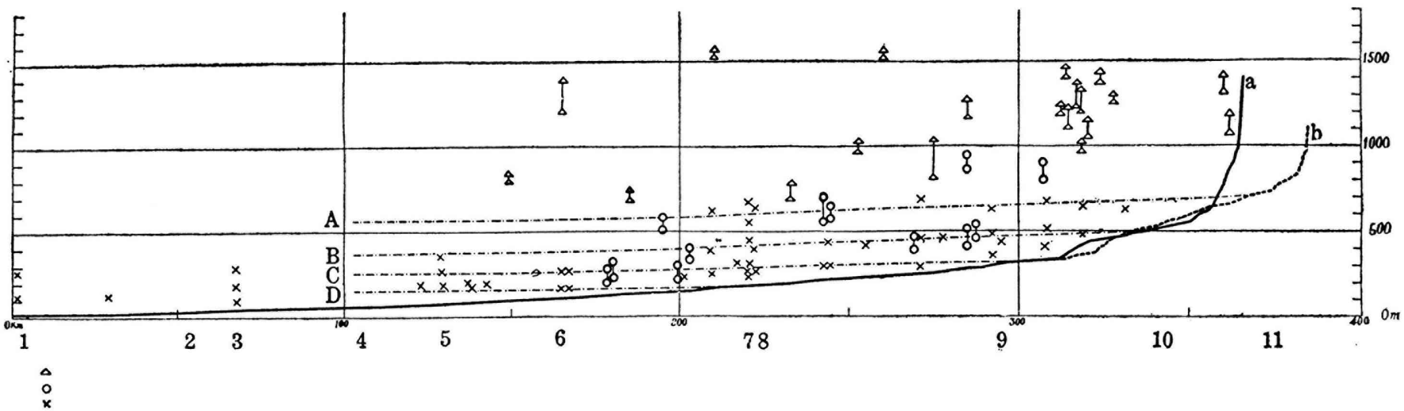
The terrain to the west of the Taebaegsan range belongs to the Hangang tributaries and the Yeoju plane extends over a wide area to the west of the topographic boundary through Weonju and Ch'ungju. The environs of Yeoju consist of granite, the land being even and flat. Hence the name *Yeoju* (*Rishu*)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



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

A. Yellow sea
B. Sea of Japan

Fig. 19. Summit Level through Central Korea.



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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

12. Destruction of the Tsushima basin

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

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

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

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

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

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

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

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

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

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

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

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

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

1. Cycle of oronization

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

2. Differentiation of geosyncline

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

3. Embryonic folding and imbrication

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

4. Granitization and fragmentation

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

5. Oronization and anoronization

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

REFERENCES

Abstracts of papers, International Geological Congress, XVII session, USSR, 1937.

AHNERT, E. (1927), Morphologische und geotektonische Skizze des russischen fernen Osten und Nord Mandschuriens. *Proc. 3rd Pan-Pacific Sci. Congr.* Tokyo, 1926, Vol. 1.

—— and I. LAUROUSHIN (1924), Subdivisions of the Jurassic, Cretaceous and Tertiary coal-bearing strata of Russian Maritime and Amur provinces and of Sachalin (Sakhalin) island. *Bull. Geol. Soc. China*, Vol. 3.

AOTI, K. (1942), Geology of Bunkei (Mun'gyeong) district in Tyosen (Korea) with special reference to the stratigraphy of the Tyosen group. *Jour. Geol. Soc. Japan*, Vol. 49.

DE CHARDIN, (1940), The granitization of China. *Bull. Geol. Soc. China*, Vol. 19.

CHOI Yuku et al. (1962), Report on the Geology and Mineral Resources of the Taebangsan Region for the Geological Survey of Korea. Geol. Soc. Korea.

ENDO, R. (1939), Geology and Mineral Resources of Manchuria. Sanshodo Book Co.

ENDO, S. (1939), Some new and interesting Miocene plants from Tyosen (Korea). *Jub. Publ. Comm. Prof. Yabe's 60th Birthday*, Vol. 2.

—— (1938), Cenozoic Plants from Tyosen (Korea), 1–2. *Jour. Geol. Soc. Japan*, Vol. 45.

—— (1942), On the fossil flora from the Shulan coal-field, Kirin Prov., and the Fushun coal-field, Fengtien Province. *Bull. Central Nat. Mus. Manch.*, No. 3.

Geological Investigation Corps of Taebangsan Region, Geological Society of Korea (1962), Geological Atlas of Taebangsan Region.

Geological map of the Union of Soviet Socialist Republics, scale 1/5,000,000 (1937). Organization Comm., XVII Intern. Geol. Congr.

Geological Sheet Maps of the Far East, scale: 1/250,000. (1954–1956) Korea 18 sheets. Compilation Comm. for Geol. Min. Res. Far East.

Geological Survey of Chosen (1928), General geological map of Chosen (Korea). Scale 1/100,000.

GOTTSCHE, C. (1886), Geologische Skizze von Korea. *Sitzungsber. königl. Preuss. Akad. d. Wiss. zu Berlin,* 36.

Guide-book of geological excursions in Chosen, No. 1. Kishu (Kilchu) district, Kankyo hokudo (Hamgyeong-bukto), (1935). *Geol. Soc. Japan.*

HAMADA, T. (1960), The Middle Palaeozoic Formations in China and Korea. I-II. *Japan. Jour. Geol. Geogr.,* Vol. 31.

HANZAWA, S. (1941), The stratigraphical relation between the Carboniferous and Permian formations in Manchuria, Korea and Japan proper. *Japan. Jour. Geol. Geogr.,* Vol. 18.

HARAGUCHI, K. (1931), Saishu (Cheju) volcano. *Bull. Geol. Surv. Chosen,* Vol. 10, Pt. 1.

HATAE, N. (1937), Neikai (Yeonghae) and Eitoku (Yeongdeok) sheets. *Geol. Atlas of Tyosen,* No. 18.

——(1939), Stratigraphical division of Heian (P'yeongan) system on fossil Foraminifera. *Jub. Publ. Comm. Prof. Yobe's 60th Birthday,* Vol. 1.

