Upper Paleozoic Formations of Coal Fields in North China

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Introduction

The author was engaged in the investigation of coal fields in North China from 1937 to 1945 and has reported, at least in outline, the results of every investigation completed. As he submitted all data and specimens to the Chinese Government following Japan's surrender in 1945, this paper has been prepared on the basis of the author's memories and papers, reports by the North China Development Company which had previously been sent to Japan, and also the data presented to Japanese scholars visiting North China.

In the coal fields of North China, there are coal seams of the Upper Paleozoic, Mesozoic and Cenozoic eras. Most of them belong to the Upper Paleozoic era; those of the Mesozoic era succeed them and are developed regionally, but those of the Cenozoic era are rare. The coal fields of the Upper Paleozoic era are widely distributed and contain coal seams of superior quality, so these have been exploited for a long time, and have been investigated and studied geologically and paleontologically by many researchers. The author examined the stratigraphic order of the Upper Paleozoic formations and their interrelations, in order to consider sedimentation facies and crustal movements. He attempted to correlate these findings with the Upper Paleozoic formations in Central and South China and those in Korea, and he will present this data as a contribution to the synthetic study of the Upper Paleozoic formations in North China.

In connection with the preparation of this paper, the author expresses his grateful thanks to Takao SAKAMOTO, Fujio HOMMA and Nobuo YAMANOUCHI, for their kind guidance rendered to the author while he was in service at the South Manchuria Railway Company and later in the North China Development Company, surveying the geology of coal fields in North China. The author is indebted also to all persons who presented data and cooperated in his investigation.

1. Upper Paleozoic Formations and Coal Field Geology

I. Correlation of Upper Paleozoic formations in the coal fields of North China

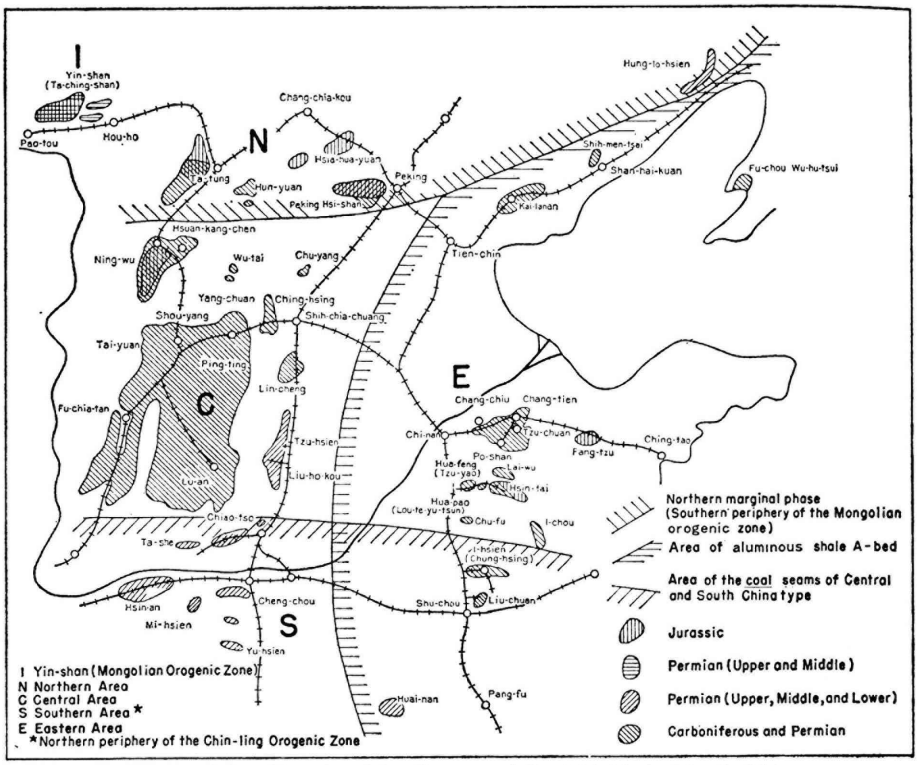

Fig. 1. Map Showing Distribution of Coal Fields in North China.

1. *Introduction*

Since the Upper Paleozoic formations in North China contain coal seams forming important coal fields, research on those formations can be accomplished by a stratigraphical study of coal field geology. Further, Mesozoic coal measures are associated with the coal fields of North China. These coal fields provide favorable conditions for a stratigraphical study of the complex, from the Paleozoic to the Mesozoic eras.

The distribution of coal fields in North China is as follows:

1) Eastern provinces: Chi-tung (Shih-men-chai and Kai-lan); Shan-tung (Tze-Po-Chang, Lai-wu, Ta-wen-kou, Hsin-tai, I-chou, Chiu-fu, Y-hsien); and Northern Chiang-su (Liu-chuan).

2) Northern provinces: Hsi-shan in the suburb of Peking; Hun-yuan; Ta-tung.

3) Northernmost provinces: Yin-shan (Ta-tsing-shan).

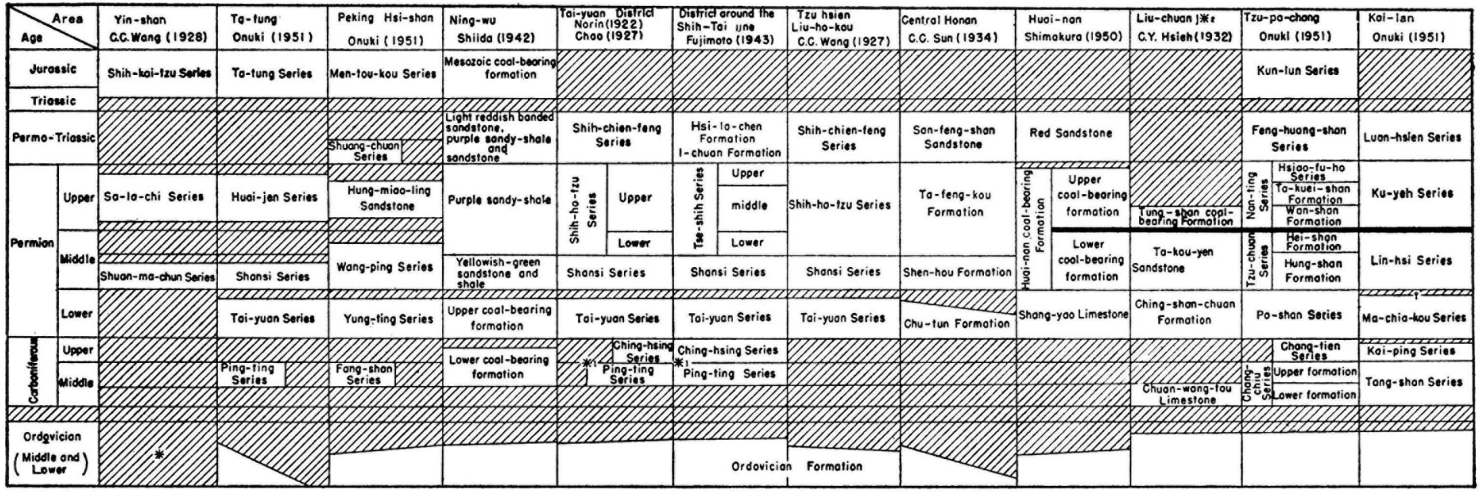

Fig. 2. Correlation of Upper Palaeozoic Formations in North China.

4) Central provinces: Ning-wu; Wu-tai; Southern Shan-hsi (Tai-yuan district, the area along the Shih-Tai Railway Line, the marginal portion of the Tsin plateau); and the eastern side of the Tai-hang mountain range (Tzu-hsien—Liu-ho-kou).

5) Southern provinces: Southern side of the Tai-hang mountain range; the Yellow River basin; Central Honan; and Huai-nan.

I will outline the stratigraphic order of each coal field in North China. The constituent formations are correlated synthetically in Fig. 2, and each bed will be explained.

2. *Carboniferous formation*

In the Upper Paleozoic areas of North China, the Moscovian of the Middle Carboniferous period is well developed, but the Uralian complex of the Upper Carboniferous period is lacking, and unconformity is present between the Middle Carboniferous formation and the Lower Permian formation in most places. Mitsuo NODA (1950) stated that this relation holds true for North China and Manchuria.

The Late Carboniferous formation is commonly called the Pen-hsi (or Pen-chi) series in North China and Manchuria, but after a detailed survey of all coal fields in North China, the author recognized the necessity of dividing the series into the Chang-chiu series and Chang-tien series in the Tze-Po-Chang coal field, and the Ping-ting series and Ching-hsing series in the region along the Shih-Tai Railway Line. Their interrelations are shown in Table 1.

Table 1. Relation between Late Carboniferous and Lower Permian formations.

Age	Area along the Shih-Tai line	Tze-po-chang		Division in the past
Lower Permian (Sakmarian)	Tai-yuan series	Po-shan series		Tai-yuan series
Upper Carboniferous (Uralian)	Ching-hsing series	Chang-tien series		Pen-chi series
Middle Carboniferous (Moscovian)	Ping-ting series	Chang-chiu series	Upper beds	
			Lower beds	

The formations, recently distinguished by the author from the Ping-ting series or the upper beds of the Chang-chiu series as stated above, are intercalated with flint-bearing limestone, commonly varying from 4 m to 10 m in thickness. This limestone is given different names in different places: Tang-shan limestone in Kai-lan; Hsu-chia-chuang limestone in Chang-chiu; Feng-shui limestone in Tze-chuan and Po-shan; Lin-cheng limestone in Ping-ting and Yang-chuan; Pan-kou limestone in Tai-yuan; Kou-chuan limestone in Ta-tung; and Fang-shan limestone in Hsi-shan in the suburbs of Peking.

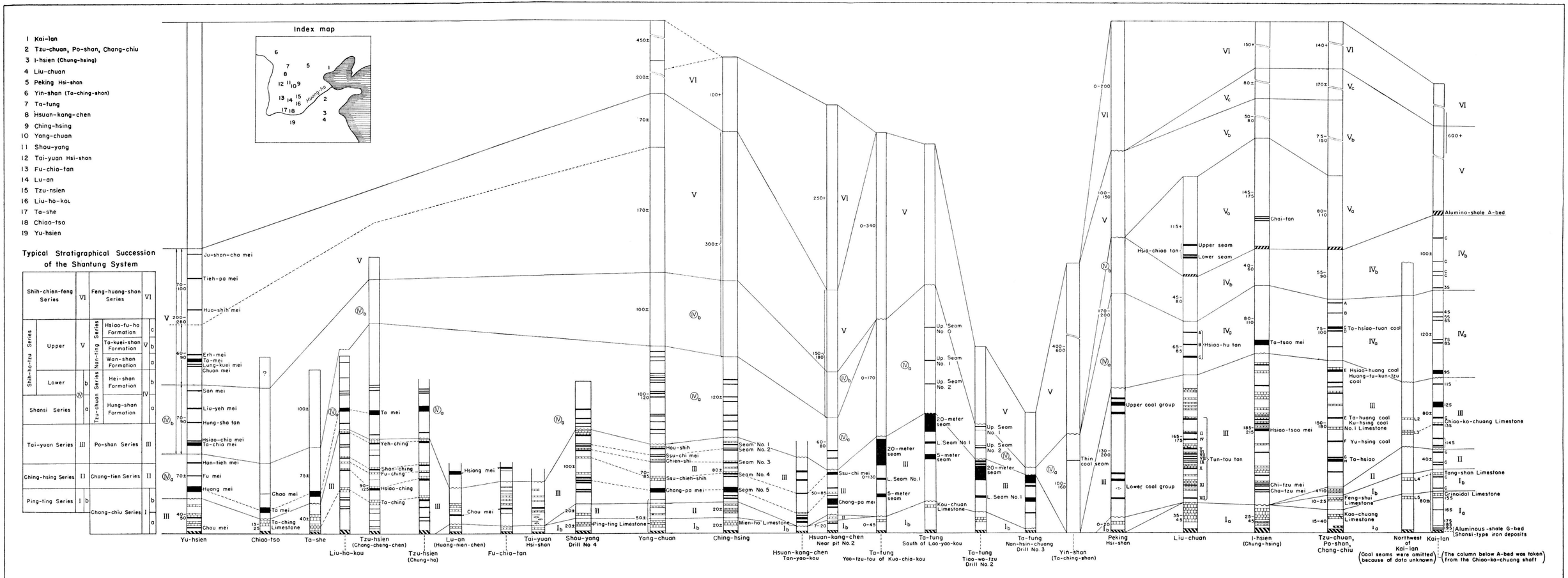

Fig. 3 Columnar Sections of the Upper Palaeozoic (Shantung System) of Coal Fields in North China

In the Tze-Po-Chang, Chung-hsing, Liu-chuan and Kai-lan regions, the lower beds of the Chang-chiu series are developed beneath them, indicating that these regions were affected by transgression earlier than other regions. The Ping-ting series and Ching-hsing series cannot be seen in Liu-ho kou in Tze-hsien (prefecture) in Ho-nan Province, which suggests that this area was affected by transgression later than other regions. This feature shall be regarded as overlapping by transgression, which advanced from the east.

