The Geology of the Pei-piao Coal Field, South Manchuria

Shōichi NISHIDA

I. Location and Access

The Pei-piao coal field, one of the most important coal fields in Je-ho (Jehol) Province, is located about 10 km northeast of the town of Ch'ao-yang. Pei-piao is the terminus of the Pei-piao line that branches at Chin-ling-ssu from the Chin—Ku line (Chin-hsien—Ku-pei-kou) which is a branch line of the Feng—Shan (Feng-tien—Shan-hai-kuan) railway.

The railway distance between Pei-piao and Chin-hsien is an easy 120 km. The coal field includes Chien-shan-tzu to the northeast and Hsing-lung-kou to the southwest, and trends northeast to southwest. Its area is 24 km by 3 km. The town of Pei-piao lies approximately in the center of the coal field. The coal field was worked in three blocks—Chien-shan-tzu, Kuan-shan and Tai-chi-ying-tzu (Tai-chi on the geologic map), until the end of World War II. The coal-bearing area consists of low hilly land. Its southeast side is surrounded by steep mountains composed of Ordovician quartzite and dolomitic limestone. There are also small mountain blocks on the northwest composed of the Upper Triassic volcanic rocks and associated detrital rocks. These mountains form a basin which trends from northeast to southwest.

II. General Statement on Stratigraphical Sequence

The stratigraphical succession of the coal field can be subdivided as follows:

Hei-cheng-tzu series	H_2	*Lycoptera*-bearing formation
	H_1	Andesite and agglomerate formation
		Clinounconformity
Yang-shan series	Y_5	Pale greenish-gray sandstone formation
	Y_4	T'u-ch'eng-tzu conglomerate formation
	Y_3	Reddish-brown sandy shale formation
	Y_2	Pyroclastic rock formation
	Y_1	Basal conglomerate
		Paraunconformity
Pei-piao series	Pu	Upper coal-bearing formation
	Pm	Main coal-bearing formation
	Pl	Pei-piao volcanic formation
		Unconformity
Ordovician system		Limestone and quartzite formation

A. Limestone and Quartzite Formation

This formation consists of an alternation of quartzite and limestone, and forms the basement of the coal field. At the southeastern border of the coal field, it is in