HISAKOSHI, S. (1943), Geology of Seizen (Cheongseon) district, Kogendo (Kangweondo), Tyosen (Korea). *Jour. Geol. Soc. Japan,* Vol. 50.

History of research in geology and minerals of Korea (Chosen) and their references (1933–39). *Chosen Kogyo-kai.*

HUKASAWA, T. (1943), Geology of Heisyo (P'yeongch'ang) district, Kogendo (Kangweondo), Tyosen (Korea). *Jour. Geol. Soc. Japan,* Vol. 50.

ICHIMURA, T. (1927), Wajun (Hwasun) coal field. *Rep. Surv. Coal-fields, Chosen,* No. 2.

——(1928), Tsusen (T'ongch'eon) coal-fields. *Rep. Surv. Coal-fields, Chosen,* No. 3.

IMAMURA, S. and KUSUMI, H. (1951), On the Inkstone Group of Inakura-mura District, Oda-gun, Okayama Prefecture, Japan. *Geol. Rep. Hiroshima Univ.,* No. 1.

INOUYE. K. (1907), Geology and Mineral Resources of Korea. *Bull. Geol. Surv. Japan,* Vol. 20, No. 1.

IWAYA, Y. (1943), Geology of Girinkitsu (Uiimgil) district, Kogendo (Kangweondo), Tyosen (Korea). *Jour. Geol. Soc. Japan,* Vol. 50.

KAMBE, N. (1951), Mesozoic formation in the southern part of Yabu-gun, Hyogo Prefecture. *Jour. Geol. Soc. Japan,* Vol. 57.

KANEHARA, K. (1936), The Geology of the northern part of Geizitu (Yongil) district, North Keisyodo (Keongsang-do), Korea. *Jour. Geol. Soc. Japan,* Vol. 43.

—— (1936), Neogene Shells from South Tyosen (Korea). *Japan. Jour. Geol. Geogr.,* Vol. 13.

——(1937), The Geology of the northern part of Geizitu (Yongil) district, North Keishodo (Keongsang-do), Korea. *Japan. Jour. Geol. Geogr.,* Vol. 14.

KATO, T. (1925), Periods of igneous activity in Japan with special reference to metallogeny. *Jour. Geol. Soc. Tokyo,* Vol. 31.

—— (1932), The volcanic activity in southern Korea and southwestern Japan during late Mesozoic period. *Bull. Geol. Soc. Japan,* Vol. 1, No. 2.

KAWASAKI, S. (1925), Some Older Mesozoic plants in Korea. *Bull. Geol. Surv. Chosen (Korea),* Vol. 4, pt. 1.

—— (1926), Addition to the Older Mesozoic plants in Korea. *Bull. Geol. Surv. Chosen,* Vol. 4, pt. 2.

—— (1926), Geology and Mineral Resources of Korea. *Geology and Mineral Resources of the Japanese Empire,* pt. 2.

—— (1927), Mesozoic formations and diastrophism of Korea. *Proc. 3d Pan-Pacif. Sci. Congr. Tokyo,* 1926, Vol. 2.

——(1927), The Flora of the Heian (P'yeongan) System, pt. 1. *Bull. Geol. Surv. Chosen,* Vol. 6, No. 1.

—— (1931, 34), The Flora of the Heian System, pt. 2. *Bull. Geol. Surv. Chosen,* Vol. 6, pt. 2.

—— (1939), Second Addition to the Older Mesozoic plants in Korea. *Bull. Geol. Surv. Tyosen,* Vol. 4, pt. 3.

——(1939), Addition to the flora of the Heian (P'yeongan) system. *Bull. Geol. Surv. Tyosen,* Vol. 6, pt. 5.

—— and Konno, E. (1932), The Flora of the Heian system, pt. 3. *Bull. Geol. Surv. Chosen,* Vol. 6, pt. 3.

Kinosaki, Y. (1929), Kainan (Haenam) and Usuiei (Usuyeong) Sheets. *Geological Atlas Chosen,* No. 9.

Kobatake, N. (1930), Geology of the Bunkei (Mun'gyeong) Coal Field, Korea. *Chikyu, the Globe,* Vol. 8.

——(1942), Geology of the Tanyo (Tan'yang) Coal-field and its environs in North Chuseido (Ch'ungch'eong-do). *Sci. Rept. Geol. Inst., Kyoto Univ.,* Vol. 1.

——(1947), On the so-called Yokusen (Okch'eon) system with special reference to its lower part. *Jour. Geol. Soc. Japan,* Vol. 53.

Kobayashi, K. (1947), On the basaltic rock in the Shiragi (Silla) series in the west of Sanchoku (Samch'eok) town, Central Chosen (Korea). *Kagaku,* Vol. 17.

——(1947), Unconformity at the base of the Shiragi series in the Sanchoku (Samch'eok) coal-field in Chosen (Korea). *Kagaku,* Vol. 17.

——(1947), Geologic Structure of the northern part of the Sanchoku (Samch'eok) coal-field. *Jour. Geol. Soc. Japan,* Vol. 53.

——(1947), Geology of Santyoku (Samch'eok) district, Kogendo, (Kangweon-do), Korea. *Jour. Geol. Soc. Japan,* Vol. 53.

——and T. Yoshida (1949), Geology of the Kosiri (Kot'ori) district in the Santyoku (Samch'eok) coal-field, Korea. *Jour. Geol. Soc. Japan,* Vol. 55.

Kobayashi, T. (1926), Note on the Mesozoic formations in Prov. Nagato, Chugoku, Japan. *Jour. Geol. Soc. Tokyo,* Vol. 38.

—— (1927), Ordovician Fossils from Korea and South Manchuria. *Proc. Imp. Acad.,* Vol. 5.

—— (1927), Ordovician fossils from Korea and South Manchuria. *Japan. Jour. Geol. Geogr.,* Vol. 5.

——(1927), On the geological history of Kogendo (Kangweon-do) limestone plateau in Korea. *Jour. Geol. Soc. Tokyo,* (Japan), Vol. 34.