As stated above, in the North China coal fields there are two cases for the Ching-hsing series or Chang-tien series, corresponding to the Uralian, i.e. Upper Carboniferous period. In one case, these series grade into the Permian formation conformably. In the other, these are not developed, and there is an unconformity between the Middle Carboniferous formation and the Permian formation. Their relations are as follows:

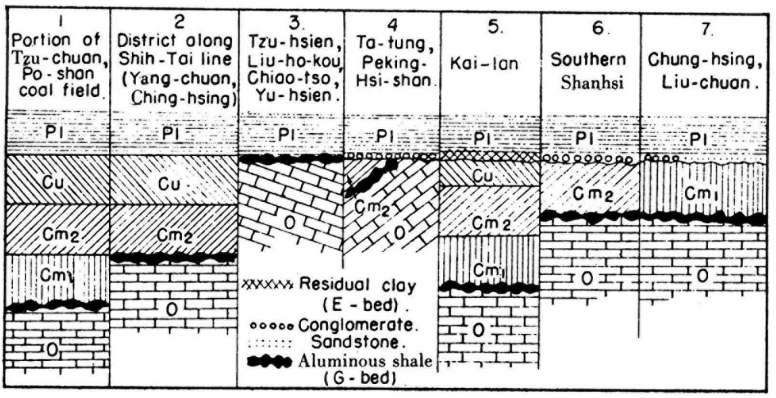

Fig. 4. Boundary between Permian and Carboniferous.

1, 2	Cases of Conformity	Pl. Permian (Lower)	Tai-yuan Series, Po-shan Series.
3, 4		Cu. Carboniferous (Upper)	Ching-hsing Series, Chang-tien Series.
5, 6, 7	Cases of Unconformity	Cm_2. Carboniferous (Middle)	Ping-ting Series, Upper Chang-chiu Series.
		Cm_1. Carboniferous (Lower)	Lower Chang-chiu Series.
		O. Ordovician	

(a) Cases of conformity

Regions along the Shih-Tai Railway Line, including Ching-hsing, Yang-chuan and Shou-yang, and Tze-po-chang district (exception: part of Tze-Po-Chang).

(b) Cases of unconformity

(i) Regions where the Ching-hsing series is lacking:—Ta-tung, Hun-yuan, part of Tai-yuan, southern Shan-hsi, Hsi-shan in the suburbs of Peking, and Lai-wu.

(ii) Regions where the Chang-tien series and the upper beds of Chang-chiu series are lacking:—Chung-hsing and Liu-chuan.

(iii) Regions where the Chang-tien series or the upper part of Ching-hsing series are lacking:—part of Tze-Po-Chang, Hsien-kang-chen, Kai-lan, and part of Tai-yuan district.

(iv) Regions where the Carboniferous formation is wholly lacking (Lower Permian formation covers Cambro-Ordovician formation directly):—Ho-nan district, Huai-nan district, part of Ta-tung, most of Hsi-shan in the suburbs of Peking, and part of Lai-wu.

3. *Permian formation*

The Permian formation is divided into marginal-facies and central-facies types by the rock facies of sediments and the stratigraphical conditions of unconformity. The marginal facies is further divided into Yin-shan and Tsin-pei types, and the central facies into Tsin-nan and Shan-tung types. On the other hand, the Permian formation can be stratigraphically divided into three, i.e., upper, middle and lower beds. The names of strata belonging to the Permian period differ according to district as shown in Fig. 2, but are classified on the basis of sedimentation facies as shown in Table 2.

In relation to the table, it should be noted that in the central facies, (1) the gap of sedimentation is small, (2) the rock facies is fine-grained and the Tai-yuan series includes limestone, and (3) "A" bed of aluminous shale (Shan-tung type) or clay (Tsin-nan type) is contained in the base of the upper beds. On the other hand, in the marginal facies, (1) the gap of sedimentation is big, as seen in the table, and unconformity is often seen, (2) the rock facies is coarse-grained and the Tai-yuan series contains no limestone, and (3) the horizon of "A" bed of aluminous shale is lacking, with apparent unconformity.

In the central facies, the Tsin-nan type shows unconformity between the Tai-yuan series and the Shan-hsi series, but the Shan-tung type involves almost no unconformity. The Yin-shan type of marginal facies lacks the Tai-yuan series, but the Tai-pei type contains the series although it varies in thickness.

(a) Lower Permian formation

It consists of marine deposits, which are named Tai-yuan series, Po-shan series, Ma-chia-kou series, Ching-shan-chuan series, Shang-yao limestone, Chu-tun beds and Yung-ting series.

(b) Middle Permian formation

The strata deposited after this formation are terrigenous in North China, and parallel unconformity is often found between them and Lower Permian strata that are marine deposits. This relation is the most remarkable in the Yin-shan mountain range, and the Shuan-ma-chun series rests upon the Sinian formation directly. In the Shan-tung type coal fields, the complex, ranging from the lower limit of "A" bed of aluminous shale to the upper limit of the marine Po-shan series, is distinguished by the name of Tze-chuan series in Shan-tung, Ma-chia-kou series in Chi-tung and Lower coal measure in Huai-nan, and "A" bed of aluminous shale has an important significance stratigraphically, as has already been stated. The terrigenous formation is called the Shan-hsi series in the Tsin-nan type coal fields,

Table 2. Representative Names.

Facies		Marginal facies		Central facies				Fossils	
Type		Yin-shan type	Tsin-pei type	Tsin-nan type		Shan-tung type			
Permo-Trias				Shih-chien-feng series		Feng-huang-shan series		*Lepidodendron**	
Permian	Upper	Sa-la-tsi series	Huai-jen series	Shih-ho-tzu series	Upper	Nan-ting series		*Gigantopteris*	*G. nicotianaefolia*
	Middle				Lower	Tze-chuan series	Hei-shan bed		*G. whitei*
		Shuan-ma-chun series	Shan-hsi series	Shan-hsi series			Humg-shan bed		
	Lower		Tai-yuan series	Tai-yuan series		Po-shan series		*Pseudoschwagerina princeps*	

* Quarry at Hsi-luo-chen in the west of Yang-chuan along the Shi-Tai Railway Line. Collected by Haruyoshi Fujimoto (1946). "A" bed of aluminous shale.

and the corresponding formations are named the Shen-hou beds in Ho-nan and the Shuan-ma-chuan series in Yin-shan. In both the Shan-hsi series and the Shen-hou beds, the higher the horizon, the rarer the intercalation of coal seams, and rocks with yellowish-green and red coloration appear. This red-rock complex is called the Shih-ho-tzu series in the Tsin-nan coal field, and is divided into upper and lower parts, with the "A" bed of aluminous shale taken for the key bed of division. In the regions of the marginal facies, such as Ta-tung, Yin-shan and Hsi-shan of Peking, an unconformity (a good-sized gap) is found between the complex corresponding to the Upper Shih-ho-tzu series (that is, the Huai-jen series, the Sa-la-tsi series and the Hung-miao-ling sandstone bed) and the underlying complex (Shan-hsi series and corresponding formations). Accordingly, the "A" bed of aluminous

shale is supposed to have formed in the coal fields of Shan-tung type during the erosion period of this gap.

The Shan-hsi series passes gradually into the Shih-ho-tzu series, so the boundary between the two can hardly be determined and evidence of unconformity is not seen in the Shih-ho-tzu series. Therefore, the Shih-ho-tzu series is regarded as Middle Permian or Upper Permian in age.

(c) Upper Permian formation

"A" bed of aluminous shale occurs at the base in the Shan-tung type coal fields. This formation has long been known as the Ku-yeh formation in Kai-lan, which corresponds to the Nan-ting series in Tze-Po-Chang and the upper coal measure of Huai-nan. It is also represented by the Upper Shih-ho-tzu series in Tsin-nan and other regions and the upper part of the Ta-feng-kou formation in Ho-nan, in the coal fields of the Tsin-nan type. In the regions of marginal facies, the Huai-jen series of Ta-tung, the Sa-la-tsi series of Yin-shan, and the Hung-mioa-ling sandstone of Hsi-shan, Peking correspond to this, and all contain *Gigantopteris nicotinaefolia* flora.

(d) Permo-Triassic formation

A complex consisting of red sandstone is better developed in the upper horizon than the Shih-ho-tzu series, and it is named the Feng-huang-shan series in Tze-Po-Chang, the Shuang-chuan series in Hsi-shan, Peking, and the Shih-chien-feng series in Shan-hsi district. The formation distributed along the Shih-Tai Railway Line was divided by Haruyoshi FUJIMOTO (1943) into the Chin-chuan formation and the Hsi-lo-chen formation, in ascending order. FUJIMOTO (1946) collected many plant fossils, including *Lepidodendron* and *Calamites*, from a quarry in the vicinity of Hsi-luo-chen hamlet west of Yang-chuan along the Shih-Tai Railway Line. This red sandstone complex was regarded as Triassic in the past, but, as these fossils suggest Paleozoic in age, the author provisionally assigns its age to the Permo-Triassic period. This problem involves the serious questions that the determination of geologic ages necessiates further more investigations and researches in detail.

II. Correlation of Upper Paleozoic formations in North, Central and South China

1. *Stratigraphic succession in coal fields of Central and South China*

It is necessary to refer to the stratigraphic succession in coal fields of Central and South China for both the stratigraphic correlation and the consideration of the geologic age of North China coal fields. The stratigraphic succession in the central district of Hu-nan Province, in the mountainous district of Nanking, and in the Chang-hsing coal field of Che-kiang Province is shown in Table 3 to provide an outline.

Table 3. Outline of Stratigraphic Succession in Coal Fields of Central China.

Age		Central district, Hu-nan district	Nanking mountainland	Chang-hsing coal field, Che-kiang Province
Permian	Upper	Thinly bedded muddy limestone	Tung-yang-kang system (120 m)	Chang-hsing limestone (20 m)
		Tou-ling coal measure*	Lung-tan coal measure* (80 m)	Lung-tan coal measure* (300 m)
	Middle	*Doliolina* limestone	Ku-feng formation (0–10 m)	Ku-feng limestone (10 m)
		Yuan-chia-chung coal measure**	Chi-hsia formation (150 m)	Chi-hsia limestone (140 m)
	Lower	Tzu-men-chiao limestone (upper)	Chuan-shan limestone (20 m)	Chuan-shan limestone (30 m)
Carboniferous	Middle	Tzu-men-chiao limestone (middle)	Huang-lung limestone (100 m)	Huang-lung limestone (30 m)
	Lower	Tzu-men-chiao limestone (lower)	Ho-chou limestone (10 m)	
		Tzu-shui system**	Kao-li formation** (15–50 m)	Kao-li shale** (40 m)
			Chin-ling limestone (4–6 m)	
		Chiu-chin-chung manganiferous system	Wu-tung formation** (200–300 m)	Wu-tung quartzite** (270+ m)

* Principal coal measure. ** Thin coal seam is intercalated.

As the table shows, the Lower Carboniferous formation and Middle Permian formation are locally intercalated with thin seams of coal, but the principal coal-bearing formations are the Lung-tan coal measure and corresponding strata. The Lung-tan coal measure is composed of terrigenous marine deposits and yields *Lyttonia* fauna and *Gigantopteris* flora. The fact that the Lung-tan coal measure yields animal and plant fossils and is intercalated with workable coal seams is especially important for the correlation of coal measures between North China and Central to South China. Table 4 shows the stratigraphic succession and index fossils of the Paleozoic coal fields in Central and South China.

The Lung-tan coal measure is the principal coal producer in Central and South China, as already stated. According to C. T. HUANG (1932), the formations to be correlated with the Lung-tan coal measure are as shown in Table 5.

Thus, the principal coal measure in Central and South China corresponds to the

Lung-tan coal measure of the Le-ping system. It is intercalated with limestone and presents a terrigenous marine facies characteristically yielding *Gigantopteris nicotinaefolia*. It is also important as a formation containing the so-called Le-ping paleofauna represented by *Lyttonia*.

Table 4. Stratigraphic Succession and Index Fossils of Coal Fields in Central and South China.

