64. *The Akiyoshi Orogenic Cycle in the Mongolian Geosyncline**.

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Since Schönmann had expressed the opinion in 1929 that the Mongolio-Amur *Faltengürtel* had been a geosyncline which was disturbed by late Mesozoic orogeneses, it was a moot question among geologists, as discussed by Stille, Obrutschew and others¹⁾. It is the object of this paper to demonstrate that the Akiyoshi, instead of the Sakawa, cycle of orogenesis²⁾ is responsible for the oronization of the Mongolian geosyncline.

A thick Palaeozoic complex for which I proposed the name, Mammo (滿蒙) group³⁾, is the sediment in the geosyncline existing between the *Altenscheitel* and the Yenshan orogenic zone. Because it is one of the least known but nevertheless one of the most important formational unit in the geology of Eastern Asia, I have paid special attention to it since I studied a small collection of fossils from Soron in the middle part of the Great Khingan range in 1931⁴⁾. On the basis of fresh evidences which we obtained in Manchoukuo, its stratigraphic succession can now be roughly sketched as follows:

1. The lowest of the group so far known is the Ordovician *Orthis* sandstone of the Tyktaminda on the Siberian side of the Upper Amur valley where it is overlain by the Gotlandian *Calymene* marly shale. In the same area there is a good display of the fossiliferous Devonian formation composed mostly of shale and limestone in the lower part, of marl, limestone and reef limestone in the middle and of limestone in the upper part⁵⁾.

The North Manchourian plateau has been a piece of *terra incognita*. Lately

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1) G. Schönmann, Über den mongolisch-amurischen Faltengürtel and Stille's comment on it. C. Min. usw., Abt. B. 1929; W. Obrutschew, zur Existenzfrage eines mongolisch-amurischen Faltengsgürtels, C. Min. usw., 1930.

2) T. Kobayashi (1941), The Sakawa Orogenic Cycle and its Bearing on the Origin of the Japanese Islands. Jour. Fac. Sci. Imp. Univ. Tokyo, Sect. 2, vol. 5, pt. 7.

3) T. Kobayashi and J. Nonaka, On the Mammo Group. Jour. Geogr. Tokyo. (In print).

4) T. Kobayashi (1931), Upper Palaeozoic Shells of Soron in the Great Khingan Range. Japan. Jour. Geol. Geogr. vol. 8.

5) W. A. Obrutschew (1926), Geologie von Sibirien. Fortsch. Geol. u. Pal. Hft. 15; A. Krystofovich (1926), Geology in the Pacific Russian Scientific Investigation; E. Ahnert (1928), Morphologische und Geotektonische Skizze des russischen fern Ostens und Nordmanhuriens. Proc. Third Pan-Pacific Sci. Congr. Tokyo, 1926, 1926, vol. 1.; F. Raupach (1934), Stratigraphische und tektonische Entwicklung des russischen Fernen Osten, der Mandschurei und zentral Mongolei; K. Leuchs (1935), Geologie von Asien Bd. 1. Th. 1. For Siberian Geology I am much indebted to these works, but for the recent advancement I referred to abstracts of the Russian papers.

R. Kondo discovered fossils in a limestone at a point 41 km. eastnortheast of Houlungmen (霍龍門). As a result of a preliminary study in collaboration with Nonaka I found that *Spirifer* cfr. *tonkinensis*, a phacopid and a few other fossils contained in his collection suggest the Eiferian age for this fauna. Prior to this Hatori discovered another fossil locality in the vicinity of Mishan west of the Hanka lake in a limestone of the Heitai formation which contains tuff. According to Yabe the Heitai fauna is Upper Devonian¹⁾.