—— (1930), Cambrian and Ordovician faunas of South Korea and the bearing of the Tsinling-Keijo (Seoul) line on Ordovician palaeogeography. *Proc. Imp. Acad.,* Vol. 6.

——(1930), The significance of the unconformity at the base of the Daido (Daedong) formation. *Jour. Geol. Soc. Japan,* Vol. 37.

——(1930), Three types of the Chosen (Korea) and Sinian systems in Korea and

Manchuria and the bearing of the Tsinling-Keijo line on the palaeogeography. *Jour. Geol. Soc. Japan,* Vol. 37.

—— (1931), Studies on the Ordovician stratigraphy and palaeontology of North Korea with some notes on the Ordovician fossils of Shantung and Liaotung. *Bull. Geol. Surv. Chosen,* Vol. 10, pt. 1.

—— (1931), Topography and Cenozoic geology in Korean peninsula. *Geogr. Rev. Japan,* Vol. 7.

—— (1933), The natural boundary between the Cambrian and Ordovician systems discussed from the Asiatic standpoint. *Rep. XVI. Intern. Geol. Congr. Washington,* 1933.

—— (1933), A sketch of Korean Geology. *Am. Jour. Sci.,* Vol. 26.

—— (1933), Faunal study of the Wanwanian (basal Ordovician) series with special notes on the Rebeiridae and Ellesmereoceroids. *Jour. Fac. Sci. Imp. Univ. Tokyo,* Sect. 2, Vol. 3, pt. 7.

—— (1933), On the Occurrence of Xiphosuran remains in Chosen (Korea). *Japan. Jour. Geol. Geogr.,* Vol. 10.

—— (1933–34), The Ozarkian question and my view. *Jour. Geol. Soc. Japan,* Vols. 40–41.

—— (1934), Brief notes on the geomorphology of the Korean peninsula and its relation to the Cenozoic history. *Proc. 5th Pacific Congr., Canada,* 1953, Vol. 2.

—— (1934), The Cambro-Ordovician formations and faunas of South Chosen (Korea). Palaeontology, pt. 1, Middle Ordovician Faunas. *Jour. Fac. Sci. Imp. Univ. Tokyo,* Sect. 2, Vol. 3, pt. 8.

—— (1934), The Cambro-Ordovician Formations and Faunas of South Chosen, palaeontology, pt. 2, Lower Ordovician faunas. *Jour. Fac. Sci. Imp. Univ. Tokyo,* Sect. 2, Vol. 3, pt. 9.

—— (1935), The Cambro-Ordovician formations and faunas of South Chosen, Palaeontology, pt. 3. Cambrian faunas of South Chosen with a special study on the Cambrian Trilobite genera and families. *Jour. Fac. Sci. Imp. Univ. Tokyo,* Sect. 2, Vol. 4, pt. 3.

——(1935), Is the Kenjiho (Kyeomip'o) limestone conglomerate a Gotlandian deposit? *Jour. Geogr. Tokyo,* Vol. 47.

—— (1936), *Coreanoceras,* one of the most specialized piloceroids and its benthonic adaptation. *Japan. Jour. Geol. Geogr.,* Vol. 13.

—— (1937), An occurrence of a new Permian Phyllocarid in South Chosen. *Jour. Geol. Soc. Japan,* Vol. 46.

—— (1937), The geological age of the Mesozoic land floras in western Japan discussed from the stratigraphic standpoint. *Japan. Jour. Geol. Geogr.,* Vol. 46.

—— (1938), On the Noric age of the Nariwa flora of the Rhaeto-Liassic aspect. *Japan. Jour. Geol. Geogr.,* Vol. 15.

—— (1941), The Sakawa orogenic cycle and its bearing on the origin of the Japanese islands. *Jour. Fac. Sci. Imp. Univ. Tokyo,* Sect. 2, Vol. 5, pt. 7.

—— (1941), Occurrence of the Kushan Trilobites in northern Anhui and a Note on the Rakuroan complex of the Shankiangan basin. *Jour. Geol. Soc. Japan,* Vol. 48.

—— (1942), On the geological history of the Sungari series. *Proc. Imp. Acad.,* Vol. 18.

—— (1942), On the climatic bearing of the Mesozoic floras in Eastern Asia. *Japan. Jour. Geol. Geogr.,* Vol. 18.

—— (1942), The Sakawa orogenic cycle in the Amur geosyncline. *Proc. Imp. Acad.,* Vol. 18.

—— (1942), The Akiyoshi orogenic cycle in the Mongolian geosyncline. *Proc. Imp. Acad.*, Vol. 18.

—— (1942), Stratigraphic relation among the Mesozoic fossil beds in the Koreo-Manchurian land and their age determination. *Proc. Imp. Acad.*, Vol. 18.

—— (1942), A few Cambrian Trilobites from southwestern Shansi. *Jour. Geol. Soc. Japan*, Vol. 49.

—— (1943), Outline of the Cambrian system in the Yangtze basin, 1–3. *Proc. Imp. Acad.*, Vol. 19.

——(1944), The Discovery of *Olenus* in South Chosen (Korea). *Proc. Imp. Acad.*, Vol. 20.

—— (1944), On the Cambrian sea-connection between South Chosen and eastern Teinshan. *Proc. Imp. Acad.*, Vol. 20.

—— (1944), The zoopalaeogeographic province in the Upper Cambrian and Lower Ordovician Periods. *Japan. Jour. Geol. Geogr.*, Vol. 20.

—— (1949), The *Glyptagnostus* hemera, the oldest world instant. *Japan. Jour. Geol. Geogr.*, Vol. 21.

—— (1950), Chugoku region. *Regional geology of Japan*. Asakura Book Co.

—— (1950), On the Mesozoic history of Eastern Asia. *Jour. Geogr. Tokyo*, Vol. 59.

—— (1951), Older Mesozoic *Estherites* from Eastern Asia. *Jour. Fac. Sci. Univ. Tokyo*, Sect. 2, Vol. 7, pt. 10.