Age		System	Western C. China & western S. China		Eastern C. China	Fossils
Permian	Upper	Le-ping system	Chang-hsing limestone		Chang-hsing limestone	*Lyttonia* fauna *Oldhamina* *Gigantopteris*
			Chu-tang system (marine)	Lai-pa-kou system (terrigenous)	Lung-tan coal measure	
			O-mei-shan basalt			
	Middle	Yang-hsin system	Mao-kou limestone		Ku-feng formation	*Neoschwagerina* fauna
			Chi-hsia limestone		Chi-hsia limestone	*Tetrapora* fauna
	Lower	Chuan-shan system	Chuan-shan limestone		Chuan-shan limestone	*Pseudoschwagerina princeps*
Carboniferous	Middle	Wei-ning	Wei-ning limestone		Huang-lung limestone	*Fusulinella bocki*, *Staffella sphaeroidea*

Table 5. Contemporaneous Coal Measures in Central and South China.

Name of formation	Area	Corresponding formation	Author
Lung-tan coal measure	South Kiang-su	Le-ping system	L.C. LIU, J.C. CHAO
Li-hsien coal measure	West Che-kiang	Le-ping system	L.C. LIU, A.T. CHAO
Fang-chung coal measure	S. Kiang-su	Le-ping system	C. J. HSIEH
Yen-wa coal measure	S. Kiang-su	Le-ping system	L.C. LIU
Chu-tang system	S. An-hwei	Chu-tang formation	L.F. YEH, C. LI
Hsuan-ching coal measure	S. An-hwei	Le-ping system	L.F. YEH, C. LI
Tao-chung coal measure	S. An-hwei	Chu-tang fm. (Lai-pa-kou series)	Ichiro HAYASAKA

Ku-feng system	S. An-hwei	*Gastrioceras zitteri* horizon	S. CHU
Feng-tien coal measure	W. Kiang-si	Le-ping system	C.C. WANG
Chin-hsien c. m.	C. Kiang-si	Le-ping system	H.C. TAN, S.W. WANG
Lao-hu-shan c. m.	W. An-hwei NW. Kiang-si	Le-ping system	C.C. WANG
Tan-shan-wan c. m.	SE. Hu-pei	Le-ping system	C.J. HSIEH
Pao-an shale	SE. Hu-pei	*Gastrioceras zitteri* horizon	C.J. HSIEH
Mao-chuang c. m.	SW. Hu-pei	Le-ping system	C. J.HSIEH, L.C. LIU
Chung-tzo-shan limestone	W. Hu-pei	Le-ping system + Mao-kou limestone	S.K. LI
Tou-ling system	C. Hu-nan	Le-ping system	C.C. TIEN
Lai-pa-kou formation	C. Hu-nan	Lai-pa-kou fm.	RICHTHOFEN
Chiao-tzu-shan c. m.	W. Kwei-chow	Le-ping system	S.H. LO
Hsuan-chia-ping c. m.	S. Kwei-chow	Le-ping system	S.H. LO
Hu-kou shale	S. Fu-kien	Le-ping system (?)	S.W. WANG
Huang-kang-ling c. m.	N. Canton (Kuang-tung)	Lai-pa-kou series or Le-ping system (?)	C.T. FENG

2. *Correlation*

The stratigraphic succession in Paleozoic coal fields in North China and Central and South China is correlated as shown in Fig. 5. The basis for correlation is explained as follows:

(a) Chang-chiu series

The Chang-chiu series yields *Fusulinella bocki, Staffella sphaeroidea, Spirifer mosquensis* and others. Its age is regarded as Middle Carboniferous (Moscovian), and it is correlated with the Huang-lung limestone and the Wei-ning limestone.

(b) Chang-tien series

Upper Paleozoic formations are lacking in Central and South China, and an unconformity is believed to exist between Middle Carboniferous and Lower Permian formations. Although an unconformity is recognized in most places of North China, too, the central portion of the sedimentary basin, including most of the Tze-Po-Chang coal field and the area along the Shih-Tai Railway Line, is supposed to have been covered by sea water continuously during the Middle Carboniferous to Upper Carboniferous period, as has already been stated.

(c) Po-shan series

Many fossils of Fusulinidae including *Pseudoschwagerina princeps* are found in the

Po-shan series, and the series is paleontologically correlated with the Chuan-shan limestone in Central and South China.

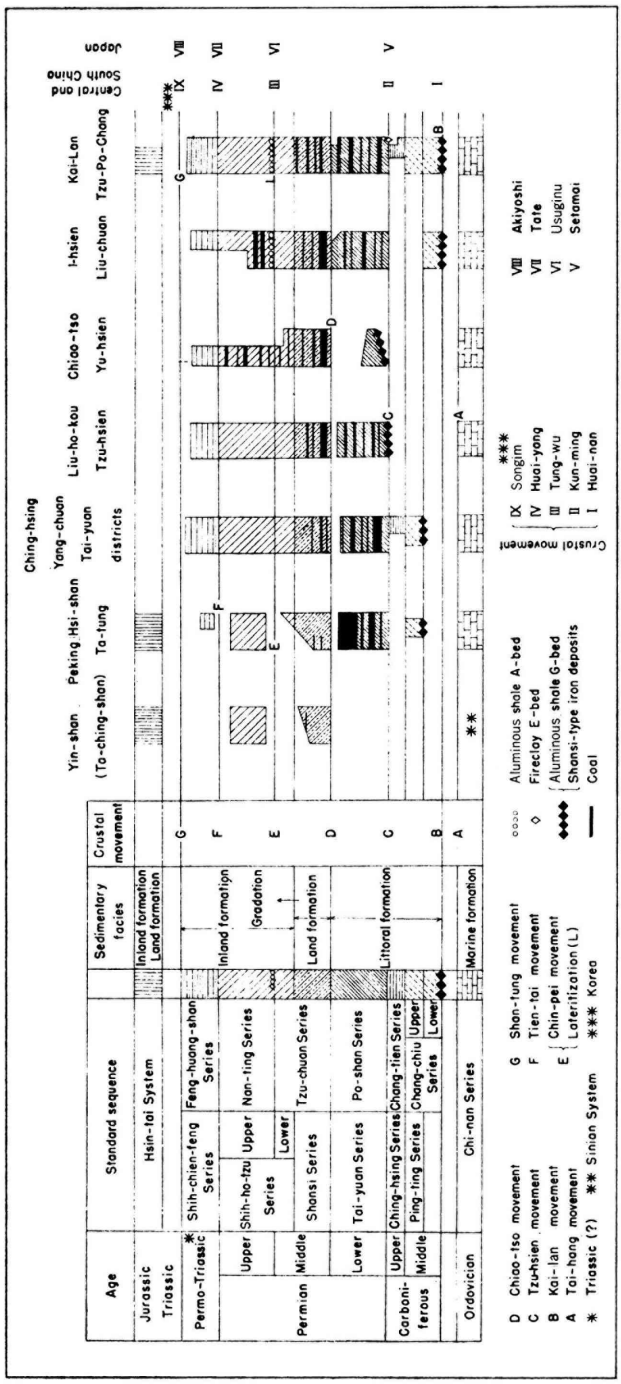

Fig. 5. Correlation of the Stratigraphical Successions of the Coal Fields of North China, Central and South China.

(d) Tze-chuan series

In North China the Tze-chuan series and younger strata show a terrestrial or inland facies, so that it is difficult to correlate them with the contemporaneous formations in Central and South China which show a marine facies. However, on the basis of the locally correlatable horizons, their stratigraphic positions and their unconformable relations, we may be able to make the following correlation.

We can see throughout North China that the relation between the Tze-chuan series and the Po-shan series, or between the Shan-si series and the Tai-yuan series, is disconformable. On the other hand, in Central and South China the Chi-hsia limestone and the Chuan-shan limestone are almost always conformable, though it is true that, in Fu-kien Province, the Chi-hsia limestone rests unconformably on the Lower Carboniferous Wu-tung formation (HOU, 1935), so it cannot be denied that there was a partial unconformity or an extensive transgression between them. Consequently, it may not be unreasonable to correlate stratigraphically the Chi-hsia limestone with the Tze-chuan series or the Shan-hsi series. The "A" bed of aluminous shale is developed upon the Tze-chuan series, and in this horizon in the region showing the marginal facies of North China an unconformity is seen, which is regarded as contemporaneous with the unconformity after the Yang-shin system. Therefore, if a correlation is made for the crustal movement after the deposition of the Chuan-shan system, Po-shan series or Tai-yuan series, and for the succeeding crustal movement after the deposition of the Tze-chuan series and the Yang-hsin system, it may become possible to regard the Tze-chuan series as nearly contemporaneous with the Yang-hsin system of Central and South China. According to C. C. TIEN, a coal measure named Yuan-chia-chung occurs below *Doliolina* limestone in the central district of Hu-nan Province, but this is a littoral deposit to be correlated with the Chi-hsia limestone.

(e) Nan-ting series

As often stated, it is almost certain that the Nan-ting series of Shan-tung, upper part of the Shih-ho-tzu series of Shan-hsi, and the Huai-jen series of Ta-tung are all in the same horizon. From the fact that these formations yield *Gigantopteris* flora and that the Nan-ting series in the Y-hsien and Liu-chuan coal fields contain coal seams which correspond to the principal coal seams in Central and South China, the Nan-ting series of North China can be correlated with the Lung-tan coal measure of the Le-ping system of Central and South China.

The Lung-tan coal measure and corresponding formations in Central and South China are littoral deposits characteristically yielding *Lyttonia* and plant fossils such as *Gigantopteris nicotinaefolia.*

In this connection, *Lyttonia* is found in all Permian formations in Japan (Sakamotosawa series, Kanokura series, Toyoma series). It serves as an important fossil of Le-ping fauna, facilitating correlation of the Le-ping system of the Upper Permian period in Central and South China with the Toyoma series of Japan. This fossil is yielded from the Chi-hsia limestone (Middle Permian) of China and also from the A-tang series of Manchuria (to be correlated with the Tai-yuan series and

the Po-shan series of North China, and with the Sakamotosawa series of Japan) yielding *Pseudoschwagerina* at Yang-shu-kou in the Wu-hu-tsui coal field.

(f) Feng-huang-shan series

The Feng-huang-shan series in Shan-tung is a red sandstone, lying conformably upon the Nan-ting series, which corresponds to the Shih-chien-feng series (NORIN, 1922) in Shan-hsi, the Chin-chuan formation and the Hsi-lo-chen formation (FUJIMOTO, 1943, 1946) along the Shih-Tai Railway Line. FUJIMOTO collected important Permian plant fossils, including *Lepidodendron* and *Calamites*, from the Hsi-lo-chen formation, thus raising a question important for determining the age of the Shih-chien-feng series, which was regarded as Triassic in the past. However, the author has no data for judging the geologic age of this series, and so tentatively treats it as Permo-Triassic.

In Central and South China, the formation covering the Lung-tan coal measure is the Chang-hsing limestone, containing *Oldhamina* of the *Lyttonia* fauna. On it lies the Triassic Ching-lung limestone or corresponding Ta-yeh limestone, and these are all marine deposits. These rocks are quite different from the red formation of the Feng-huang-shan series of North China in sedimentary environment and it is impossible to connect them paleontologically.

(g) Correlation of coal seams

The correlation among coal measures in North China was not complete in the past. In North China, those containing workable coal seams are the Po-shan series (Tai-yuan series) and the Hung-shan formation of the Tze-chuan series (Shan-si series), but in the area covering southern Shan-tung Province and central Ho-nan Province, including Huai-nan, the Nan-ting series (Upper Shih-ho-tzu series), too, is intercalated with workable coal seams (ONUKI 1945a, 1946). In Central and South China important workable coal seams are contained only in the Lung-tan coal measure, which is in the same horizon as the Nan-ting series.

III. Correlation of Upper Paleozoic formations between North China, Manchuria and Korea

1. *General remarks*

The Upper Paleozoic formations in South Manchuria and North Korea, contiguous to North China, are well represented by the Tai-tzu-ho system in the former and by the Pyongan (Heian) system in the latter. The stratigraphic succession of the Upper Paleozoic formations in these regions closely resembles that of the Shan-tung system, named by the author (ONUKI, 1944a, b), in Chi-tung and Shan-tung districts in the eastern part of North China. On the other hand, it also resembles the sequence in the Jehol district and in the area of Ta-tung to Hsi-shan in the suburbs of Peking, where the strata show a marginal facies of a vast depositional basin. The relation is indicated in Fig. 6.

2. *Relation between the eastern region of North China, South Manchuria and North Korea*

The close resemblance of stratigraphic succession between the eastern part of

North China, namely Chi-tung and Shan-tung, and South Manchuria and North Korea is unanimously accepted according to previous studies, so only two or three problems will be considered here.