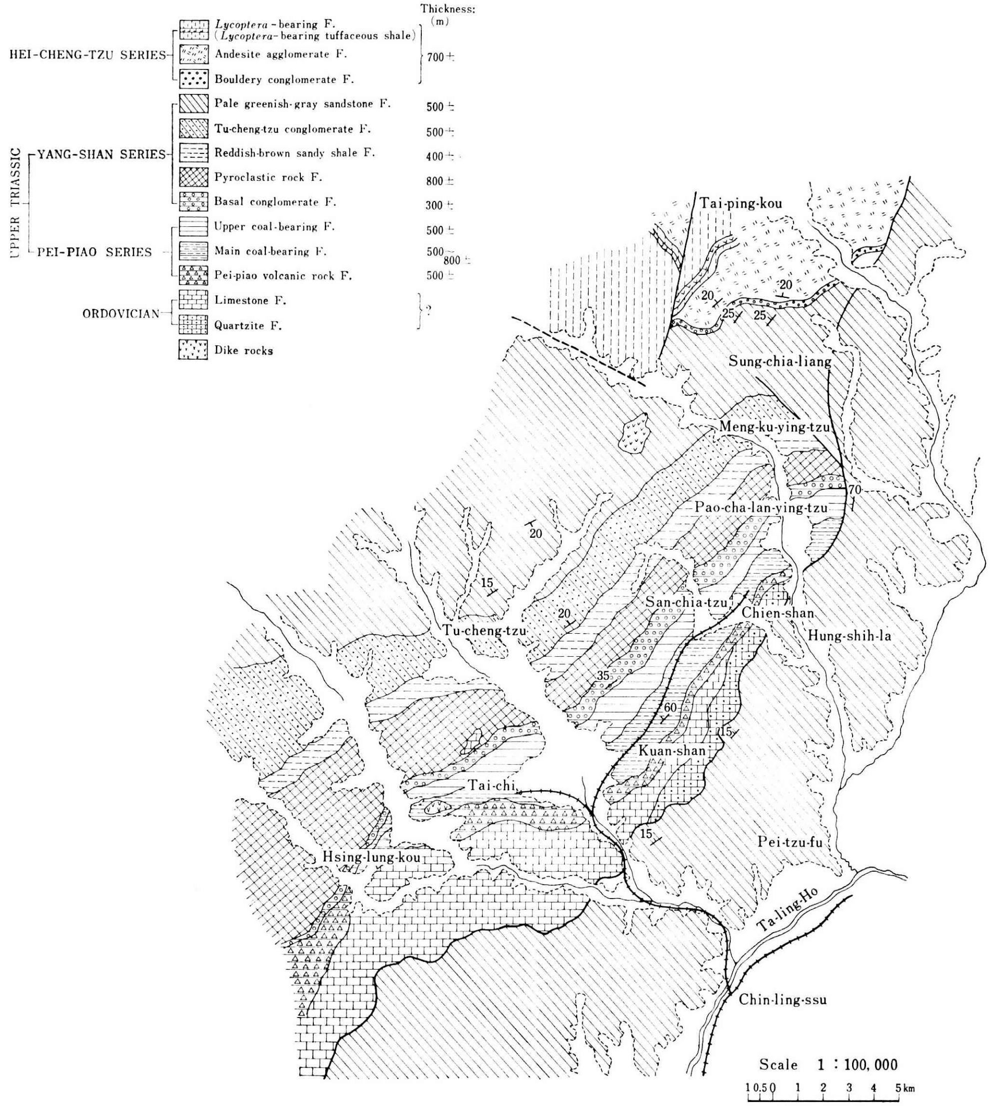

Fig. 1. Geological map of the Pei-piao coal field.

contact with the pale-green sandstone as the result at an overthrust fault. This fault forms the uppermost horizon of the Yang-shan series.

The central part of the overthrust fault dips gently, less than 15°, but it becomes considerably steeper toward the north and south. Quartzite is extremely rare. Only one exposure southeast of Chien-shan-tzu is known. It is generally grayish white and brownish gray. Limestone is generally dolomitic, with 20 percent MgO; some of it has become *Cryptozoon* limestone. *Maclurites bigsbyi* and *Armenoceras* sp., which indicate the Ordovician age were discovered in the formation. The formation was once thought to be Sinian, but the fossils proved it to be Ordovician.

B. Pei-piao Series

As stated above, it consists of three formations. Although it has been found in various localities along the Chin—Ku line, other than in the Pei-piao coal field, the name Pei-piao coal field lends itself to the type locality because it forms a most important chronological and stratigraphical unit in the study of coal-field structure of Manchuria.

(1) *Pei-piao Volcanic Formation (Pl)*. (Tan, H. C. G., 1926, Lower volcanic formation; Matsuzawa, I. 1939, Pei-piao volcanic formation). This formation stretches along the foot of the mountains composed of the Ordovician formations in a narrow area trending from northeast to southwest. Good exposures were observed in various places such as Chien-shan-tzu, Pei-piao and Sung-chia-cheng-tzu. The thickness is 450 m near Chien-shan-tzu and about 500 m near Pei-piao. No direct evidence is available regarding its relation to the Ordovician formation, but judging from the boring tests and the underground workings, it may be assumed that the formation directly underlies the principal coal measure, and unconformably overlies the Ordovician formation. The principal coal measures generally contain key plant fossils. Therefore, the age of the volcanic formation can also be determined with certain accuracy, in accordance with its relation to the stratigraphical sequence. From the available data it has been assumed to be the oldest Mesozoic volcanic rock in Manchuria.