—— (1952), Pre-Cambrian history of Eastern Asia. *Japan. Jour. Geol. Geogr.*, Vol. 22.

—— (1952), On the southern wing of the Akiyoshi orogenic zone in Indochina and South China and its tectonic relationship with the other wing in Japan. *Japan. Jour. Geol. Geogr.*, Vol. 22.

——(1952), Late Palaeozoic and Triassic Palaeogeography of Eastern Asia and its Relation to the Floral Evolution. *Compte Rendu, 3e Congr. de Strat. et de Géol. du Carbonifère* Heerlen, 1951.

—— (1952), Geology of the Kangweondo Limestone Plateau and its Relation to the Geology of the Neighbouring Areas. *Geology and Mineral Resources of the Far East*, Vol. 1.

—— (1953), Geology of South Korea with Special Reference to the Limestone Plateau of Kogendo (Kangweondo). The Cambro-Ordovician Formations and the Faunas of South Chosen, Part IV. *Jour. Fac. Sci. Univ. Tokyo*, Sec. 2, Vol. 8, pt. 4.

—— (1956), The Cambrian of Korea and its Relation to the Other Cambrian Territories. El Sistema Cámbrico, su Paleogeografia y el Problema du su Base. Tom. 1, *XX Congr. Intern. México*, 1956.

——(1956), Geology of Eastern Asia, Vol. 1. Asakura Book Co.

——(1958), Some Cambro-Ordovician Fossils from the Tan'yang or Tanyo District, South Korea. *Trans. Proc. Pal. Soc. Japan*, No. 30,.

—— (1958–62), The Cambro-Ordovician Formations and Faunas of South Chosen, Part V-IX.

Palaeontology 4. Some Ordovician Gastropods from the Mun'gyeong or Bunkei District, South Korea. *Ibid.*, Vol. 9, pt. 2, 1958.

Palaeontology 5. Additional Lower Ordovician Fossils from South Korea. *Ibid.* Vol. 12, pt. 2. 1960.

Palaeontology 6. Supplement to the Cambrian Faunas of the Tsuibon Zone with Notes on some Trilobite Genera and Families. *Ibid.* Vol. 12, pt. 2, 1960.

Palaeontology 7. Cambrian Faunas of the Mun'gyeong (Bunkei) District and the

Samposan Formation of the Yeongweol (Neietsu) District. *Ibid.* Vol. 8, pt. 2, 1961. Palaeontology 8. The Machari Fauna. *Ibid.* Vol. 14, pt. 1, 1962.

—— (1960), The Ordovician of Korea and its Relation to the Other Ordovician Territories. *Rep. Intern. Geol. Congr. 1960, Copenhagen. XXII. Ordovician and Silurian Stratigraphy and Correlation.*

—— (1961), Modern Progress of Geology in Japan. *Jour. of Geography, Tokyo.* Vol. 70, No. 6.

—— (1966), Stratigraphy of the Chosen Group in Korea and South Manchuria and its Relation to the Cambro-Ordovician Formations of Other Areas. Section A. The Chosen Group of South Korea. The Cambro-Ordovician Formations and Faunas of South Korea, Part X. *Ibid.* Vol. 16, pt. 1.

——and K. Aoti (1942), A Study on the geology of the Bunkei (Mun'gyeong) district in South Chosen with special reference to the stratigraphy of South Chosen. *Proc. Imp. Acad.*, Vol. 18.

——, A. Huzita and T. Kimura (1945), On the geology of the central part of southern Shikoku. *Japan. Jour. Geol. Geogr.*, Vol. 20.

—— and K. Ichikawa (1951), On *Palaeopharus*, a late Triassic pelecypod genus. *Trans. Proc. Pal. Soc. Japan*, N.S. No. 1.

—— Iwaya and S. Hisakoshi (1943), Lattice analysis of the crustal deformation of the Shorin (Songim) phase in the Yokusen (Okch'eon) geosyncline. Brief notes on the geologic history of the Yokusen orogenic zone 3. *Proc. Imp. Acad.*, Vol. 19.

—— and Y. Kido. (19), Cretaceous *Estherites* from the Kyöngsang group in the Tsushima basin. *Japan. Jour. Geol. Geogr.*, Vol. 20.

—— K. Suzuki, and F. Takai (1942), A preliminary report on the four distinct suites of Mesozoic faunas in the Koreo-Manchurian land. *Jour. Fac. Sci. Imp. Univ. Tokyo*, Sect. 2, Vol. 6, pt. 4.

——I. Yosimura, Y. Iwaya and T. Hukasawa (1941), The Yokusen (Okch'en) geosyncline in the Heian (P'yeongan) period. Brief notes on the geologic history of the Yokusen orogenic zone 2. *Proc. Imp. Acad.*, Vol. 18.

——I. Yoshimura, Y. Iwaya and T. Hukasawa (1941), The Yokusen (Okch'en) geosyncline in the Chosen (Korean) period. Brief notes on the geologic history of the Yokusen orogenic zone 1. *Proc. Imp. Acad.*, Vol. 18.

—— (1942), Geologic structure of the western part of the limestone plateau in south Kogendo (Kangweondo). Brief notes on the geologic history of the Yokusen orogenic zone 4. *Proc. Imp. Acad.*, Vol. 20.

Koto, B. (1903), An orographic sketch of Korea. *Jour. Coll. Sci. Imp. Univ. Tokyo,* Vol. 19, Art. 1.

—— (1909), Journeys through Korea. *Jour. Coll. Sci. Imp. Univ. Tokyo,* Vol. 26, Art. 2.

—— (1915), Morphological summary of Japan and Korea. *Jour. Geol. Soc. Tokyo,* Vol. 22.

—— (1916), The great eruption of Sakura-jima in 1914. *Jour. Coll. Sci. Imp. Univ. Tokyo,* Vol. 38, Art. 3.

Krystofovich, A. (1926), Geology. *Pacific Russian Scientific Investigation.*

Leuchs, K. (1935), Geologie von Asien, Bd. 1. Th. 1.