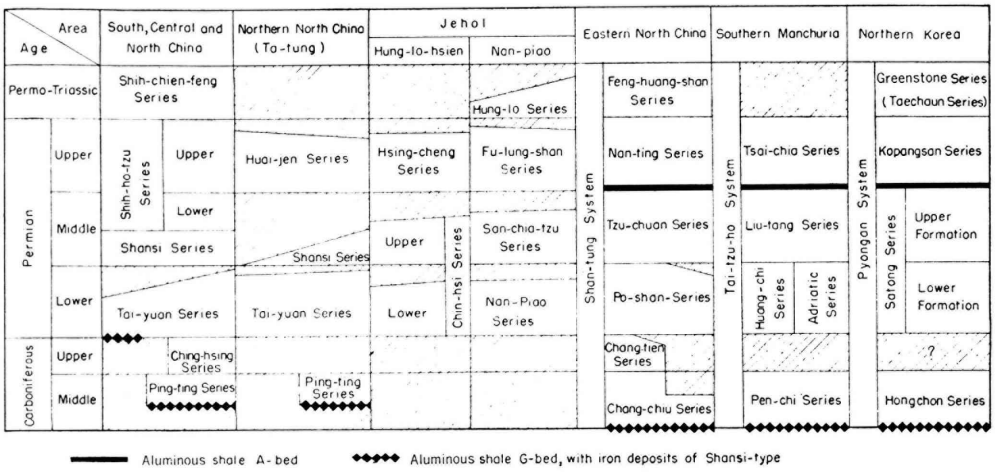

Fig. 6. Correlation between North China, Manchuria and Korea.

a. Pen-hsi (or Pen-chi) series[1)]

The Carboniferous formation in North China was treated in the past as the Pen-hsi series, as it was in Manchuria. But the author, after investigation of the Tze-Po-Chang coal field, divided the formation into the Chang-chiu series and the Chang-tien series, and the formation along the Shih-Tai Railway Line into the Ping-ting series and the Ching-hsing series. The Chang-chiu and Ping-ting series were assigned to the Middle Carboniferous, and the Chang-tien and Ching-hsing series to the Upper Carboniferous period. The lack of Upper Carboniferous in Manchuria was studied in detail by Mitsuo NODA (1950). In North China, too, an unconformity is recognized over a wide area, at the base of the Permian formation though a conformity seems to occur in limited areas, where the Chang-tien series of the Upper Carboniferous period was deposited.

b. Relation of the formations correlatable with the Po-shan series or Tai-yuan series

The formations corresponding to the Po-shan series or the Tai-yuan series of North China are intercalated with limestone and terrigenous marine sediments. The A-tang series (HANZAWA, 1941) in the Wu-hu-tsui coal field, Fu-chou, Manchuria, is located east of the Kai-lan coal field, China, across the Gulf of Pechili, and is intercalated with limestone as in North China. However, the Huang-chi

1) The transgression in Manchuria is supposed to have started earlier than in North China, so it is possible that the lower limit of the Pen-hsi series in Manchuria is somewhat older than that in North China.

series, distributed over the Tai-tzu-ho basin in Manchuria, has no limestone intercalations, and the A-tang series in Wu-hu-tsui, Fu-chou, was once regarded to be absent between the Pen-hsi series and the Huang-chi series (CHAO, 1926). But NODA collected marine animal fossils from the Huang-chi series in 1939 and made it clear that the A-tang series and the Huang-chi series are equivalent and occur in the same horizon. The Tai-yuan series in Ta-tung and Hun-yuan coal fields and the Yung-ting series in Hsi-shan in Peking contain lenses of limestone, or calcareous shale or calcareous sandstone locally but almost no limestone beds are intercalated as in the case of the Huang-chi series. This sedimentation facies is limited to regions showing the marginal facies, but this feature is similarly observed in the Tai-tzu-ho region of Manchuria.

c. "A" bed of aluminous shale

"A" bed of aluminous shale occurs in the Tai-tzu-ho region of Manchuria and in the eastern region of North China, so persistent geophysical conditions seem to have prevailed over the wide area extending from the eastern part of North China to South Manchuria and North Korea at that time. However, "A" bed of aluminous shale is entirely absent in the depositional area of the marginal facies type in the northern part of North China, and this area seems to have been subjected to erosion at the time of formation of the aluminous shale.

3. *Relation between the northern region of North China and the Jehol region of Manchuria*

a. Formations correlatable with the Ping-ting series

The Ping-ting series of the Ta-tung coal field and the Fang-shan series of Hsi-shan, Peking, are present but not developed throughout the region. The Tai-yuan series of the Ta-tung coal field and the Yung-ting series of Hsi-shan, Peking, were directly deposited upon the Cambro-Ordovician formation, with basal conglomerate. Similarly, no formation corresponding to the Ping-ting series is found in the Hung-lo-hsien coal field in Jehol surveyed by Nenji TAKAHASHI (1944a) or in the Nan-piao coal field in the same region surveyed by Li-shu CHANG (1944). The lower beds of the Chin-hsi series at Hung-lo-hsien and the Nan-piao series at Nan-piao cover the Cambro-Ordovician formation with basal conglomerate. These phenomena suggest that the northern marginal region of the North China coal fields is strikingly different from the central region in geologic structure, and was affected by crustal disturbance far more intensely than the central region in, at least, Upper Paleozoic.

b. Formations correlatable with the Tai-yuan series, Shan-si series and Huai-jen series

Formations to be correlated with the Tai-yuan series may be the lower beds of the Chin-hsi series in Hung-lo-hsien and the Nan-piao series in Nan-piao. Those to be correlated with the Shan-si series are the upper beds of the Chin-hsi series in Hung-lo-hsien and the San-chia-tzu series in Nan-piao, and those to be correlated with the Huai-jen series are the Hsing-cheng series in Hung-lo-hsien and the Fu-lung-shan series in Nan-piao.

It is not exactly known with which formation in North China the Hung-la

series is to be correlated, but it seems to be comparable to the Shuang-chuan series and the Shih-chien feng series.

The Tai-yuan series, Shan-si series and Huai-jen series in Ta-tung are unconformable with each other. Likewise, three groups in Hung-lo-hsien, namely the lower Chin-hsi series, the upper Chin-hsi series and the Hsing-cheng series, and four groups in Nan-piao, namely the Nan-piao series, San-chia-tzu series, Fu-lung-shan series and Hung-la series, are all in unconformable relation. These formations all presents the marginal facies of the great basin of North China.

c. Coal seams

As the Tai-yuan series in Ta-tung and the Yung-ting series in Hsi-shan, Peking form the principal coal measures, the lower beds of the Chin-hsi series and the Nan-piao series form the coal measures.

d. Coal seams occurring in the same horizon as the Nan-ting series

The principal coal measures in North China correspond to the Po-shan series and the Tze-chuan series, but in the southern part of North China the formations corresponding to the Nan-ting series sometimes form the principal coal measure. The principal coal measures in Manchuria are the Huang-chi series and the Liu-tang series, and those in Korea are the lower beds and the upper beds of the Jido series. The Tsai-chia series in Manchuria and the Kopangsan series in Korea, which are correlatable with the Nan-ting series, contain almost no coal. However, Nobuhiro HATAE reported recently that a coal seam was intercalated in the Kopangsan series. This fact is important for consideration of the relation of the coal-bearing formations in the southern part of North China to those in Central and South China and also those in North Korea.

2. Sedimentary Environment of Upper Paleozoic Formations

I. Sedimentary basin and cycle of sedimentation

1. *Introduction*

The Cambro-Ordovician formation is distributed widely in mountains throughout North China. Above this lie the Upper Paleozoic formations with unconformity, forming coal fields everywhere. The Cambro-Ordovician formation is a marine deposit, consisting of thick beds of limestone and dolomite, whereas the formations younger than Upper Paleozoic are composed of terrigenous-marine, terrestrial and inland deposits. The Upper Ordovician formation, Gotlandian formation, Devonian formation and Lower Carboniferous formation are lacking between the Cambro-Ordovician and the Upper Paleozoic formations. The Middle Ordovician formation is overlain directly by the Middle Carboniferous formation or Lower Permian formation, thus revealing the transgression overlap and the changes in sedimentary facies, as well as a great time gap due to erosion. However, in spite of the great erosion gap and the facies changes in Middle Paleozoic, the Lower and Upper Paleozoic formations are generally in a disconformable relation, and their sedimentary basins were not at all deformed. The sedimentary environments of the

Upper Paleozoic formations in North China will be examined in the following paragraphs.

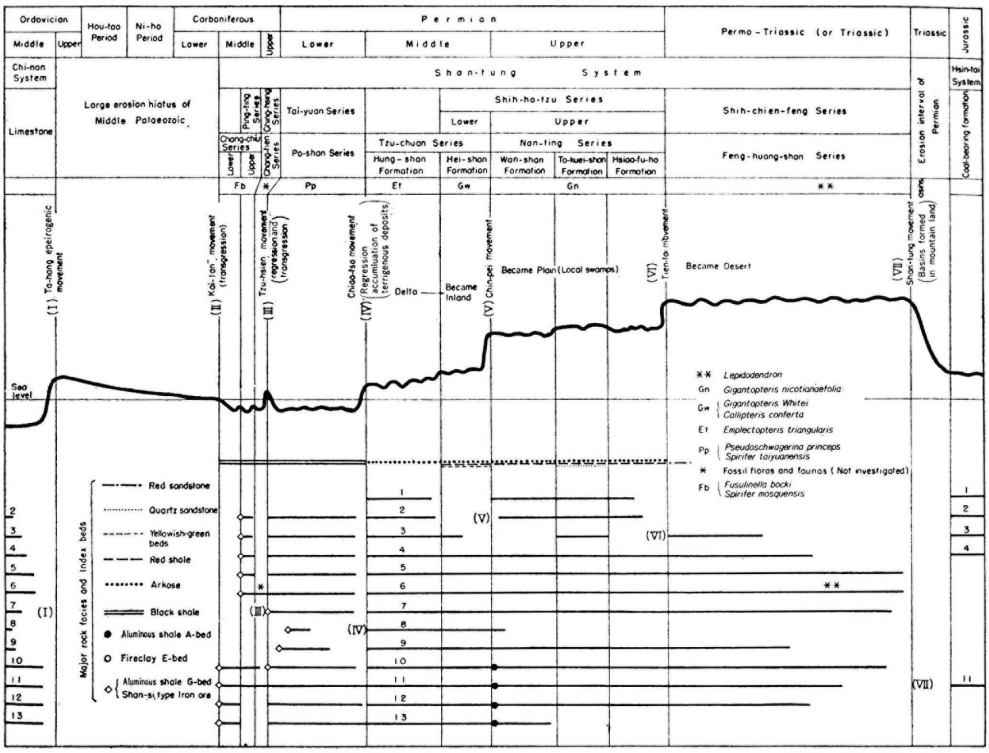

Fig. 7. Cycle of Sedimentation of the Shan-tung System.

1 Yin-shan (Ta-ching-shan)
2 Ta-tung
3 Peking Hsi-shan
4 Ning-wu
5 Tai-yuan District
6 Yang-chuan, Ching-hsing
7 Tzu-hsien, Liu-ho-kou
8 Chiao-tso, Ta-she
9 Central Honan (Yu-hsien)
10 Kai-lan
11 Tzu-chuan, Po-shan, Chang-chiu
12 I-hsien (Chung-hsing)
13 Liu-chuan

2. *Sedimentary basin and cycle of sedimentation*

Upper Paleozoic formations in North China extend over a wide area from the Yin-shan mountain range (Mongolian orogenic zone) in the north to the area in the south bounded by the so-called Chin-ling—Seoul line, running southeastward from the northern foot of the Chin-ling mountain range, and their eastern extension is widely distributed from South Manchuria to North Korea (Fig. 1). Judging from this distribution, the sedimentary basin of the Upper Paleozoic formations seems to be nearly the same as that of the Lower Paleozoic. This sedimentary basin was formed between the Mongolian orogenic zone named by Teiichi KOBAYASHI and the Chin-ling—Seoul line, and is divided into several basins. The northern one is the Ping-an—Liao-tung basin, the southern one is the

Shan-kiang-an basin, with the Yellow River basin (a plain in North China at present) connecting the two, and the western one is the Shan-hsi basin. Further, the Tai-tzuiho basin is connected with the Ping-an—Liao-tung basin in Kai-lan region, and with the Jehol—Hsi-shan, Peking—Tsin-pei region, and forms a sedimentary basin between the Mongolian orogenic zone in the north and the Wu-tai mountainland in the south. The author named it the Peking—Tsin-pei basin, although it is connected with the Shan-hsi basin through the Ning-wu region.

The state of strata in this wide sedimentary basin shows that these were not products of the sedimentary environments characterized by intense crustal displacements due to an orogenic movement, but the mode of their deposition indicates essential features of Kratogen ascribed to a slow epeirogenetic movement, presenting a cycle of sedimentation from marine to terrigenous deposition and then to inland deposition.