(2) *Main Coal-bearing Formation (Pm)*. (Tan, H. C. G., 1926, Lower coal measure; Matsuzawa, I. 1939, Pei-piao coal measure). It conformably overlies the Pei-piao volcanic formation, and contains all the workable coal seams of the coal field. It consists of an alternation of shale, sandstone, conglomerate, and 9 coal seams. Shale is gray, gray black, or greenish gray, and is sandy or marly. It often contains plant fossils, and is rich in carbonaceous matter.

Sandstone is mainly medium- or coarse-grained, and bluish gray or grayish white. The weathered surface is light grayish yellow or dark yellow. Part of it grades into fine conglomerate.

Conglomerate alternates with the sandstone. The pebbles are well ground and their diameter varies from 1 to 3 inches. It is composed of pebbles of quartzite, granite, slate, and vein quartz, of which quartzite predominates. The pebbles have been cemented by dense siliceous sandstone. The most remarkable one is the basal conglomerate of the coal measure, which is fairly indurated and has a thickness ranging from 50 to 60 m near Chien-shan-tzu. It irregularly intercalates grayish-white, medium-grained, siliceous sandstone about 3 m thick. It directly overlies the Pei-piao volcanic formation, and a gradual transition takes place between it and the underlying agglomeratic conglomerate of the Pei-piao volcanic formation, so the relationship is assumed to be conformable. Plant fossils have been found mainly in the shaly parts of the coal measure, especially in the hanging wall of seam no. 4.

Fossils that were found in the coal measure are as follows: *Neocalamites carrerei* Zeiller. *N. hoerensis* Schimper, *Coniopteris hymenophylloides* Brongniart, *Clathropteris meniscoides* Brongniart, *Hausmannia* sp., *Cladophlebis haibrnensis* L. and H., *C. denticulata* Brongniart, *C. nebbensis* (Brongniart), *C. williamsoni* Brongniart, *Baiera gracilis* Bunbury, *Ginkgoites digitata* var, *huttoni* Seward, *G. sibirica* Heer, *Phoenicopsis* cfr. *manchurensis* Yabe and Oishi, *Czekanowskia vigida* Heer, *C. setacea* Heer, *Elatocladus* cfr. *tenerrima* Feistmantel, *Podozamites lanceolatus* L. and H. This coal measure has a thickness ranging from about 800 m around Pei-piao to about 500 m around Chien-shan-tzu.

(3) *Upper Coal-bearing Formation (Pu)*. (TAN, H. C. G., 1926, Upper coal measure; MATSUZAWA, I. 1939, Jehol coal measure). It overlies the principal coal measure, and consists of an alternation of sandstone and shale, with a conglomerate at the bottom.

There is a gradual transition between the conglomerate and the top layer of sandstone of the main coal-bearing formation which suggests continuous sedimentation. Furthermore, thin conglomerate is rarely found in the upper part. Thus, the relationship between the upper and main coal-bearing formations may be considered as a transitional conformity. The shale can be subdivided into light-gray and black shales. The former is generally muddy, but often becomes sandy.

The sandstone is medium- and coarse-grained, grayish, and has a banded structure. It is compact, and has an onion structure, as the sandy shale does, and intercalates massive coarse sandstone. The shale and sandstone are generally stratified in thin layers, repeating regular alternations.

The black shale is remarkably foliated, and is well developed around Chien-shan-tzu. It alternates with the other shale and sandstone. However, it gradually thins out and eventually disappears near Pei-piao. The conglomerate is best developed in the vicinity of Chien-shan-tzu. It consists mainly of medium-sized and fairly well-ground quartzite and granite pebbles. The conglomerate serves as a partition between the upper and main coal-bearing formations. Several impure coal seams about 20 cm thick intercalate the sandy shale. Therefore, the formation is named the upper coal-bearing formation. It was first called the upper coal-bearing formation by TAN, and later it was named the Jehol coal measure by MATSUZAWA. However, as the latter is a general name covering all of Jehol, it is now losing its stratigraphical meaning. Therefore, I have followed TAN's nomenclature. Plant fossils such as *Neocalamites hoerensis* Schimper, *Phoenicopsis* sp., and *Pityo-*

phyllum sp. have been discovered near the sandy shale that contains coal seams and in the black shale. In addition, *Corbicula* sp., and well-preserved insect fossils and fish scales have also been discovered. Total thickness of the coal measure is about 500 m.