2. According to Fredericks²⁾ a formation along the Kulinda river in Transbaikalia which was formerly referred to the Devonian system is Lower Carboniferous. A limestone and shale formation of the same age seems to extend easterly to the Upper Seja. The Sair Usu formation³⁾ in Outer Mongolia shows its western extension. The Chilin formation extensive in the east of Hsinking, also consists of shale and limestone in main. *Syringopora* and other corals were found in a limestone bed, fusulinids in another and brachiopods and other fossils in shales from which the age of the formation may be suggested at Dianatio-Moscovian⁴⁾. Pyroclastic rocks which were thought by Kawada⁵⁾ to be located in the lower part, lie, according to S. Okada⁶⁾, either above the Chilin or in its uppermost part.
3. In the Russian Far East there is a formation which consists chiefly of siliceous slates containing Radiolaria, but conglomerate beds are met with in the basal part. Its thickness measures 1500 metres. Its lower part extends down to Moscovian because *Spirifer mosquiensis* is contained. A *Neoschwagerina* limestone which Ahnert found in a hill near Chavarowsk probably belongs to its upper part. The Permian formation is most extensive and comprises various facies. In Southern Ussuri a marine Middle (?) Permian formation which according to Musslenicov⁷⁾ lies on the preceding disconformably is tuffaceous and yields *Lyttonia* and many other brachiopods as described by Fredericks⁸⁾. It merges easterly with the Upper Permian calcareous formation containing *Doliolina* and *Sumatrina*.

The formation of the tuffaceous facies extends into the Touman and Kanto areas, adjacently west of Ussuri, where in the former it is called the Hekijo formation⁹⁾ and in the latter the Touman formation¹⁰⁾. Toriyama¹¹⁾ described *Pseudodoliolina* and *Parafusulina* from a limestone in the Hekijo formation; brachiopods and other fossils occur in shales of the Touman. According to Ushimaru the Touman formation is more than 800 m. thick and a conglomerate bed in the basal part contains archaegranites.

Ahnert found fossils, mostly brachiopods, at Ertsegtientzu (二層甸子) south-east of Harbin, and Fredericks determined the age of this fauna at Middle Permian.

1) H. Yabe (1940), An Occurrence of Devonian Fossils in Manchoukuo. *Proc.* **16** (1940).

2) G. Fredericks (1931), Über das Alter des Paläozoikum von Ostbaikalien. *Mem. Geol. Mus. Ak. Wiss.* 8.

3) C. Berkey and F. Morris (1927), *Geology of Mongolia*.

4) R. Saito (1940), On Some Fossils from Chilin Formation near Mincheng. *Mem. Geol. Inst. Manchoukuo* No. 15.

5) M. Kawada (1932), Explanatory Text to the Geological Map of Manchuria. Chilin Sheet.

6) S. Okada (1940), Limestone in Chilin Formation near Mincheng, Panshih Prefecture. *Mem. Geol. Inst. Manchoukuo*, No. 15.

7) D. F. Masslenikov (1937), The Permian of the Far East. Abstracts of papers of XVII Intern. Geol. Cong.

8) G. Fredericks (1923), Upper Palaeozoic of the Ussuriland; (1924), Upper Palaeozoicum of the Ussuriland, II, Permian Brachiopoda of Cape Kalouzin. *Rec. Geol. Com. Russ. Far East*. Nos. 28, 40.

9) T. Ichimura (1932), Kainei Coal Field. *Rep. Geol. Surv. Coal Field in Chosen*, vol. 1.

10) S. Ushimaru (1932), Explanatory Text to the Geological Map of Manchuria Touman-Chiang sheet.

11) R. Toriyama (1942), Some Fusulinid Fossils from Keigen District in North Kankyo-do, Tyosen. *Jour. Geol. Soc. Japan*. vol. 49.

A brachiopod-bearing marine Permian formation is known to exist in the vicinity of Borsja Railway Station in Transbaikalia¹. In Mongolia there is the Jisu Honguer formation and on its fauna Grabau wrote a monograph². In the southern part of the Great Khingan range there is the Ujimuchin limestone formation which is a correlative of the Jisu Honguer. There it is overlain by the Dabussumnor which consists of shale, sandstone and conglomerate and contains pelecypods and gastropods³. Some fossils obtained in the tuffaceous Soron formation were all new species belonging to *Pleurotomaria*, *Aviculopecten*, *Dellopecten* and *Crenipecten*. Although the Dabussumnor fauna remain undescribed, I think it probable that the Soron and Dabussum-nor are approximate in age. *Palaeofusulina* bearing limestones are known at some places in the northern part of the range.

4. Lately Choh⁴ discovered the naiad-bearing clayslate and sandstone formation along the Hahai river adjacently north of Soron and jointly with Hisakosi I made a study on this collection⁵. Besides several new species it contains *Palaeandonta* cfr. *longissima* from which it is suggested that this fauna is probably correlated to the Upper Permian Kolchugino of the Kusnetz basin⁶.