The Upper Paleozoic formations in Central and South China are distributed generally to the south of the Yang-tze River, and their deposition continued intermittently from the time of the Lower Paleozoic formation, showing the marine sedimentary facies. The sedimentary facies of the Upper Paleozoic formations in North China is strikingly different from those in Central and South China, but considering the relations among marine animal fossils there is continuity from the middle part of the Carboniferous period to the lower part of the Permian period. The strata later than the Middle Permian period in North China grade into terrigenous or inland facies. But, considering the mode of occurrence of coal, in connection with coal measures of Central and South China, and the relations among the strata yielding *Gigantopteris* flora, the relationship between North China and Central to South China is supposed to be a close one.

II. Sedimentary facies

1. *General remarks*

Looking over the sedimentary facies of the Upper Paleozoic formations in North China, the strata ranging in age from Middle Carboniferous to Lower Permian present a terrigenous marine facies, while those from Middle to Upper Permian show a continental or inland facies. The terrigenous marine deposits are divided into three series, i.e., the Chang-chiu, Chang-tien and Po-shan, and the continental deposits are divided into the Tzu-chuan series, Nan-ting series and Feng-huang-shan series. The stratigraphical division of the Upper Paleozoic formations in North China varies more or less with area, as shown in Fig. 2. On the whole, the Upper Paleozoic deposits are roughly grouped into marine and continental facies, with an unconformity in between, as evidenced in many places. Thus, it is reasonably inferred that the continental deposits came to cover North China, keeping pace with the marine regression.

2. *Shallow marine deposits*

The deposits are mainly primarily consist of black shale, which contains pyrite

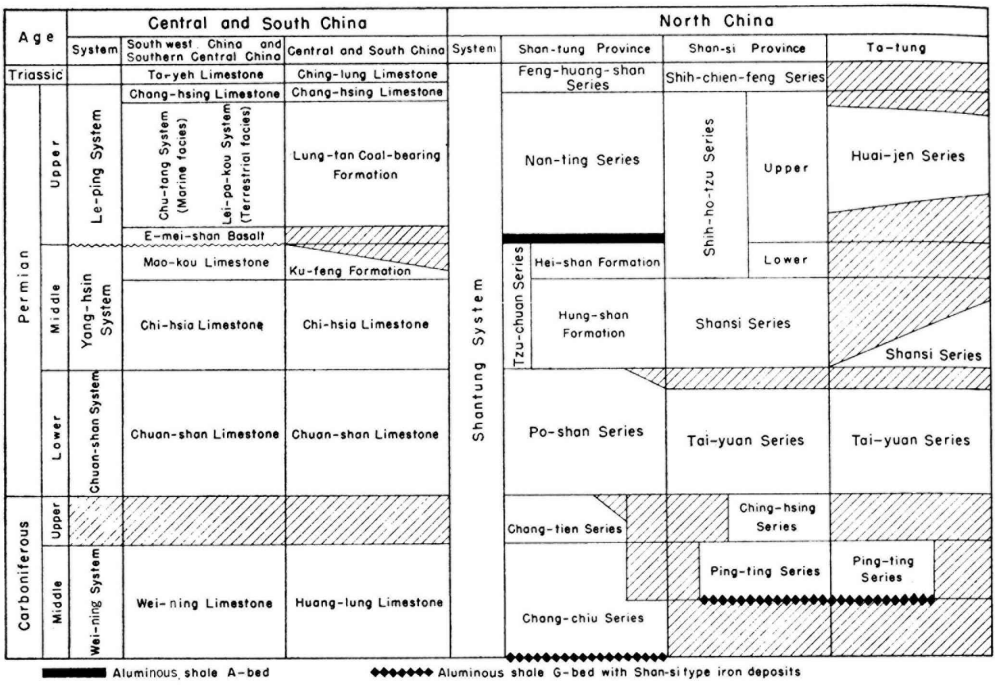

Fig. 8. Sedimentary Facies, Crustal Movement and Coal Seams of the Shan-tung System.

and is intercalated with limestone and coal seams. The coal seams also contain pyrite in masses or in bedded form. Although the sulphur content is rather high[2] the coal seams are generally uniform in thickness in each coal field. Further, soft clay and hard clay occur everywhere, providing a rich source of refractory and ceramic raw materials.

3. *Terrigenous deposits*

The terrigenous deposits are characterized by dominance of sandstone which is marked with false or irregular bedding. The sandstone constitutes a massive or thick platy formation and often makes cliffs. The formation covered the marine deposits under a deltaic environment during regression, and an unconformity is observed between the two in many places. The unconformable relation is often hardly recognized in areas that were supposedly deeper parts of the sedimentary basin, in spite of the conspicuous changes in lithology and strata from the marine facies to the terrigenous facies. However, the coal seams in the terrigenous deposits vary remarkably in thickness even within a single coal field. For example, the Ta-tsao coal of the Chung-hsing colliery varies in thickness from 10 m at its maximum to nearly zero. The coal seams intercalated in the terrigenous deposits are low in sulphur content and are excellent in terms of coal quality.

[2] The sulphur content of the coal seams intercalated in the marine deposits varies between one and 5%, and the coal is named a "stink coal". The sulphur content of the coal seams in the terrigenous deposits, on the contrary, is usually less than one percent, and the coal is named a "fragrant coal".

4. *Inland facies*

The facies gradually changes from terrigenous to inland, and red rocks become predominant. From the standpoint of age, the deposits gradually changed to an inland facies since the end of the Middle Permian period and the red rocks were added, but these rocks increased more in the Triassic than in the Upper Permian period until entire deposits came to be composed of red rocks in the last stage, and sometimes contain a gypsum layer. As stated above, conditions are supposed to have been tropical, with high temperature and dryness, from the end of Middle Permian through the early stage of the Triassic period. There was also a special condition which caused lateritization and the formation of the "A" bed aluminous shale over an extensive area from Chi-tung to South Manchuria and North Korea. Namely, that the northern region of North China was subjected to erosion during that period—a condition deduced from the unconformity in the Pre-Huai-jen series. The "A" bed aluminous shale was formed due to weathering under special topographic and climatic conditions in this period. The reason that the aluminous shale is rarely developed in the west of the Peking—Han-kou Railway may be ascribed to the influence of topography, even though the climatic conditions of the two regions were identical.

This inland formation contains coal seams in the southern regions of North China, namely, in the south of the line extending east-west at the southern margin of the Ta-hang mountain range, north of the Yellow River. In Shan-hsi, on the contrary, almost no coal has been developed, although abundant plant fossils (fossil flora of the Shih-ho-tzu series) are found in the contemporaneous formations. This suggests that the condition of the lake basin was not favorable for the formation of coal.

In the Permo-Triassic period, that is, the age of deposition of the Shih-chien-feng series and Feng-huang-shan series, the climate became warmer and drier, the land became a desert, gypsum was locally accumulated in the Shan-hsi district, and red rocks, sometimes mixed with green rocks, became dominant. The Shuang-chuan series, occurring at Hsi-shan in the suburbs of Peking, may possibly be correlated with those formations, but the plant fossils from this series contain Mesozoic elements besides the plants of the Nan-ting series or Upper Shih-ho-tzu series. This series is intercalated with several coal seams, and is supposed to have been deposited under the topographic conditions of an intermontane basin. Paleobotanically it is very interesting that Carboniferous and Permian plants, such as *Lepidodendron*, have remained in the strata corresponding to the Shih-chien-feng series.

III. Sedimentary ore deposits

Introduction

The ore deposits in the Upper Paleozoic formations include coal, aluminous shale, hard clay, soft clay, iron ores and pyrite. The mode of occurrence of these deposits will be stated to facilitate the study of the sedimentary environments.

Also, an outline of the status of limestones will be given to consider the relationship between marine and terrigenous facies.

A. Coal

1. *General remarks on coal seams*

The workable coal seams in the Paleozoic coal fields in North China are intercalated in the Po-shan series, Tze-chuan series and corresponding strata, but they are also intercalated in the Nan-ting series and corresponding strata in Chung-hsing, in the south of Liu-chuan, in central Ho-nan and in the Huai-nan coal field.

Looking over the thickness of coal seams, the coal of the Po-shan series is thicker toward the north and thinner toward the south, and is rarely developed in the central Ho-nan and Huai-nan regions. The coal of the Tze-chuan series is thicker in the south and thinner in the north, and there is almost no workable seam in the Ta-tung and Yin-shan districts in the north. The coal seams are from 6 m to 10 m thick in Chung-hsing, Tzu-hsien—Liu-ho-kou, Chiao-tso and central Ho-nan, in the southern region. The coal of the Nan-ting series is developed in Chung-hsing, Liu-chuan, central Ho-nan in the south of the southern margin of the Tai-hang mountain range, but is rarely found in most of North China, and the number of coal seams is one in Chung-hsing, two in Liu-chuan and over 10 in the Yu-hsien coal field in central Ho-nan.

2. *Coal seams of different coal fields*

Regarding the vertical mode of occurrence of coal seams, those of the lower horizons are better developed in coal fields in the north, while those of the upper horizons in coal fields in the south. This feature is specially important in considering the relationship between the coal fields of North China and those of Central and South China. The relationship is numerically shown as follows (total thickness of more than one meter):

(i) Coal seams in Po-shan series (Tai-yuan series)

Ta-tung and Hun-yuan	20 m
Ning-wu	11 m
Central Shan-hsi, Ching-hsing, Yang-chuan, Shou-yang and Tai-yuan—Hsi-shan along the Shi-Tai Railway Line	7.8 m
South of the line connecting Fu-chia-tan along the South Ta-tung—Pu-chou Railway Line and Lu-an in southern Shan-hsi	less than 2 m
South of Tse-chou	less than 1 m
Kai-lan	more than 10 m
Tze-po-chang	4 m±
Hsin-tai	more than 5 m
Tzu-hsien—Liu-ho-kou	4 m±
Chung-hsing	1.5 m
Liu-chuan	1 m
Chiao-tso—Ta-she	0 m

Central Ho-nan	0 m
(ii) Coal seams in Tze-chuan series (Hung-shan formation) or Shanhsi series	
Yin-shan, Ta-tung, Hun-yuan, Ning-wu and Hsi-shan of Peking	0 m
Kai-lan	2 m±(?)
Tze-po-chang	less than 3 m
Ta-wen-kou	less than 6 m
Chung-hsing	9 m
Fu-chia-tan	1.5 m
Liao-chou	1.8 m
Yang-chuan	1.7 m
Tze-hsien—Liu-ho-kou	6 m
Chiao-tso, Ta-she	6 m
Central Ho-nan	11 m
(iii) Coal seams in Shih-ho-tzu series North of Yellow River (the greater part of North China)	0 m
Liu-chuan	3.2 m
Central Ho-nan	more than 7 m five seams or more)

B. Aluminous shale

1. *Introduction*

There are two layers of aluminous shale, "A" bed and "G" bed. According to Takao SAKAMOTO, the former occurs at the base of the Nan-ting series and the latter at the base of the Upper Paleozoic strata.

2. *"A" bed*

The "A" bed of aluminous shale occupies the base of the Nan-ting series, and extends over Chi-tung, Shan-tung, northern Kiang-su and northern An-hwei, but is rarely developed to the west of Peking—Han-kou Railway. As SAKAMOTO determined, the "A" bed is a result of lateritization due to chemical weathering in the regions of warm and arid climate. It was formed in the eastern half of North China but not in the western half. Taking into consideration the fact that the period of its formation corresponds to the age of erosion in the northern half, it is supposed that an important topographic factor, being influenced by crustal movements, combined with the climatic factor in the process of formation. (The lower Shih-ho-tzu series and the Shan-hsi series were partly eroded in this weathering period.)

3. *"G" bed (with iron ore of Shan-hsi type)*

The "G" bed of aluminous shale is distributed widely at the base of the Upper Paleozoic formations, but its thickness and quality vary remarkably from place to place. It occurs as lenses or masses, locally as thick as 10 m or so, but sometimes pinches out suddenly. In general, it is bedded and better ores are developed in two separate beds with an interval of several meters. Iron ores are intercalated in the "G" bed, and are commonly known as Shan-hsi type iron ores, although it is

very rare that rich aluminous shale and rich iron ores occur together. Generally, an aluminous bed occurs in the upper part and an iron ore bed in the lower. If the former forms a rich ore the latter is not at all developed, while if the latter is a rich ore the former does not deserve to be treated for aluminous shale, and sometimes both are too poor to be treated for an ore, and are very thin.