Maejima, T., S. Matsushita and T. Onoyama (1935), Geology and fossils from The Hosan (Pongsan) coal-field, Kokaido (Hwanghae-do). *Chikyu, the Globe,* Vol. 23.

Makiyama, J. (1936), The Meisen Miocene of North Korea. *Mem. Coll. Sci. Kyoto Imp. Univ.*, Ser. B, Vol. 11, No. 4.

MATSUMOTO, T. (1952), Outline of the geologic structure of the basement of northern Kyushu and western Chugoku. *Sci. Rep. Fac. Sci. Kyushu Univ., Geol. 3,* No. 2.

MATSUMOTO, T. et al. (1954), The Cretaceous System in the Japanese Islands. *Japan. Soc. Prom. Sci. Tokyo.*

MATSUSHITA, K. (1950), Geology of the coal-field in northern Kyushu. *Kyushu Mining Jour. Sp. No.*

MATSUSHITA, S. (1938), The anthracite coal-field of the southern Heian-nando (P'yeon-gan-namdo). *Rep. coal-fields Chosen,* Vol. 13.

NAKAMURA, S. (1923), S. Zenra-do (Cheolla-do). Mineral resources of Chosen (Korea), Vol. 12.

——(1924), N. Keisho-do (Kyeongsang-do), No. 3. Mineral resources of Chosen (Korea). Vol. 15.

——(1924), Southern Part of Kogendo (Kangweondo). Mineral resources of Chosen (Korea), Vol. 8, No. 2.

—— (1924), On the knowledge of the Ordovician formation in Korea up to the Present. *Chikyu, the Globe,* Vol. 1.

—— and S. MATSUSHITA (1939), Pre-Cambrian in Manchuria and Korea. *Proc. 5th, Pacific Congr. Canada,* 1933.

NAKAZAWA, K. (1951), Geological Structure of the Maizuru zone in Kyoto Prefecture. *Jour. Geol. Soc. Japan,* Vol. 57.

NIINO, H. (1934), Fossil localities on the sea-bottom of the strait of Korea. *Jour. Geogr. Tokyo,* Vol. 41.

—— (1934), *Thyasira bisecta* CONRAD from the bottom of the Korean strait. *Jour. Geol. Soc. Tokyo,* Vol. 41.

—— (1934), The second finding of *Thyasira bisecta* CONRAD from the bottom of the Korean strait. *Jour. Geol. Soc. Tokyo,* Vol. 41.

OBRUTSCHEW, W. A. (1916), Geologie von Sibirien. *Fortsch. Geol. u. Pal.,* Hft. 15.

OISHI, S. (1940), The Mesozoic floras of Japan. *Jour. Fac. Sci. Hokkaido Imp. Univ.,* Sec. 4, Vol. 3, No. 1.

OZAWA, Y. and WATANABE, T. (1921), On two species of *Estheria* from the Mesozoic shale of Korea. *Japan. Jour. Geol. Geogr.* vol. 2.

PUMPELLY, (1866), Geological research in China, Mongolia and Japan. *Smithson. contr. to knowledge.*

RAUPACH F. (1934), Stratigraphische und tektonische Entwicklung des russischen Fernen Osten, der Mandschurei und Zentral Mongolei.

RICHTOFEN, F. von, (1831), China, Bd. 1.

SAITO, R. (1938), Study on the Yungning sandstone. *Bull. Geol. Inst. Manchoukuo,* No. 93.

—— (1940), The high peneplane in the northeastern part of Manchuria and its relation to the auriferous Tertiary formations containing coal measures. *Mem. Geol. Surv. Manchoukuo,* No. 5.

SHIMAMURA, S. (1925), Chinan (Chin'an) and Zenshu (Cheonju) sheets. *Geol. Atlas of Chosen,* No. 3.

——(1927), Seizan (Ch'eongsan) and Eido (Yeongdong) sheets. *Ibid.* No. 7.

——(1930) Kwanto (Wanto), Rokwato (Nohwato), Seizanto (Ch'eongsanto), Taroto (Táenangto) and Shoanto (Soanto) sheets. *Ibid.* No. 11.

——(1931), Seiyo (Ch'eongyang) Daisenri (Taech'eonni), Fuyo (Puyeo) and Ranpo (Namp'o) Sheets. *Ibid.* No. 13.

SHIMIZU, S., OZAKI, K. and T. OBATA (1934), Gotlandian deposits of northwest Korea. *Jour. Shanghai Sci. Inst.*, Sect. 2, Vol. 1.

SHIRAKI, T. (1930), Coal-fields of Kyojo-gun (Kyeongseong-gan). *Rep. Surv. Coal-fields* No. 6.

——(1933). Geological map of the Sanchoku (Samch'eok) coal-field.

——(1934), Geological map of the Bunkei (Mun'gyeong) coal-field.

—— (1940), The Sanchoku coal-field in Kogendo, *Rep. Surv. Coal-Fields, Chosen,* Vol. 14.

SUZUKI J. (1935), On the metamorphic rocks in the southeastern part of Koryo-gun (Kangnŭng-gun), Kogendo (Kangweon-do). *Jour. Geol. Soc. Japan,* Vol. 42.

SUZUKI, K. (1940), Non-marine Molluscan faunule of the Shiragi (Silla) series in South Tyosen (Korea). *Japan. Jour. Geol. Geogr.*, Vol. 17.

—— (1949), Development of the fossil non-marine Molluscan faunas in Eastern Asia. *Japan. Jour. Geol. Geogr.*, Vol. 21.

TADA, F. and S. INOUYE (1935), Topography and human geography of the upper Nandai (Namdae-ch'eon) river in Kishu (Kilchu), Kankyo-hoku-do (Hamgyeong-bukto). *Guide-book of geological excursions in Korea,* No. 5.

TAKAHASHI, E. (1950), On the horizon of fossil plants, *Estherites* and mollusks of the Tonjin formation of the Kimpo (Kŭmp'o) coal-field, Korea. *Jour. Geol. Soc. Japan,* Vol. 56.