In South Ussuri there is also a continental Tungusian series which lies disconformably on the marine Lower or Middle Permian formation. It contains coal seams and yields *Noeggeratiopsis aequilis* and other plants.

5. According to Berkey and Morris the Khangai greywacke formation is pre-Cambrian which is intruded by Mongolian batholith and the Permo-Carboniferous formations lie on the granitized floor, but the fact that either the Sair Usu or the Jisu Honguer lies unconformably on the granite or the greywacke formation is not actually determined. On the other hand Upper Devonian or Lower Carboniferous fossils were found at Scharan-gol, and further at Gurban Saikan Devonian fossils were obtained in boulders which are thought to be derived from the greywacke series. Tchaikovsky⁷ and other geologists therefore referred the series to the Carboniferous or Devonian while Ussov and some others think the series in the Kentai range to be pre-Cambrian. According to Obrutschew a graywacke formation steeply inclined, is overlain by a marine Palaeozoic formation in a tributary of Tschikoi.

Our knowledge on the Mammo group is still meager, and the stratigraphic position of the greywacke series is still in debate, but on the basis of the fossil finds it may be concluded that at least a part of the series is a member of the group. In the Sanho area in Barga the group is said to overlie the granitic gneiss. If this fact is considered together with the Ordovician sandstone at the lowest of the group in the Upper Amur Valley, the group is presumed to overlie

1) G. Fredericks (1930), Permablagerungen in Transbaikalien. Bull. Geol. Prosp. Serv. Leningard, 49.

2) A. W. Grabau (1931), The Permian of Mongolia.

3) Licent and Teilhard's Linici formation corresponds to either one of the two or the sum of them. E. Licent and P. Teilhard de Chardin (1930), Geological Observation in Northern Manchuria and Barga. Bull. Geol. Soc. China, vol. 9.

4) R. Choh (1941), A New Fossil locality in the Soron Formation. Jour. Geol. Soc. Japan, vol. 48.

5) T. Kobayashi and S. Hisakosi, On Some Naiads from the Upper Palaeozoic Formations in Eastern Asia. Japan. Jour. Geol. Geogr. (In print).

6) Along the Urka in the Upper Amur Valley there is a shale and sandstone formation yielding plants of the Upper Carboniferous or Permian age; plant remains are contained in a clayslate bed in the middle Chilin formation which are however associated with *Pecten*.

7) V. K. Tchaikovsky (1935), New data on the Geology of the central part of the Mongolian National Republic. Problems of Soviet Geology, vol. 5.

A very Tentative Correlation of the Inai and Mammo Formations
with some others in Eastern Asia.

Geological Age	Phase of Movement	Japanese Islands		Mongolian		Geosyncline	Chosen-S. Manchoukuo
		Zohoin	Inai	Marine	Non-Marine		
Ladinic	Akiyoshi			Lianchioho			
Anisic			Inai Onagawa Kurotaki Taho (Kojima)	Monophyllites Flemingites Velopecten iwanoii Meekoceras Pseudomonotis bittneri	(Pleuromeia)	Greenstone	
Skytic							
Permian	Tate	Toyoma		Hekijo	Hahai, Tungusian		Kobosan
	Usuginu pre-Usuginu	Maiya { Kanaikura Sakamotozawa		Soron Dabussumnor			Liutang Huangchi opif
Carboniferous	Sakamoto	Nagaiwa Onimaru		Sair Usu	Chilin Graywacke		Koten
	(Nanpiao)	Omori Nakazato Ono	Ohira	Heitai Houlungmen			
Gotlandian	Salair	present		Tyktaminda ^{sh}			
Ordovician				ss			
Cambrian							Chosen

the pre-Cambrian *Grundgebirge* discordantly. Kouzmin¹⁾ noted that the crustal movement of the Salair phase can be recognized in eastern Transbaikalia. Is it too much of a conjecture to suggest that the Mongolian geosyncline was produced on the south side of the *Altenscheitel* by this movement?

The part of the greywacke series which belong to the Mammo group must be a *Flysch* in the Mongolian geosyncline. Judging from the fossil evidences, the geosyncline expanded southward in the Devonian and farther to the south in the Permo-Carboniferous. Recently, a clino-uncomfortable relation of the Rakuroan with the Heian was found in the Nanpiao coal-field in Eastern Jehol. According to Choh this discordance means foldings followed by faultings²⁾. It is propable therefore that this movement which I called the Nanpiao phase has something to do with the southerly expansion of the Mongolian geosyncline.