A clay, named Shan-tung brown clay, thinly covers the limestone in Shan-tung and Ho-pei Provinces. This is a *terra rossa*. It is not difficult to suppose that the Ordovician limestone was affected by weathering for a long time up to the deposition of the Upper Paleozoic, and insoluble matters were left behind, to become *terra rossa*. Considering that the complex containing a "G" bed is composed of red rocks, the climate seems to have been warm and humid at that time. According to soil-chemical experiments for clay containing free alumina and iron, it is known that if the pH is 8 or higher, the colloidal alumina congeals, while if pH is 7 or slightly lower, the iron congeals. Therefore, iron ore is formed in neutral ground water and aluminous shale is formed in alkaline ground water.

The horizons, in which the "G" bed of aluminous shale and Shan-hsi type iron ores occur, are three, according to the stratigraphical succession in different areas:

a. Base of the Po-shan series on top of the Ordovician limestone.

b. Base of the Ping-ting series on top of the Ordovician limestone.

c. Base of the Chang-chiu series on top of the Ordovician limestone.

Since the Upper Paleozoic formations are the great deposits formed by a regional overlapping due to transgression, the "G" bed is developed at the base of the Chang-chiu series in Shan-tung and Chi-tung districts; at the base of the Ping-ting series in Ta-tung, Shan-hsi Province and in part of Hsi-shan of Peking; and at the base of strata corresponding to the Po-shan series in Tzu-hsien—Liu-ho-kou, Chiao-tso, Ta-she and in central Ho-nan. Therefore, at the contact with the Ordovician limestone, the stratigraphical horizons of the Ordovician formation as well as of the Upper Paleozoic formations are widely variable and accordingly the amount of time gap differs remarkably.

4. *Hard clay*

The horizons in which hard clay occurs are quite different from those of "A" and "G" beds of aluminous shale. The clay is mostly hard clay of excellent quality, being kaolin, and is associated with coal seams. Two or three examples will be given below.

i. Kaolin of Ta-tung and Hun-yuan coal fields. This forms thick "partings" alternating with such coal seams as "20 m seam" and "5 m seam", of the Tai-yuan series. Alternating beds of coal and kaolin are more than 30 m thick on the outcrops at Kou-chuan-kou and Chin-shan-ssu and even the thickness of kaolin alone amounts to 12 m or so.

ii. Kaolin of Ching-hsing and Yang-chuan coal fields. Seam No. 2 of the Ching-hsing coal field is intercalated with a kaolin bed, 0.10–0.30 m thick, which serves as an important key for the determination of stratigraphic order. This applies to the Yang-chuan coal field, too.

iii. Kaolin of Tze-Po-Chang coal field. In the Tze-Po-Chang coal field, a kaolin bed 0.6–2 m thick occurs all over the coal field beneath the Ta-hsiao coal seam (GH bed) of the Po-shan series, and it is an index bed for the investigation of this coal field. The author named this the Li-chia-ling hard clay (ONUKI, 1951–1945).

In this coal field, the "Ao" bed of hard clay, associated with iron ore, occurs also in the upper part of the Wan-shan formation of the Nan-ting series, although the clay is sometimes absent and the bed consists only of iron ore.

5. *Soft clay*

This clay, being important as ceramic raw material, occurs in many horizons, chiefly in the Chang-chiu, Chang-tien and Po-shan series and corresponding strata, but sometimes also in the Nan-ting series and corresponding strata. Especially, the clays associated with "G" bed are of excellent quality and are often utilized.

C. Pyrite

Pyrite is abundantly contained in marine units of the Upper Paleozoic formations, and occurs in bedded form or masses in coal seams. Sometimes it forms a thick bed at the base of the Upper Paleozoic formations.

Pyrite in the Po-shan coal field (called the Po-shan type pyrite) has been known for a long time. It forms a bed having a thickness of over 0.10 m in the Po-shan series coal seams, or occurs as scattered lenses or nodules. It is contained in such coal seams as E, E' and F of the Tze-chuan colliery, and also in the Huang-tu-tun-tzu coal, Ta-huang coal and Hsiao-huang coal of the Po-shan and Hsi-po collieries. A good example of its mode of occurrence is seen in the Hsiao-tsao coal of the Chung-hsing colliery.

Pyrite which forms a thick bed at the base of the Upper Paleozoic formations (Hsin-po type pyrite) is found in Chiao-tso and Yang-chuan. At the time of investigation of the Chiao-tso coal field in 1942, a pyrite bed of about 1.2 m in thickness was being mined in the tableland west of Ping-hsin in the western extremity of this coal field. In the Yang-chuan and Hun-yuan coal fields, pyrite is similarly developed, and especially in the former the ore reserves were known to be great, according to Ko SHIIDA.

IV. Transgression and limestone

1. *Carboniferous period*

In the middle stage of the Carboniferous period of North China, the transgression started in the east and gradually advanced westward. As a result, the lower beds of the Chang-chiu series are developed in the Shan-tung and Chi-tung regions, but are not found in the area west of the Peking—Han-kou Railway. As the transgression advanced farther west, the upper beds of the Chang-chiu series and their equivalent Ping-ting series were deposited, while the Ho-nan district was not yet covered with sea water.

In the later stage of the Carboniferous period, a regression took place, and the marginal portion of the depositional basin became land. However, the central

portion of the basin, corresponding to the location of today's Shin-Tai Railway Line, was still under sea water. This is the reason the relation between the Carboniferous formation and the succeeding Early Permian formation deposited by a new transgression is sometimes unconformable and sometimes conformable. And, even in the case of unconformity, some areas are covered with the basal conglomerate or basal sandstone of the Permian formation, while other areas are covered with residual clay (e.g. E bed at Kai-lan and the main-bed clay at Fu-chou). These features may be ascribed to the topographic changes caused by the crustal movement.

2. *Permian period*

In the beginning of the Permian period, transgression took place again and most of North China, except the Yin-shan region, was inundated with sea water, and the Po-shan series and corresponding strata (Tai-yuan series) were deposited. The Po-shan series and its equivalents are composed chiefly of black shale intercalated with limestone. The total thickness of limestones occurring in the Po-shan series was estimated by SHIIDA (1944) as follows:

Liu-chuan	40 m
Chung-hsing	30 m
Tze-hsien	12 m
Ta-wen-kou	10 m
Tze-Po-Chang	46 m
Fu-chia-tan	12.4 m
Lu-an	9 m
Hsi-shan of Tai-yuan	7.5 m
Hsien-kang-chen	1 m
Ning-wu	0.8 m
Hsi-shan of Peking	0 m
Ta-tung	0 m
Hun-yuan	1.5 m

From the above list, it may be seen that the thickness is greater in the southeastern regions and is thin in the west or entirely disappears toward the north. The number of limestone beds shows a similar tendency; there are more than 10 in Chung-hsing, 5 in Tze-hsien, 3 or 4 in Tze-Po-Chang, 3 in the region along the Shin-Tai Railway, one or 2 in Ning-wu, and almost none in Hsi-shan of Peking, and in Ta-tung.

3. Crustal Movements of Upper Paleozoic Era

Introduction

The Upper Paleozoic formation, covering the Lower Paleozoic formation with parallel unconformity in North China, grades from littoral to terrigenous deposits and then to inland deposits, and finally becomes desert deposits, but several unconformities may be seen. Judging from them, erosion gaps and crustal move-

ments seem to have occurred, so consideration will be given to them in this chapter.

I. Tai-hang epeirogenic movement and Pre-Shan-tung unconformity

After the Ordovician limestone had been deposited, the Cambro-Ordovician sedimentary basin, between the Mongolian orogenic zone and the Chin-ling—Seoul line, was upheaved by an epeirogenic movement and became land. This movement is named the Tai-hang epeirogenic movement, from the Tai-hang mountain range lying in the central portion of this basin and consisting of the Cambro-Ordovician strata. As a result, the Cambro-Ordovician formation in North China was affected by erosion for a long period, until the Middle Paleozoic and Lower Carboniferous. A wide area was lowered to a peneplain or a level land surface, close to sea level. But, in the Middle Carboniferous period (Moscovian), the ground began to subside and to be gradually covered with sea water, and the Shan-tung system was deposited. Because of this great erosion gap in the Middle Paleozoic era, residual clays occur at the base of the Shan-tung system, indicating the unconformity of the pre-Shan-tung system. This unconformity is a parallel unconformity in spite of the great erosion gap caused by the Tai-hang epeirogenic movement, and the sedimentary basin has undergone almost no deformation from the Lower Paleozoic through the Upper Paleozoic era, thus presenting a distinct geological division of North China, Manchuria and Korea. In this respect, the role played by the Tai-hang movement is quite significant.

II. Kai-lan movement (Huai-nan movement)

In the Middle Carboniferous period, the land subsided gradually, to be covered with sea water. The regions of Kai-lan and Shan-tung were flooded first, and the lower beds of the Chang-chiu series, the oldest formation of the Upper Paleozoic era in North China, were deposited there. Thereafter, transgression gradually advanced into the interior of North China, and almost all of North China except the southern part of Ho-pei Province, central and northern portions of Ho-nan Province, northern portion of An-hwei Province and the Yin-shan district of Mongolia, were submerged below the sea, and the upper beds of the Chang-chiu series and the Ping-ting series were deposited in the same horizon.

This subsidence, or transgression movement, continued from Moscovian to Uralian. The transgression age of the Huai-nan movement in Central and South China coincides with the deposition stage of the Chang-chiu series, and the author gave the name of Kai-lan movement to this transgression movement in North China.

III. Tze-hsien movement (Kun-ming movement)

1. Unconformity at the base of Permian formation

After the transgression, which ranged in age from Middle Carboniferous to Upper Carboniferous (Uralian), a regression again took place in North China, following an upheaval of land at the end of the Upper Carboniferous period. The deeper portion of the sedimentary basin was still under water but the marginal and shallow portions were raised above the sea and were subjected to erosion. Thereafter in the Lower Permian period (Sakmarian), a wide area submerged be-

low the sea again, and the Po-shan series, or the corresponding Tai-yuan series, was deposited. This upheaval of land is reflected by various states of unconformity between Carboniferous and Lower Permian formations, such as the lack of all strata or part of the Ching-hsing series between the Ping-ting series and the Tai-yuan series, the lack of all strata or part of the Chang-tien series between the Chang-chiu series and the Po-shan series, the lack of upper beds of the Chang-chiu series and the whole Chang-tien series; in one extreme case the Tai-yuan series rests directly upon the Cambro-Ordovician formation. Thus, the gap due to the erosion before the Lower Permian period is observable in various states of stratigraphic relation everywhere in North China.

2. State of the base of Permian formation in coal fields of North China

Several examples will be given as explanation.

a) In the Ta-tung coal field, the Tai-yuan series overlies the Ping-ting series with basal conglomerate and the Ching-hsing series is lacking. However, in the northern area of this coal field, the Tai-yuan series directly covers the Cambrian formation.

b) In Hsi-shan of Peking, the Middle Carboniferous formation is seen only in the vicinity of Fang-shan, and the Lower Permian Yung-ting series covers the Cambro-Ordovician formation directly.

c) In the southwestern region of North China, extending over much of Tzu-hsien—Liu-ho-kou, central Ho-nan, and Chiao-tso and Ta-she coal fields, the Carboniferous formation is rarely developed and the Lower Permian formation rests directly upon the Ordovician formation. The Tai-yuan series in this region contains several beds of limestone, the lowermost of which is named Ta-ching limestone and serves as an index bed in many coal fields. The strata between the Ta-ching limestone and the underlying Ordovician formation are 50 m thick at Liu-ho-kou, 40 m at Peng-cheng-chen, 10 m at Ai-kou-tsun in An-yang-hsien, and only 2 m or so in the Ta-she coal field.

d) Mitsuo NODA (1944) observed similar unconformity in the Lai-wu coal field.

3. Tze-hsien (Kun-ming) movement

The distribution of the Po-shan series or the Tai-yuan series is wider by far than that of the Carboniferous formation. The author gave the name of Tze-hsien movement to the movement of upheaval and subsidence near the end of the Upper Carboniferous period. This seems to be contemporaneous with the Kun-ming movement in Central and South China and also with the Setamai movement in Japan. In Manchuria, the boundary between the Carboniferous period and the Permian period was placed between the Pen-hsi series (Moscovian) and the Huang-chi series by NODA (1950) who attached importance to the lack of Uralian. In North China, too, similar unconformity is found, as already stated. However, the two series are not always in contact unconformably; in some areas the deposition was continuous from the Carboniferous period to the Permian period.

IV. Chiao-tso movement (*Fig.* 8)

1. Difference of sedimentary facies between Tai-yuan series and Shan-hsi series

The period from the Tai-yuan series through the Shan-hsi series is that of transition from marine to terrigenous deposition. That is, the Tai-yuan series is composed of black shale intercalated with limestone, whereas the Shan-hsi series consists mainly of sandstone.