TAKAI, F. (1939), Eocene mammals found from the Hosan (Pongsan) coal-field, Tyosen. *Jour. Fac. Sci. Imp. Univ. Tokyo,* Sec. 2, Vol. 5, pt. 6.

—— (1944), Eocene Mammals from the Ube and Hosan coal-fields in Nippon. *Proc. Imp. Acad. Tokyo,* Vol. 20.

TAKAI, F., MATSUMOTO, T. and TORIYAMA, R. (1962), Geology of Japan. *Univ. of Tokyo Press.*

TATEIWA, I. (1924), Ennichi (Yeonil), Kuryuho (Kuryongp'o) and Choyo (Choyang) sheets. *Geol. Atlas Chosen,* No. 2.

(1925), Kyokudo (Kŭktong), Meisen (Myeongch'eon), Shichihosan (Ch'ilbongsan) and Kotendo (Kocheomdong) sheets. *Geol. Atlas Chosen,* No. 4.

——(1929), Keishu (Kyeongju), Eisen (Yeongch'eon), Taikyu (Taegu) and Wakwan (Waekwan) sheets. *Geol. Atlas Chosen,* No. 10.

—— (1933), On the cycle of erosion in Korea. *Proc. 5th Pacific Sci. Congr. Canada,* Vol. 2.

—— (1934), Cretaceous flora of Tsushima, Japan. *Japan Jour. Geol. Geogr.*, Vol. 11.

TCHAYCHOVSKY, V. K. (1935), New data on the geology of the central part of the Mongolian National Republic. *Problems of Soviet Geology,* Vol. 5.

TETIAEFF, M. (1933), Neue Angaben über die Verbreitung marine Trias in Transbaikalien. *Bull. Geol. Prosp. Serv. USSR.*

TOMITA, T. (1935), On the chemical composition of the Cenozoic alkaline suite of the circum-Japan sea region. *Jour. Shanghai Soct. Inst.*, Sect. 2, Vol. 2.

YABE, H. (1905), Mesozoic Plants from Korea. *Jour. Coll. Sci. Imp. Univ. Tokyo,* Vol. 20, Art. 3.

—— (1906), A contribution to the genus *Fusulina* with notes on a *Fusulina* limestone from Korea. *Jour. Coll. Sci. Imp. Univ. Tokyo,* Vol. 21, Art. 5.

—— (1908), On the occurrence of the genus *Gigantopteris* in Korea. *Jour. Coll. Sci. Imp. Univ. Tokyo,* Vol. 23, Art. 9.

—— (1927), Cretaceous stratigraphy of the Japanese islands. *Sci. Rep. Tohoku Imp. Univ.*, ser. 2, Vol. 11, No. 1.

—— (1944), Palaeogene age of the coal formation of the Ube coal-field, Yamaguchi prefecture. *Proc. Imp. Acad. Tokyo,* Vol. 20.

—— and T. SUGIYAMA (1959), Discovery of corals of Devonian type from Tyosen (Korea). *Proc. Imp. Acad.,* Vol. 15.

——and SUZUKI, A. (1955), Second occurrence of colonial coral of Devonian type in Tyosen (Korea). *Proc. Japan. Acad.* Vol. 31.

——and TAYAMA, R. (1929), On some remarkable examples of Drowned valleys found around the Japanese islands. *Rec. Oceanogr. Works,* Vol. 2, No. 1.

YAMAGUCHI, T. (1951), On the so-called Yonchon system and its regional metamorphism. *Jour. Geol. Soc. Japan,* Vol. 57.

YAMANARI, F. (1924), Mitsuyo (Milyang) and Yusen (Yuch'eon) sheets. *Geol. Atlas Chosen,* No. 1.

—— (1926), On the imbricated structure in Kogendo. *Geogr. Rev. Japan,* Vol. 1.

YOKOYAMA, M. (1923), On some fossil shells from the Island of Saishu (Cheju) in the Strait of Tsushima. *Jour. Coll. Sci. Imp. Univ. Tokyo,* Vol. 44, Art. 7.

YOSHIKAWA, T. (1947), The geomorphic history of Central Korea. *Jour. Geol. Soc. Japan,* Vol. 53.

—— (1950), Rock Floors of Central Korea. *Geogr. Rev. Japan,* Vol. 22.

YOSHIMURA, I. (1950), Geology of the Neietsu (Yeongweol) district, Kogendo (Kangweon-do), Tyosen. *Jour. Geol. Soc. Japan,* Vol. 43.

Plate I

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

Explanation of Plate II

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

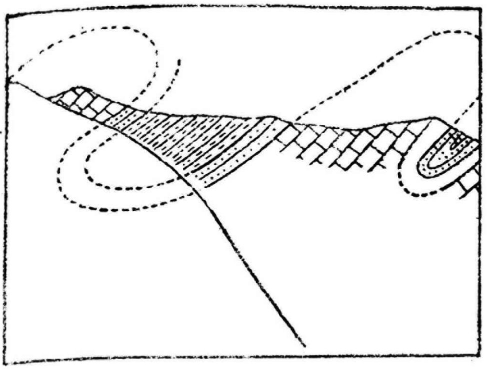
Figure 2. The Kongsuweon tectonic line along which the great limestone formation of the Korean system thrusts itself onto the Daedong series. 1. Cheosa-dong and Cheoam on the Hangang river in the NNE of Yeongweol.

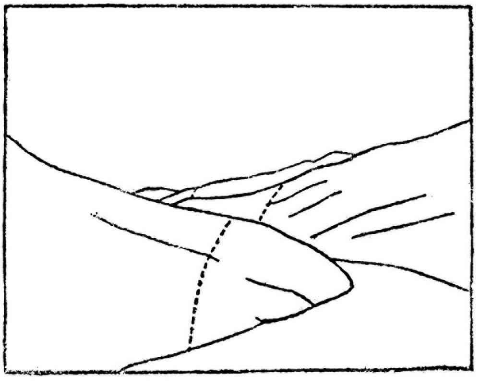
Figure 3. Strong intraformational folding of the great limestone formation, in fluidal aspect below the simply monoclinal basal conglomerate of the Bansong series on the large cliff at Ch'ori, about 3km. to the east of Yeongweol.