C. Yang-shan Series

As previously stated, this series consists of four formations. It lies directly over the Pei-piao series, and is covered unconformably by the Upper Jurassic Hei-cheng-tzu series. A most significant feature of the series is the discovery of the footprint of *Jeholsauripus*. It was first discovered at Yang-shan, about 73 km south of Ch'ao-yang. I designated the series after the name of the locality.

(1) *Basal conglomerate* (Y_1). The basal conglomerate lies directly over the Pei-piao series, and occupies the basement of the Yang-shan series. The pebbles of the conglomerate are generally well-rounded or half-rounded boulders of granite, gneiss, and quartzite, usually the size of a man's head, but sometimes more than one meter in size. These boulders are compactly cemented by coarse sandstone, but not as compactly as the Pei-piao series. The conglomerate often contains thin beds or lenses of coarse sandstone, and the alternations of conglomerate and sandstone are repeated to the upper level, but generally are not sufficiently sorted. In like manner, volcanic detritus becomes a mixture near the top, and it grades into a pyroclastic bed.

The thickness of the formation varies greatly in different localities. Near Chien-shan-tzu it attains a thickness of as much as 300 m and to the south it is about 200 m. It nearly disappears around Tai-chi-ying-tzu. This conglomerate formation is associated with the pyroclastics to the top, and was named the Upper volcanic formation by Tan, Matsuzawa included it in his Ma-chuan-tzu volcanic formation (Jehol volcanic formation). The relationship between the conglomerate and the underlying Pei-piao series is a parallel unconformity. There is no information on the discovery of fossils in both the conglomerate and the overlying pyroclastic formation. However, I found the following fossils in the siliceous shale that is intercalated in the upper part of the conglomerate, at a place west of Chien-shan-tzu. They are the plant fossils *Neccalamites hoerensis* Schimper, *Cladophlebis haibrnensis* L. and H., *Cladophlebis williamsoni* Brongniart, *Cladophlebis denticulata* Brongniart, *Coniopteris hymenophylloides* Brongniart, *Taeniopteris spatulata, Ginkyoides* sp., *Czekanowskia* sp., and *Pterophyllum* sp., and shell and insect fossils.

In addition, a zone rich in silicified wood, *Xenoxylon latiporosum* (Cramer) Gothan has been found in the tuff, which is very useful as a key bed. Thus, it is noteworthy that they have a considerable number of common facies, both in flora and fauna, with the Pei-piao series.

(2) *Pyroclastic rock formation* (Y_2). (Tan, H. C. G., 1926, Upper volcanic rock formation; Matsuzawa, I. 1939, Jehol volcanic rock formation, Ma-chuan-tzu volcanic rock formation).

The lower limit of the formation is above the conglomerate where effusive volcanic rocks became rapidly prevalent, and its upper limit is marked by the beginning of the deposition of the reddish-brown sandy shale. Accordingly, the limits of both the upper and lower parts are transitional and are considerably ambiguous. In addition, the formation often intercalates agglomeratic and tuff, and both the upper and lower limits usually contain agglomeratic conglomerate. The volcanic rocks display quite regular transitional properties; in ascending order they are, basalt—andesite—dacite or more acidic liparite (ASANO, G). The effusion are initiated by peridote, basalt, quartz basalt and hyalocrystalline basalt, followed by augite andesite and two-pyroxene andesite which were erupted in such a manner that they became alternated with pyroclastic rocks. Then, dacite containing augite and hornblende was erupted, and finally liparite was produced. The thickness of the formation is about 800 m.