In the past, little attention was paid to the unconformity between the two, but this unconformity is seen in districts to be mentioned later, and in other districts of North China, and when considered together with the lithological difference between the two series, comes to have more importance than was hitherto assumed.

2. Base of Shan-hsi series

a) In the Yin-shan mountain range in the Ho-ho district, the Shuan-ma-chun series, corresponding to the Shan-hsi series, directly overlies the quartzite or the limestone of the Sinian system and the strata corresponding to the Tai-yuan series cannot be found.

b) The author discovered an unconformity between the Shan-hsi series and the Tai-yuan series in 1941, and estimated this erosion gap at 5 m to 10 m.

c) Ko SHIIDA observed similar unconformity in the Ning-wu coal field and estimated the erosion gap as more than 15 meters.

d) SHIIDA observed an unconformity between the Tai-yuan series and the Shan-hsi series in the vicinity of Tai-yuan and in the Yang-chuan coal field and emphasized the geological significance of this unconformity because the former is marine and the latter is terrigenous.

e) Haruyoshi FUJIMOTO found similar unconformity in the Yang-chuan coal field along the Shin-Tai Railway. The erosion gap exceeds ten meters in the area extending from the Tai-yuan district to the Shin-Tai Railway.

f) The author observed this unconformity in the Ching-hsing coal field in 1942.

g) C. C. WANG observed this unconformity in the Lin-cheng and the Tze-hsien—Liu-ho-kou coal fields.

h) T. F. HOU found this unconformity in the Chiao-tso coal field and reported it in 1930. The author observed this relation in the northern mountains of Chiao-tso during his exploration of the Chiao-tso coal field in 1941, and also postulated its presence by boring logs. As already stated, five layers of limestone are intercalated in the Tai-yuan series in the Tze-hsien—Liu-ho-kou coal fields, and a complex, 70 m to 100 m thick, is developed upon the Ta-ching limestone, which is the lowermost layer. In the Chao-tso coal field, however, about 50 m to 75 m of this complex has been eroded away, and the basal conglomerate of the Shen-hou series, corresponding to the Shan-hsi series, sometimes rests directly on the Ta-ching limestone which occurs in the same horizon as the Chu-tan series and the Tai-yuan series. In the central region of Ho-nan Province, the Chu-tan series is eroded to the extent of 35 m to 50 m.

i) According to the results of boring at the Ching-hsing colliery, more than 10 meters is sometimes lacking in the uppermost part of the Po-shan series.

j) In the Wang-ping-kou district of Wang-ping-hsien, west of Peking, a basal

conglomerate is developed in the Wang-ping series and its relation to the Yung-ting series is of parallel unconformity.

3. Nature of Chiao-tso movement

The time gap represented by the above-mentioned unconformity is larger in the areas along the Yellow River, and is greatest in the Chiao-tso coal field, and this feature can be explained only by assuming a regional upwarping. In this connection, the lack of the Lower Cambrian formation in the Vicinity of Tsi-shan of southern Shan-shi, as studied by Teiichii KOBAYASHI, the clino-unconformity between the Sinian system and the Cambrian formation in Yui-ho in the southern end of the Tai-hang mountain range, as observed by Shinji YAMANE, and the change of coaly material into anthracite in Chao-tso—Ta-she region are all significant.

The sea, which had covered much of North China in the Lower Permian period, retreated completely by the end of the period, and the terrigenous deposits again covered the former with parallel unconformity in the Middle Permian period. The regression of this period is called the Chiao-tso movement. The boundary between the Chuan-shan limestone and the Chi-hsia limestone in Central and South China corresponds to this age. The two are mostly conformable, but in the Fu-kien district (HOU, 1935) the Chi-hsia limestone directly covers the Lower Carboniferous Wu-tung formation with distinct unconformity. The boundary between the Sakamotosawa series and the Kanokura series in Japan seems to correspond to this, but no unconformity has been found as yet between the two.

V. Tsin-pei movement (Tung-wu movement)

1. An example of crustal movement after the deposition of Shan-hsi series

In the Ta-tung coal field, after deposition of the Shan-hsi series, the land upheaved and was eroded; the amount of erosion is more than 170m, and is greatest toward the north, so that the Huai-jen series came to cover the Tai-yuan series toward the north, and covers even the Cambrian formation on the northern margin. This clearly shows a remarkable movement of the ground prior to the deposition of the Huai-jen series.

In Hsi-shan, Peking, the contemporaneous movement is inferred from the unconformity between the Hung-miao-ling sandstone, which is supposedly of the same horizon as part of the Huai-jen series, and the Wang-ping series that constitutes the basement.

In the region of the Yin-shan mountain range north of Ho-ho and Pao-tou, the Sa-la-tsi series, regarded as of the same horizon as the Huai-jen series, covers the Shuan-ma-chun series and the Sinian system with unconformity.

2. Nature of Tsin-pei movement (Tung-wu movement)

In the northern region of North China, that is, the Peking—Tsin-pei basin to the south of the Mongolian orogenic zone, an unconformity before the deposition of the Huai-jen series is recognized, and similar relations are reported by Nenji TAKAHASHI from Hung-lo-hsien of Chin-hsi district, Jehol, and by L. H. CHANG from the Nan-piao coal field. Accordingly, this movement shall be regarded as a

large scale crustal movement extending over a wide area from the northern region of North China to the Jehol district. The author gave the name of Tsin-pei movement to this movement, after a conventional name of the Ta-tung district. In the period of this movement, however, the Shin-ho-tzu series was being deposited in the area extending from the central part of Shan-hsi Province to the central part of Ho-nan Province, and judging from the sedimentary facies an inland deposition seems to have been carried on continuously with repeated advances and retreats.

In an extensive area stretching from South Manchuria and North Korea to Chi-tung, Shan-tung, northern Kiang-su and Huai-nan, the "A" bed of aluminous shale occurs at the base of the author's Nan-ting series. This is a special horizon of the red complex to be correlated with the Shih-ho-tzu series. According to T. SAKAMOTO, the aluminous shale is a product of climatic and topographic conditions which prevailed then, so this horizon can be regarded as an unconformity plane of this age.

3. Paleontological views of the Tsin-pei movement

The Huai-jen series of the Ta-tung coal field has been proved by Hikoji MORITA to be correlated with the Upper Shih-ho-tzu series in Shan-hsi Province. This series characteristically yields *Gigantopteris* flora. In the area from the southern part of Shan-tung Province to the northern part of Kiang-su Province and the northern part of An-hwei Province, there is a complex intercalated with coal above the "A" bed of aluminous shale which contains *Gigantopteris* flora. This complex is the author's Nan-ting series and is supposed to correspond to the Upper Shih-ho-tzu series and the Huai-jen series. Therefore, from a paleontological viewpoint, the age of the unconformity, or erosion period, below the Huai-jen series can be assigned to the age of formation of the "A" bed of aluminous shale, and the period when the materials for aluminous shale were completely lateritized and redeposited may be assigned to the period preceeding the partial erosion of the Lower Shih-ho-tzu series and the Shan-hsi-series.

4. Contemporaneous movements in Central and South China and Japan

In Central and South China, a distinct unconformity is found between the Lung-tan coal measure, yielding *Gigantopteris* flora, and the Ku-feng formation and corresponding beds, yielding *Neoschwagerina*, and the deposition of the Lung-tan coal measure was preceded by a period of volcanic activity of O-mei-shan basalt. J. S. LEE called the movement in Central and South China at that time the Tung-wu movement, which seems to be contemporaneous with the author's Tsin-pei movement. The age of the particular sedimentary facies containing the Usuginu conglomerate, which is transitional between the Kanokura series and the Toyoma series in Japan may correspond to this, although the state of deposition has remarkably changed since that time.

VI. Tien-tai movement (Huai-nan movement)

The Shuang-chuan series in Peking—Hsi-shan covers the Hung-miao-ling sandstone with unconformity and, according to Misaburo SHIMAKURA, the red sand-

stone bed overlies the Huai-nan coal measure with unconformity in the Huai-nan coal field. Therefore, this unconformity is important geologically from the viewpoint of the change of the sedimentary facies. Presuming a period of crustal movement prior to the deposition of the Shuang-chuan series, this movement was named Tien-tai movement after the name of Tien-tai-shan where the Shuang-chuan series is typically developed. This seems to be correlated with the Huai-yang movement in Central and South China and also with the movement of the Tate stage in Japan.

VII. Shan-tung movement

1. Crustal movement before the deposition of Ta-tung series

Taking the Ta-tung coal field as an example, the coal measure of the Ta-tung series of Triassic to Jurassic period rests upon the Huai-jen series with unconformity. This unconformity is observed distinctly in the upper reaches of E-mo-kou in Huai-jen-hsien, and upon examining the boring logs and outcrops in the northern and northernmost parts of the Ta-tung coal field, it is known that the Ta-tung series overlies directly whole complexes ranging from the Huai-jen series to Cambrian formation and then to the Sang-kan gneiss. As to the coal measures, only Paleozoic coal measures are developed in the central and southern parts of the Ta-tung coal field, whereas in the northern part the Tai-yuan series, which is Paleozoic coal-bearing formation, coexists with the Mesozoic coal-bearing Ta-tung series. On the other hand, in the northernmost part of this coal field, the coal measures of the Ta-tung series are widely distributed, resting directly upon the Cambrian formation and the gneiss. From this fact it is clear that there was a crustal movement before the deposition of the Ta-tung series, and the amount of upheaval was greater toward the north. Erosion accompanied the upheaval, and the Ta-tung series was deposited with a gradual northward overlapping. Similar relations are seen in the Yin-shan area where the Shih-kai-tzu series rests unconformably on the Sa-la-tsi series, and in the Peking—Hsi-shan area where the Men-tou-kou series overlies the Shuang-chuan series with unconformity.

2. Importance of Shan-tung movement

In the Tze-po-chang coal field, Shan-tung Province, the Kun-lun series that constitutes the lower beds of the Hsin-tai system covers the Feng-huang-shan series with unconformity. The author previously called the Upper Paleozoic formations in the Shan-tung district by the name of Shan-tung system, so the movement represented by this unconformity below the Hsin-tai system shall be called Shan-tung movement. This movement caused drastic changes in the sedimentary facies and the shape of sedimentary basin of the Shan-tung system, which had graded from marine deposits to terrigenous deposits and then to inland deposits, and started an entirely new cycle of sedimentation. The Shan-tung movement may be contemporaneous with the Akiyoshi orogenic movement in Japan and the Songnim stage in Korea. Taking these features into consideration, it may be concluded that the Upper Paleozoic crustal movements in North China, ranging from the Kai-lan movement to the Tien-tai movement, were minor movements in the course of the

cycle of sedimentation of the Shan-tung system, while the Shan-tung movement which took place last is by far the most important from the viewpoint of structural geology.

Summary

1. Before the Middle Carboniferous sedimentation

The whole of North China was upheaved uniformly to become land by the Tai-hang epeirogenic movement after the deposition of the Ordovician formation, but was affected by erosion over a long period of time—from Middle Paleozoic to Lower Carboniferous—and was degraded nearly to the base level plane. The Ordovician limestone produced residual clay on the surface as a result of weathering during the erosion of the Middle Paleozoic era. In this clay, alumina and iron were concentrated to form high-grade ores as a consequence of lateritization under a tropical climate. These ores are known as the "G" bed aluminous shale and the iron ores of the Shan-hsi type, and occur at the base of the Upper Paleozoic formations all over North China.

2. Nature of Kai-lan transgression

After the Middle Carboniferous period, the land subsided and gradual transgression occurred first in the east and then in the west, and the deposition of the Upper Paleozoic formation was started. This sedimentary basin is regarded as the same as that of the Lower Paleozoic era, as has been already stated. The deposition during the period from Middle Carboniferous to Upper Carboniferous was carried out in the form of overlapping due to transgression, and this movement was named the Kai-lan movement.

All area was submerged below the sea by this movement, but not equally, and the states of overlapping are different, partly resulting from the relief of the surface of the Ordovician formation and partly due to the degree of subsidence of the land, varying with region. As a result, there is a rather wide difference among the lower limits of the Shan-tung system. In this sedimentary basin, the area that first went under water includes Kai-lan on the western margin of the Pyongan—Liao-tung basin of T. KOBAYASHI, and Shan-tung Province, as well as northern Kiang-su in the northeastern part of the Shan-kiang-an basin, and the lower beds of the Chang-chiu series and corresponding strata were deposited there. These two basins were connected with the Yellow River basin of KOBAYASHI. The transgression advanced farther and reached the Shan-hsi basin and the Peking—Tsin-pei basin, there depositing the Upper Chang-chiu series and its equivalent Ping-ting series. The southern limit of the transgression during the Kai-lan movement did not go as far as the southern part of the Shan-kiang-an basin (central Ho-nan and northern An-hwei), and its northern limit failed to reach the Yin-shan region.