From the facts above mentioned it appears that the Upper Carboniferous formation is not well represented in the Mammo group. Recently Hanzawa³⁾ has pointed out that there is a hiatus in the Heian group at the Uralian stage in South Manchoukuo while Minato⁴⁾ found in the Southern Kitakami mountainland the presence of a remarkable discordance at the base of the Sakumarian Maiya series, showing the crustal movement of the Sakamoto phase. It may therefore be expected that future study will prove that the southerly expansion of the geosyncline depends upon this movement.

During the Permian period the sea however retreated easterly with the result that limnic formations were deposited in the Great Khingan range and in South Ussuri in the latter part of the period. A discordance between the Dabussum-nor and Ujimuchin formations and some others in Russian Far East tell of the fluctuation of strand-line caused by the upheavals of the Sakamoto, Kanaikura, Usuginu and Tate phases till at length the sea completely retreated from the geosyncline at the end of the Permian period.

The thick Usuginu conglomerate in the Japanese islands is probably a synorogenic deposit in the peri-orogenic zone. Furthermore climatic change⁵⁾ clearly recorded in changes of the mode of sedimentation and of the aspect of flora in the Heian group implying that a great palaeogeographic change occurred in Eastern Asia caused by these movements

1) A. Kouzmin (1937), Matériaux sur la stratigraphie et la tectonique de la Transbaikalia oriental. Abstracts of papers of Intern. XVII Geol. Congr.

2) T. Kobayashi and R. Choh, Fossil Zonation of the Cambro-Ordovician Chosen Group in Eastern Jehol. Japan. Jour. Geol. Geogr. (In print).

3) S. Hanzawa (1941), The stratigraphic Relation between the Carboniferous and Permian Formations in Manchuria, Korea and Japan proper. Japan. Jour. Geol. Geogr. vol. 18.

4) M. Minato (1942), Unconformity of the Pre-Sakamotozawa Stage in the Kitakami Mountainland, Northeast Japan. Jour. Geol. Soc. Japan, vol. 49. His Setamai phase is a synonym of my Sakamoto phase in 1941.

5) T. Kobayashi, On the Climatic Bearing of the Mesozoic Floras in Eastern Asia. Japan. Jour. Geol. Geogr. (In print).

can hardly be overlooked, and in fact the invasion of the early Triassic sea were restricted to the South Ussuri and Amur embayments.

6. In the vicinity of Vladivostok the Inai formation is found in small isolated patches. It overlies granite with a discordance in between, indicating the movement of the Tate phase. The Kojima conglomerate bed 265 metres thick at the base, contains, like the Yasuba conglomerates, boulders of granitic rocks and fossiliferous Palaeozoic limestones beside Skytic pelecypods in matrix.

The conglomerate bed is overlain by the Onagawa sandstone and clayslate formation 680 metres thick, which is calcareous in the lower part as in the case of Nippon. As a result of Kiparisova's revision on the pelecypod fauna¹⁾ *Pecten (Velopecten) bittneri*, *Meekoceras* and *Pseudomonotis iwanoi* zones were distinguished in ascending order in the lower sandstone beds. The upper sandstone and shale beds may be the latest Skytic, if not the earliest Anisic, because they yield Skytic *Flemingites* on the one hand and *Ctenodonta elliptica* var. *praeursor* of *Muschelkalk* on the other. It is interesting to see that while *Pleuromeia* was found here in the upper division, plant remains rarely occur in the middle part of the Onagawa in Nippon.

The Inai sandy clayslate formation about 125 metres thick is represented here by quartzose sandstone in addition to arkose beds at the base and top. Diener's *Monophyllites* and Wittenburg's *Ptychites* are said to have been procured from this formation.

Thus the Inai series in Nippon and South Ussuri are similar in succession and facies, but it is much thicker in the former, attaining over 2500 metres. A *Daonella*-bearing Ladinic Zohoin shale is limited to exist at Lianchioho, and its stratigraphic relation with the younger and older Triassic formations is unknown. The base of the Mongugai series (s. str.)²⁾ which corresponds to the sum of the Mine and Kuruma series in Nippon, is marked off by the discordance of the Akiyoshi phase.