(3) *Reddish-brown Sandy Shale Formation* (Y_3). This formation consists mainly of reddish-brown sandy shale, with alternations of agglomerate, agglomeratic-conglomerate, and sandstone. It is a transition zone between the pyroclastic rock formation and the T'u-cheng-tzu conglomerate formation, which will be described later.

The formation is valuable as a key bed because of its peculiar color. It is generally tuffaceous with frequent intercalations of bedded or lenticular calcareous masses. The agglomeratic property of the upper part of the conglomerate contained in the formation decreases gradually, and the conglomerate becomes the T'u-cheng-tzu conglomerate. At the same time, the reddish-brown sandy shale that alternates with the agglomeratic conglomerate gradually decreases in thickness and tapers away. A noteworthy point is that the overlying agglomeratic conglomerate contains a small amount of egg-sized granite pebbles. The total thickness of the formation is not certain, but it is inferred to be about 400 m.

(4) *T'u-ch'eng-tzu Conglomerate Formation* (Y_4). The conglomerate formation extends throughout the northwest area of the Pei-piao coal field, and also in the southeast area from Chin-ling-ssu to both sides of the Chin—Ku line (Chin-hsien —Ku-pei-kou). The best exposures can be observed near T'u-cheng-tzu and Chin-ling-ssu. I use in this paper the name T'u-ch'eng-tzu conglomerate which is conventionally used by the engineers of the Pei-piao coal mine. The aspect of the lower limit has already been discussed in the preceding section. The upper limit has been placed on a horizon where the size of the constituent pebbles gradually becomes smaller, and the strata become abundant in pebbly sandstone and sandstone. This means merely that there is a transitional boundary between horizons with different petrographical properties. These pebbles are generally half-rounded and the majority are egg size, but larger boulders can also be found. They consist mainly of granite, quartzite, volcanic rocks, and rarely limestone.

The cementing material is fairly compact indurated medium-grained sandstone, and the rock as a whole is massive. The conglomerate formation is frequently fine-grained, and often intercalates grayish-white or reddish-white medium-grained sandstone. The thickness may vary, as the upper and lower limits have settled artificially, but it has been roughly estimated at 500 m.

(5) *Pale Greenish-gray sandstone Formation (Y_5)*. This formation, probably Upper Triassic, consists mainly of the sandstone that graded from the foregoing T'u-ch'eng-tzu formation, and is unconformably overlain by the Hei-cheng-tzu series. It extends mainly to the eastern part of the Pei-piao coal field, and in the vicinity of Nan-ling, along the Chin—Ku line. In the eastern area of the Pei-piao coal field, the formation has been overlain by the Ordovician formation as the result of an overthrust fault. The horizon near the lower limit contains a grayish-white medium-grained sandstone with a mixture of conglomerate or pebbly sandstone. The upper half is occupied mainly by pale-greenish or reddish-gray medium- or fine-grained sandstone, with rare intercalations of tuffaceous sandstone. The sandstone is generally compact, and has a peculiar appearance due to its thick aspect.

A characteristic of the sandstone is its remarkable cross-bedding. It can be seen both microscopically and megascopically that the rock consists of well-worn oölitic sand grains, and it can be assumed that the rock was formed under semi-desert conditions. Another special characteristic of the formation is the discovery of fossil footprints of *Jeholsauripus satoi* Yabe, Inai & Shikama, *Jeholosauripus gigas* Endo, Nishida & Shikama (M.S.).

a. Stratigraphical Relationship between the Pei-piao and the Yang-shan Series

There is an abrupt change in rock facies between the basal conglomerate of the Yang-shan series and the underlying Pei-piao series, and a fairly abrupt erosion surface was also found there. The relationship may be inferred as a paraunconformity.

