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

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I. Introductory Note

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

A. ORDOVICIAN

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

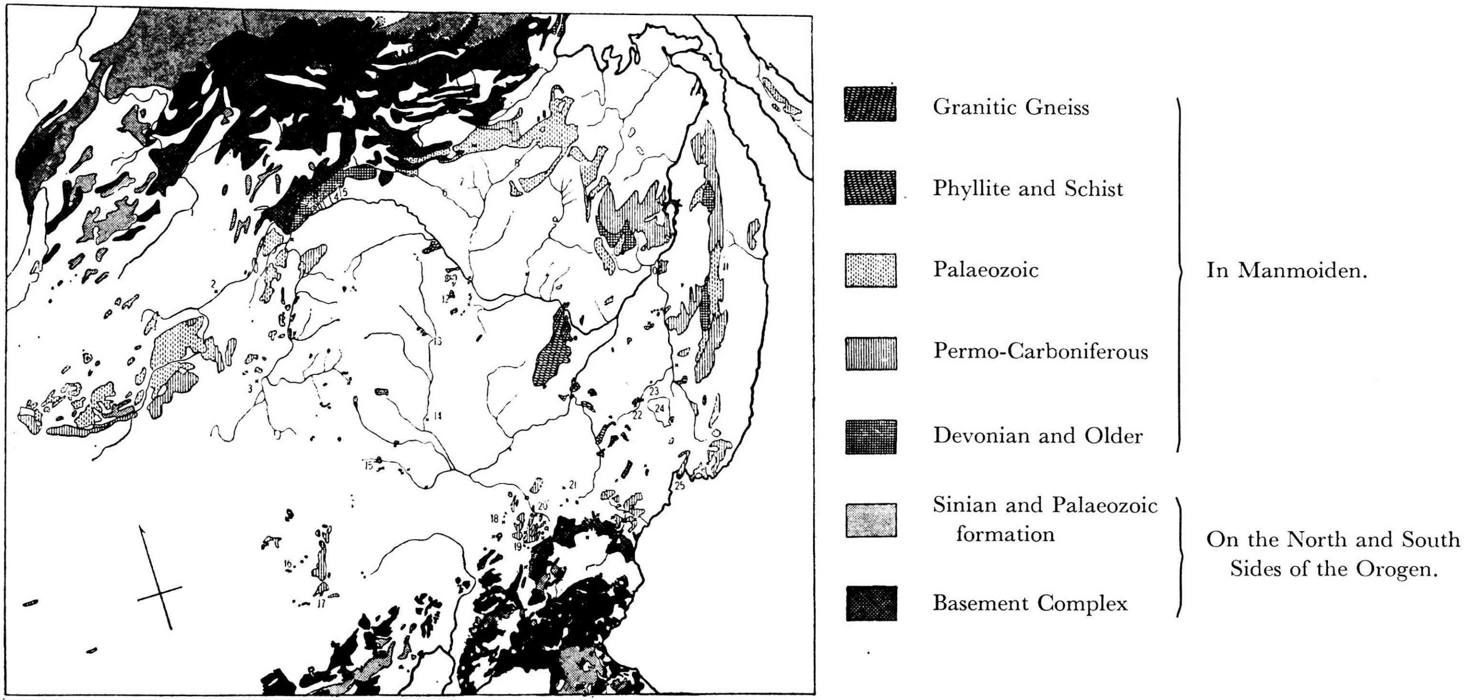

Fig. 1. Distribution of Older Rocks in Manchuria.

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

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

B. Silurian

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

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

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

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

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

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

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

C. Devonian

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

D. Carboniferous

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

3. Upper Carboniferous Panshih group

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

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

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

2. Middle Carboniferous Mincheng group

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

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

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

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

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

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

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

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

E. Permian

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

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

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

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

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

Licent and Teilhard de Chardin (1930) found crinoidal limestone at Kharto, west of Erekto on the railway line between Tsitsihar and Mandsduri (or Man-chouli). According to Ushimaru and others (1932), Upper Palaeozoic graywacke, quartzite and limestone are found near Djalaitewanfu and *Palaeofusulina*, brachio-pods and pelecypods are found in a limestone at Wannuobo.

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

Schwagerina pusila (Schellwien)
Ozawainella angulata (Colani)
Codonofusiella cf. *paradoxina* Dunbar and Skinner
Cribrogenerina permica Lange
Waagenophyllum sp.

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

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

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

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

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

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

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

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

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

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

Aviculopecten cf. *subclathratus* KAYS.