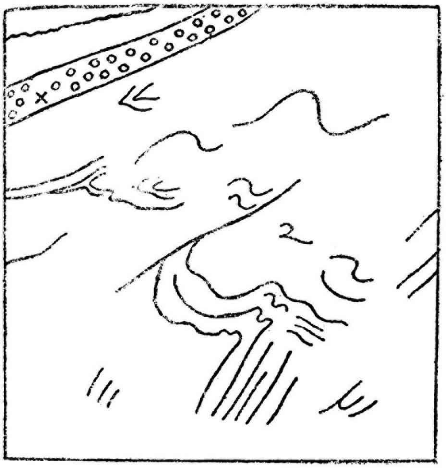
Figure 4. Para-unconformity between the Hongjeom series above and the Tsuibon limestone below, exposed on the bank of the Naktong-gang, at a point adjacently north of Dongjeom-ni, Sangchang-myeon, Samch'eok-gun, Kangweondo.

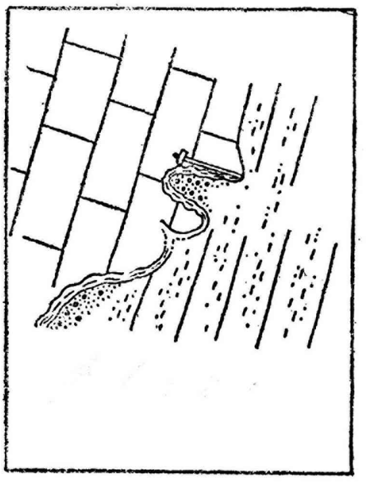
Figure 5. Another exposure of the same para-unconformable relation as the preceding seen at Kyesanmal, Sangchang-myeon, Samch'eok-gun, Kangweondo.

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









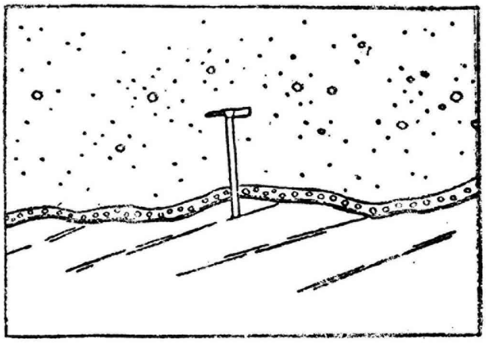
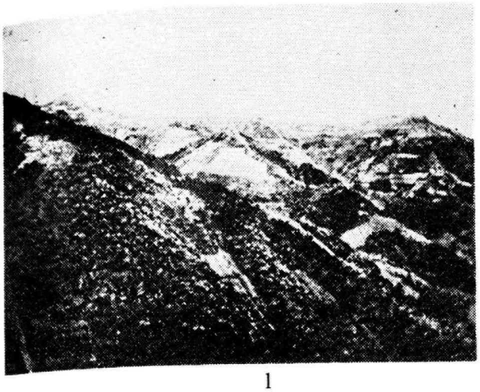


Plate II


1


2


3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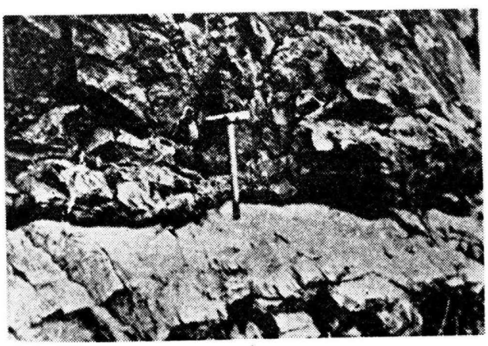
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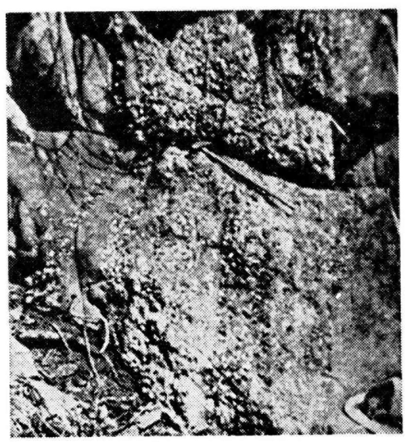
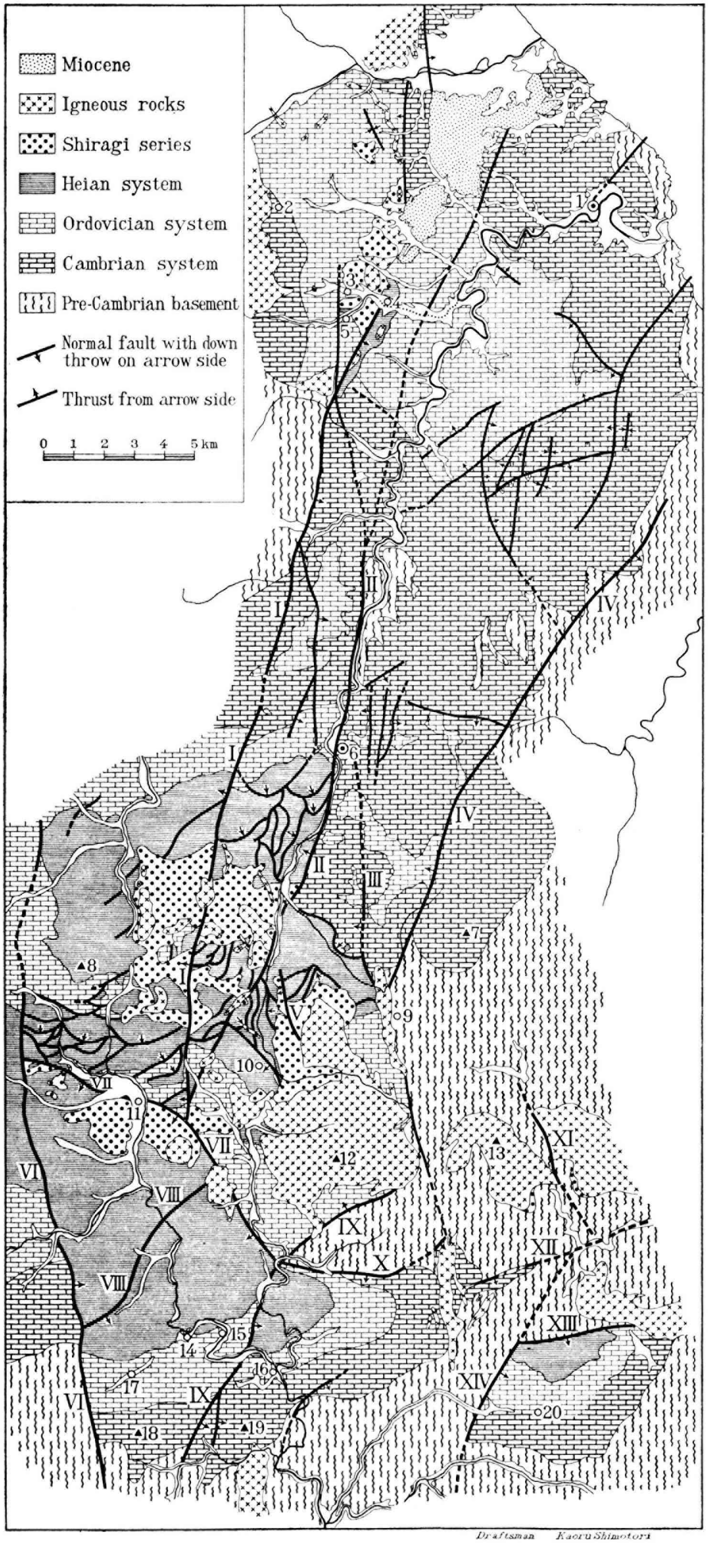