The upper coal-bearing bed is covered by the basal conglomerate of the Yang-shan series at Chien-shan-tzu, Pei-piao, and Tai-chi-ying-tzu. However, in the southern part of the coal field, or around Hsing-lung-kou, the conglomerate formation directly overlies the main coal-bearing formation and the Pei-piao volcanic rock formation. Accordingly, a clino-unconformity might exist between the two series, but it could be more reasonably interpreted as a paraunconformity inasmuch as the rock facies of the Pei-piao series change remarkably to the northeast and southwest.

D. Hei-cheng-tzu Series

This series extends around Hsia-sun-chia-liang, about 4 km north of Meng-ku-ying-tzu-ts'un of the Pei-piao coal field.

A large bouldery conglomerate 30 m thick forms the basement and covers the underlying pale-green sandstone formation. The succession of strata, in ascending order, is large bouldery conglomerate, andesitic agglomerate formation, and *Lycoptera*-bearing formation, formed principally of volcanic detritus. In the upper part of the formation there are two beds of grayish-white, fissile, tuffaceous shale about 25 m thick, with many fossils including *Lycoptera davidi* Sauvage, *Estheria mid-dendorffii* R. Jones, and insects. The total thickness probably is not less than 700 m. From the paleontological standpoint the formation may be correlated with the Lower Fu-hsin series, or the I-hsien volcanic rock formation of the Fu-hsin coal field.

a. Stratigraphical Relationship between the Yang-shan and the Hei-cheng-tzu Series

As previously stated, the Hei-cheng-tzu series covers the pale-green sandstone formation, or the uppermost part of the Yang-shan series. The relationship can most clearly be observed at Hsia-sun-chia-wan-tzu, where there are remarkable differences in both strike and dip. A clear clinounconformity has been observed in the mode of distribution of the two series. Crustal movement probably took place after the deposition of the Yang-shan series and before the deposition of Hei-cheng-tzu series. The author regarded the movement as the second step of the Yen-shan movement, and as far the Pei-piao coal field is concerned, the movement was a certain block movement.

III. Coal Seams and Properties of the Coal

All the coal seams that have been worked in the Pei-piao coal field are contained in the Main coal-bearing formation. There are 3–14 coal seams in the Upper coalbearing formation.

The number of coal seams differs with each block, and each coal seam differs in thickness and extent. Such a phenomenon could also be inferred from the sedimentation facies of the Pei-piao series, as stated previously. Accordingly, it is extremely difficult to correlate the coal seams throughout the coal field, and to make general statements on the number, thickness, mutual relationships, and extent of the coal seams. However, certain coal seams such as San-tsao (no. 3 seam) and Ssu-tsao (no. 4 seam) can be traced throughout the coal field. Variations in the general strike as measured successively from the northeast to the southwest are as follows: the Chien-shan-tzu block strikes N50°–70°E, the Pei-piao block N60°–75°E, the Tai-chi-ying-tzu block E–W, or N70°–75°W, and the Hsing-lung-kou block N40°–45°E. The dip is generally N40°–50°NW, but often less than a 35° angle. Midway between Chien-shan-tzu and Pei-piao the dip angle is steeper than 70°. There are 7 workable coal seams in the Chien-shan-tzu block, the northeastern part of the coal field, and there are 3 workable seams in the Pei-piao (Kuan-shan) block in the central part of the coal field. There are three or four principal ones which vary in thickness from 1.2 m to 3.5 m, and often attain a thickness of 5 m.

A description of the coal seams of the Pei-piao block, which is the representative and principal part of the coal field, follows. The Kuan-shan shaft cuts through 16 coal seams, 8 of which have been workable. They are as follows, in descending order: no. 2 seam (thin and unworkable), no. 3 seam (4.75 m thick, with partings;