7. In Transbaikalia a thick Triassic sandstone and shale formation of some 2000 metres' thickness with a crystalline limestone bed at its base is overlain by the basal conglomerate of the Kochigatani series³⁾. The formation is unfossiliferous, but it is probably an equivalent of the Inai series, because *Claraia* and a few other Skytic fossils contained in the basal conglomerate of the Jurassic formation appear to have been derived from it.

It is noteworthy that there is a granitic mass which is overlain by the Jurassic formation while a contact effect of a granitic intrusion is found in the Inai series. If the two facts are brought together, it can be suggested that the plutonism introduced by the Akiyoshi orogenic cycle did not last until the Middle Triassic period, although the presence of the pre-Skytic granite is ascertained in Ussuri. A granodiorite mass of Uljatui, a granite mass of Sektui and a gneissose granite of the Gasimur tributary, all in Transbaikalia, are suggested to be referable to the same palaeoplutonic suite with those above mentioned.

Most of the plutonics in central and northern Manchoukuo form intrusive masses in the Mammo group which are overlain by the Mesozoic formations among which the Daido series is the oldest. If

1) L. Kiparisova. The Lower Triassic Pelecypoda of the Ussuriland. Akad. d. Sc. USSR. Trav. de l'Inst. Géol. vol. 7.

2) T. Kobayashi (1942), Stratigraphic Relation among the Mesozoic Fossil-beds in the Korea-Manchurian Land and their Ages. Proc. **18** (1942).

3) M. Tetiaeff (1933), Neue Angaben über die Verbreitung mariner Trias in Transbaikalien. Bull. Geol. Prosp. Serv. USSR. vol. 50.

the facts obtained in Mongolia and farther west by Berkey, Morris, Teilhard¹⁾ and others are taken into consideration the palaeoplutonism was earlier on the western side than on the east as I have noted already. Where the group is captured by intrusive rocks it is so highly metamorphosed as to have been thought at one time to be Archean, but Krystofovich has mentioned that at least a part of the Archean rocks in the Sichota-Alins are metamorphics of a much younger age. Even the Mashan metamorphic group²⁾ on the west side of the Hanka lake might belong to the same kind.

Tuff in the Heitai formation shows a volcanism roughly contemporaneous with that in the Nakazato-Ohira stage but they are not comparable in violence. The volcanism however, became more violent in the Mongolian geosyncline in the Permian period when it has almost ceased in the Chichibu. Of the structure of the Mammo group little is known, but the fact that patches of the Devonian and older formations are aligned in three zones³⁾ as well as metamorphic masses are mostly embraced by the plutonic rocks is remarkable. Although it is still premature to decide, I am inclined to think that the Mongolian geosyncline is a parageosyncline and the Mammo *Orogen* is of the German type (s.l.). For the oronization the intrusion of the Mongolian batholith is probably most responsible.

Except in the Amur geosyncline which will be discussed later, the Daido and later blankets on the already granitized floor are, though cut by many faults, not much folded.

In summarizing the salient facts presented above, it may be concluded that the history of Mongolian geosyncline begins with Ordovician lasting until the early Triassic. Although the stratigraphic succession of the Mammo is not yet known exactly, approximate equivalents of crustal movements of the Chichibu geosyncline can be recognized in the Mongolian. The paroxysmal phase of the orogenic cycle was however earlier in the latter. Namely, it is either the Usuginu or Tate phase or both but the Ladinic Akiyoshi in Nippon and the Noric Momonoki in Indochina. As the paroxysmal phase was shifted from North to South, the post-orogenic emergence was shifted in the same direction in Eastern Asia. While the Ladinic sea flooded extensively over the southeastern part of Asia, the northeastern part became land completely at the time. Between these two parts the sea lingered on, leaving embayments in the Japanese islands and South Ussuri.

1) P. Teilhard de Chardin, (1940), The Granitization of China. Bull. Geol. Soc. China. vol. 19.

2) G. Asano (1941), Metamorphic Rocks containing Sillimanite or Andalusite as Essential constituent, with reference to the "Mashan Series." Bull. Geol. Inst. Manchoukuo No. 101.

3) The northern zone extends over the Upper Amur Valley; the middle one comprises the Houlungmen patch and another Devonian exposure in the Bureya mountain; and the southern zone is represented by the Heitai formation and the Devonian ones on the western flank of the Sichota Alins.