6

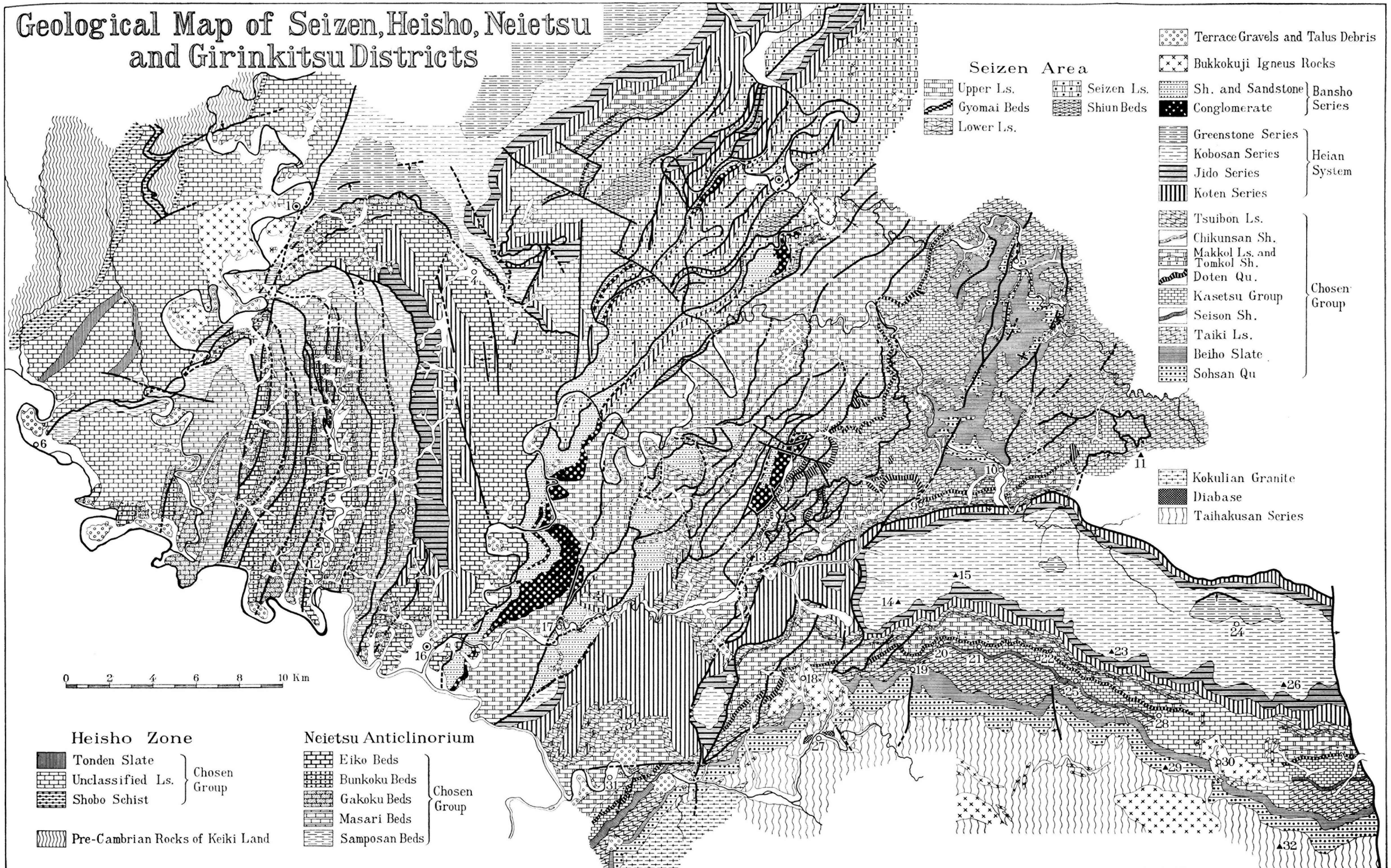
Geological Map (II) of the Taebaegsan Dislocation Zone.



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

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

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



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