the principal seam), no. 4 seam (1.98 m thick, no partings; the principal seam), no. 5-A seam (1.27 m thick, no partings), no. 5-B seam (1.30 m thick, no partings), no. 6 seam (1.00 m thick, no partings), no. 7 seam (1.27 m thick, no partings), and no. 8 seam (1.06 m thick, with partings). Of the 8 workable seams named above, seams 3 and 4 are the principal ones in the area. The most important coal seams throughout the entire coal field are only two or three. The quality of coal seam differs according to locality, and may even differ in one and the same seam. The coal seams of the central block near Pei-piao (Kuan-shan) generally contain high-grade bituminous coal and produce much lustrous lump coal, and that of the northeast block, or the Chien-shan-tzu block shows a defect that a large part of the coal is slack coal. The latter is due to the effect of strong crustal disturbances, and block is not very suitable for mining. The seams of the southwest block or around Tai-chi-ying-tzu, however, have not been disturbed, but the number of workable seams decreases. Analyses of the coal seams of the Kuan-shan shaft, Pei-piao block, are as follows:

	Moisture content (%)	Volatile matter (%)	Fixed carbon (%)	Ash (%)	Sulfur (%)	Heat value (cal)	Coking property
A	1.45	35.44	55.75	7.16	0.73	6,975	Coking
B	2.05	38.45	46.59	12.91	0.55	6,837	Coking
C	1.45	46.53	45.43	6.59	0.26	7,788	Coking
D	2.12	36.42	46.71	14.42	0.52	6,918	Coking

Note: Analyses by the Central Laboratory, South Manchuria Railway Co. (1929).

A rough estimate of the known coal reserves of the main coal-bearing area of the coal field that extends from the northeastern part of Chien-shan-tzu to the southwestern part of Tai-chi-ying-tzu is 40 million tons. Coal production in 1943 was roughly 1,000 tons per day at Chien-shan-tzu, 3,000 tons per day at Kuan-shan, and 1,000 tons per day at Tai-chi-ying-tzu.

IV. The Chronological Correlation between the Pei-piao and the Yang-shan Series

I would like to discuss the geologic age of the Pei-piao and the Yang-shan series as the problem is important and interesting, but this would require a lengthy dissertation. Therefore, only an outline will be given here for reference. The first point to be considered is the flora found in the Pei-piao series.

About 17 species of plants have been found, of which two or three are important for the determination of geologic age. Judging from its aspect, the Pei-piao flora could be the traditional Rhaeto-Liassic flora. However, a new chronological conclusion has been attained in the Far East. The age of the strata, which was considered to be Rhaeto-Liassic base on its floral aspect, should be revised to the older Upper Triassic because of its faunal and stratigraphical aspects. Examples are the Nariha flora of Japan, Hongey flora of French Indochina, and the Mongugai flora of Siberia.

The Pei-piao series has also fallen into the same category because of the discovery of *Jeholosauripus* from the Yang-shan series, and the subsequent revision to the Upper Triassic. The Yang-shan series, as well as the Pei-piao series, contains a number of plant fossils and some important common species are found in both. However, evidence of the living conditions of the flora from the former indicates a more arid climate than the latter.

Jeholosauripus, the fossil footprint that characterizes the Yang-shan series, closely resembles the Grallator of Grallatoridae from the Connecticut Valley U.S.A. Based on this fact the Yang-shan series can be correlated with the Newark series. Accordingly, it is possibly Triassic.

References

MATSUZAWA, I. (1939), On the Coal Measure of the Pei-piao Coal Field and its Geological Age, *Jour. Geography*, no. 602.

NISHIDA, S. (1942), On a Few Facts in Connection with the Mesozoic Formation of the Pei-piao Coal Field and the Vicinity, *Bull. Geol. Surv. Manch.*, no. 107.

—— (1958), On the Crustal Movements of Mesozoic Era in Manchuria, Jubilee Publication in Commemoration of Prof. Jun SUZUKI, M. J. A. Sixtieth Birthday.

—— (1966), Mesozoic Crustal Movements in Northeastern China, *Chikyu Kagaku*, vol. 24, no. 5.

TAN, H. C. G. (1926), Geology of the Pei-piao Coal Field, Ch'ao-yang District, Jehol, *Bull. Geol. Surv. China*, no. 8.