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

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

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

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

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

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

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

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

List 3. Kaishantun Fauna (After NODA, 1956)

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

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

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

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

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

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

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

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

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

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

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

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

F. PALAEOZOIC HISTORY

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

G. Triassic Formations

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

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

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

H. The Basement Complex

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

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

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

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

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

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

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

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

Silur-Ordovician(?) limestone and clayslate.

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

Lower Cambrian(?) clayslate and sandstone in alternation.

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

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

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

Pre-Sinian granite-gneiss with mice schist lenses.

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

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

III. The Epirogeneses of the Hwangho Basin

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

6. ENDO (1944) reported the occurrence of the Tangshihan i.e. early Middle Cambrian brachiopods from the Pataochiang coal field, Tunghua-hsien.

These fossil localities are the northeasternmost ones of the Hwangho basin which suggest the shoreline of this part of the basin as shown in Fig. 2.

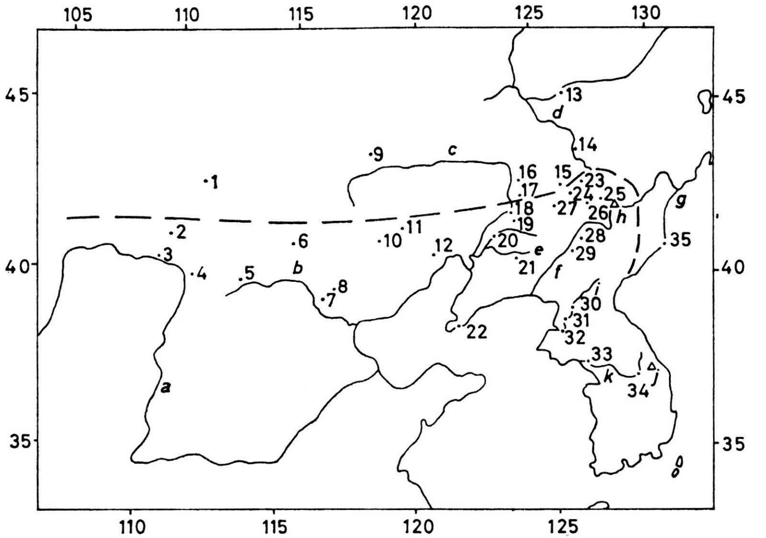

Fig. 2. Map showing the northern shoreline (broken line) of the Hwangho basin.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

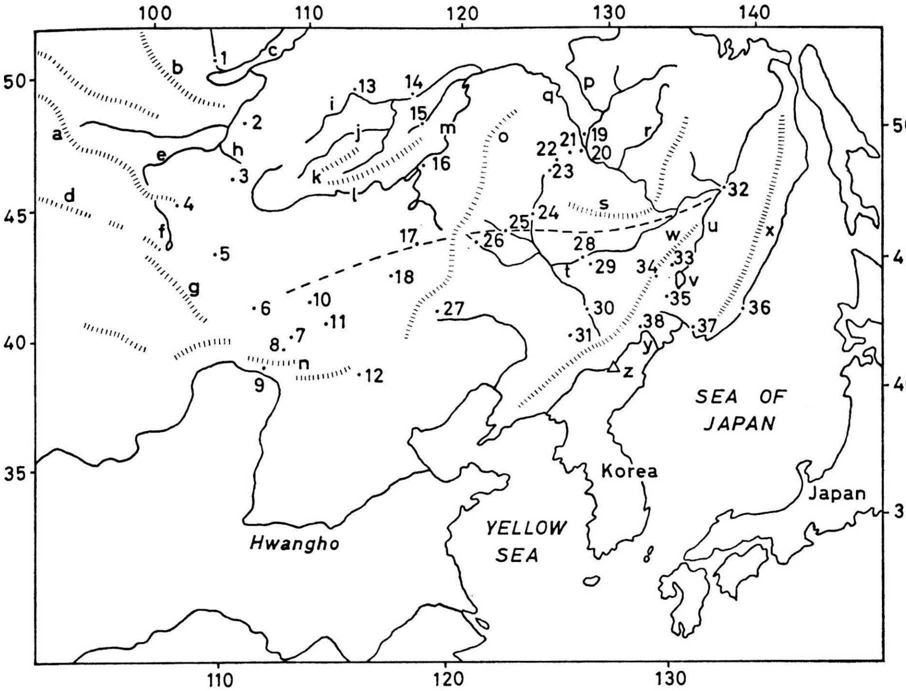

Fig. 3. Map showing the subsiding axis of the Mongolian geosyncline in the Permo-Carboniferous period.

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

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

Broken Line: Geosynclinal Axis

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

VII. Conclusion: The Akiyoshi Orogeny of the Mongolian Geosyncline

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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