3. Characteristics of Tze-hsien movement

At the end of the Carboniferous period, ground upheaval and regression took place, and most of the area formerly covered by sea owing to the Kai-lan move-

ment became land, later eroded. However, deposition continued in some portions of the basin, namely, the area along the Shih-Tai Railway and the Tze-Po-Chang and Kai-lan region. Later, a large scale transgression occurred again, inundating the whole area of the Kai-lan transgression and even the southern portion of the Shan-kiang-an basin, which had survived the earlier transgression. This movement of upheaval and subsidence is named the Tze-hsien movement, as has been stated already. The deposits produced by this movement are the Po-shan series and corresponding Tai-yuan series. At the base of these deposits, a basal conglomerate or basal sandstone is developed, occasionally forming a bed of residual clay (E bed in Kai-lan). In the southern part of the Shan-kiang-an basin, which was covered with sea water for the first time, the deposits have the "G" bed of aluminous shale and the Shan-hsi type iron ores at the base. The Tse-hsien movement is thus represented by the so-called Pre-Sakmarian unconformity, and is correlated with the Setamai movement in Japan, the Kun-ming movement in Central and South China, and the movement of the Nan-piao stage in Manchuria.

The formations deposited as a result of the Tze-hsien movement have already been described; they are composed mainly of black shale, abound in limestone and iron sulphides, and are intercalated with the type of coal named stink coal. There are more than 10 layers of limestone in the southern region, amounting to 40 m in total thickness, but these decrease toward the north, where only three or five layers are found in the area along the Shih-Tai Railway and in the Tai-yuan district and none in the Ta-tung and Peking—Hsi-shan region. On the other hand, coal seams become thicker northward, thinner southward, and almost nonexistent in the area extending from central Ho-nan to Huai-nan.

4. Chao-tso movement and land of North China

The complete regression of the sea, which once covered virtually all of North China at the end of the Lower Permian period, is clearly indicated by the unconformity at the base of the Tze-chuan and the Shan-hsi series of the Middle Permian period. The Tze-chuan and Shan-hsi series are composed mainly of thick platy sandstone, false-bedded or irregularly bedded, or gravelly rocks, and belong to terrigenous deposits, showing a facies of wide deltaic deposition. The amount of erosion of the Po-shan series, Tai-yuan series and corresponding formations by the unconformity at the base of the Tze-chuan series or Shan-hsi series is greater in the southern region than in the northern region, being 5 m to 10 m in Ta-tung, more than 15 m in Hsien-kang-chen, over 10 m in Tai-yuan and the area along the Shih-Tai Railway, 50 m to 75 m in Chao-tso—Ta-she, and 35 m to 50 m in Yu-hsien. In the Yin-shan region, the northernmost part of North China, the Middle Permian formation (Shuan-ma-chun series) covers the Sinian system with unconformity, and the deposition of the Upper Paleozoic formation seems to have started for the first time in this period. The unconformity dividing the marine deposits and the terrigenous deposits of the Upper Paleozoic strata in North China has a special significance, and the author named the movement of that time the Chaotso movement, as has been stated.

The total thickness of coal seams of the Hung-shan formation of the Tzu-chuan series or Shan-hsi series increases to the south and decreases to the north, and almost no coal seam is developed in the northern region. It is noteworthy also that the thickness of a coal seam varies even within one and the same coal field.

5. Paleogeographical significance of red formations

The afore-said deltaic deposits passed gradually into an inland basin facies from the latter half of the Middle Permian period, and as the climate became higher in temperature and more arid the red rocks increased. The boundaries between the Shan-hsi series and the Shih-ho-tzu series in the Shan-hsi district, and between the Hung-shan formation and the Hei-shan formation of the Tzu-chuan series in the Shan-tung district, are placed at the lower limit of the introduction of red rocks.

The red-rock complex in the eastern part of North China, South Manchuria and North Korea contains the "A" bed of aluminous shale in a nearly equal horizon. Immediately above this horizon lies the Nan-ting series yielding *Gigantopteris* flora. This series is correlated with the Upper Shih-ho-tzu series of the Shan-hsi district and the Huai-jen series of the Ta-tung coal field, and is supposed to be contemporaneous with the Lung-tan coal measure of Central and South China. The unconformity plane at the base of the Lung-tan coal measure is contemporaneous with the unconformity plane at the base of the Huai-jen series and also with the unconformity plane indicated by the "A" bed of aluminous shale. The crustal movement represented by this unconformity is called the Tsin-pei movement which the author regarded as contemporaneous with the Tung-wu movement of Central and South China and the movement of the Usuginu stage of Japan.

In the inland basin of the Upper Permian period, where the Upper Shih-ho-tzu series, Huai-jen series and Nan-ting series were deposited, the climate was remarkably arid, with the landform of a plain, so that the growth of plants seems to have been hindered. However, in the southern region, a lake basin or swamps formed which favored the formation of coal seams. Such coal seams are found in the I-hsien coal field in the southeastern part of Shan-tung Province, the Liu-chuan coal field in northern Kiang-su Province, the coal fields of Yu-hsien and Mi-hsien in central Ho-nan Province, and the Huai-nan coal field in northern An-hwei Province. During this period, the Lung-tan coal measure, an important coal producer, was being deposited in Central and South China.

6. Paleogeographic significance of dark-red complex

The Shih-chien-feng series is developed upon the Shih-ho-tzu series, while the Feng-huang-shan series is upon the Nan-ting series. The Shih-chien-feng series is composed mainly of dark-red sandstone, and is several hundred meters thick, sometimes containing gypsum beds. These features indicate that the depositional environments were strikingly different from those of the underlying formations. Namely, the formations beneath the Shih-chien-feng or Nan-ting series had been deposited in a plain where lakes or swamps developed in favor of coal formation, but with the changing climatic conditions the environment turned to those of a desert. In the past the Shih-chien-feng series and corresponding formations were

regarded as Triassic in age, but since FUJIMOTO collected *Lepidodendron, Calamites* and other plants of supposedly Paleozoic age at Hsi-lo-chen along the Shih-Tai Railway, the question of the age of this series needs further examination.

The author considers the Shuang-chuan series developed in Peking—Hsi-shan to correspond nearly to the lower part of the Shih-chien-feng series, but the latter is unconformable with the underlying Hung-miao-ling sandstone on the southern slope of Tien-tai-shan, which is the type locality of this series, so the crustal movement responsible for this unconformity was named the Tien-tai movement. SHIMAKURA regards the red sandstone above the Huai-nan coal measure as Triassic and the relation between the two to be unconformable. Thus, even when no unconformity is recognized between the Shih-chien-feng series and the Shih-ho-tzu series or its equivalents in various parts of North China, a crustal movement is reasonably inferred from the striking change in the rock facies. The relation between the Kopangsan series and the Green-rock series in Korea is comparable to this, and the Huai-yang movement in Central and South China and the movement of the Tate stage in Japan also seem to correspond to the Tien-tai movement.

7. Shan-tung cycle of sedimentation and Shan-tung movement

Considering the above, the continuous deposition from the marine deposits of the Middle Carboniferous period to the terrigenous and then to inland deposits of probably Permo-Triassic age can be regarded as that of one great cycle, so the author named it the Shan-tung cycle of sedimentation, all deposits being grouped in the Shan-tung system. The crustal movement interrupting this cycle is very important in North China, and is called the Shan-tung movement by the author. The Shan-tung movement seems to be contemporaneous with the Akiyoshi orogenic movement in Japan and the movement of the Songnim stage in Korea. After this movement, no such extensive regional deposition as that in Paleozoic era has taken place in North China up to the present. However, intermontane basins formed in the various places where deposition of coal began at the end of the Triassic period and continued to the Jurassic period, as exemplified by the Men-tou-kou series of the Men-tou-kou coal field, the Ta-tung formation which is the upper coal-bearing formation in the Ta-tung coal field, and the Fang-tzu series of the Fang-tzu coal field.

It may be appropriate to end this paper with the following remark: the sedimentary environments in North China, as indicated by the cycle of sedimentation of the Shan-tung system, were not associated with orogenic movements but resulted from very slow movements of the Kratogen-type ground.

REFERENCES

ANDERSON, J. G. (1924); Report on the Changchiu coal field in Shantung. *BGSC*, vol. 3, no. 6 (E).

ARAKAWA, Kenji (1941); Survey report of the Kiuju Colliery, in Mentowkow, Hopei Province. Data on mine investigation in North China, published by the Kōa-in (China Affairs Board).

BESSHO, B. (1941); Arrangement of bed rocks in the Huainan coal field. *Jour. Geogr.*, vol. 53, no. 631 (J).

CHANG, L. H. (1940A); Explanatory text of Paoshin Geologic sheet map, northern Tatung coal field. *Industry Dept., Mongolian Government* (J).

—— (1940B); Explanatory text of Nanhsinchuang sheet, northern Tatung coal field. *Industry Dept., Mongolian Government* (J).

—— (1941); Preliminary report of geologic survey team for Tatung coal field (Introductory note to the Survey team of S. Manchuria Railway Co., 1938–1940). *JGSJ*, vol. 48, no. 575 (J).

CHANG, L. H. (1944); Geology of the western half of Nanpiao coal field, with special reference to the stratigraphy of Palaeozoic formation. *Bull. Ore Deposit and Geology* (S. Manchuria Railway Company), no. 1 (J).

CHAO, Y. T. and C. C. TIEN (1924); On the stratigraphy of the Tse Chow and Liu Ho Kou coal fields on the border between S. Chihli and Honan. *BGSC*, vol. 3, no. 6 (E).

CHAO, Y. T. (1926); Succession of the marine beds in the Chang Chiu coal field of Shantung. *BGSC*, vol. 5, no. 8 (E).

—— (1927); Age of the Taiyuan Series. *BGSC*, vol. 6, (E).

—— (1927, 1928); Productidae of China. *Pal. Sinica*, ser. B, vol. 5, fasc. II and III (E).

CHAO, Y. T., C. Y. LEE, and T. F. HOU (1929); Geology of Kaiping Basin and its environs. *BGSC*, vol. 8, no. 12 (E).

CHEN, M. K., and Y. H. HSING (1935); Note on a thrust in the western hills of Peiping. *BGSC*, vol. 14, no. 4 (E).

CHI, Y. S. (1934); Geology of the Changhsing coal fields, Chekiang Province. *BGSC*, vol. 13, no. 24 (E).

CHI, Y. S., and C. H. PAN (1933); Shuangchuan Series and its Triassic plant fossils in Peking—Sishan, *BGSC*, vol. 12, no. 4 (E).

CHU, T. O., and C. LI (1924); Geology and Ore deposits of Ching Hsing District, Chihli Province. *BGSC*, vol. 3, no. 6 (E).

ENDO, S. (1950); Illustration for classification of plant fossils from the Far East.

FUJIMOTO, H. (1943); Outline of geology along the Shih-Tai railway. Outline of Investigation in earlier half of 1943. Investigation Bureau, North China Development Co. (J).

—— (1946); Geology of Yangchuan coal field, Shansi Province. *JGSJ*, vol. 52 (J).

GRABAU, A. W. (1920); A Lower Permian fauna from the Kaiping coal basin. *BGSC*, no. 2 (E).

—— (1923–1924); Stratigraphy of China. Pts. I and II (E).

GUNTHERN (1936); Beitrag zur Geologie des Kaipin Beckens. *Mem. Nat. Res. Inst. Geol., Academia Sinica*, no. 5 (G).

HALLE, T. G. (1927); Palaeozoic plants from central Shansi. *Pal. Sinica* ser. A, vol. 2, fasc. 1 (E).

HANZAWA, S. (1941); Stratigraphical relation between the Carboniferous and Permian Formations in Manchuria, Korea and Japan. *JJGG*, vol. 18, no. 3 (E).

HAYASAKA, I. (1933); Carboniferous period and Permian period, Tokyo, Iwanami Pub. Co. (J).

HORIUCHI, Kazuo (1941); Survey report of aluminous shale in Tzechuan coal field, Shantung Province. Data on mine investigation in North China, Kōa-in (China Affairs Board) (J).

Hou, T. F. (1930); Geology of Hsiuwu coal field, Honan. *BGSC*, vol. 9, no. 15 (E).

—— (1931); The clay deposits and porcelain industry of Pengchangchen, Hopei. *BGSC*, vol. 10, no. 17 (E).

Hou, T. F., Y. L. Wang, and C. C. Chang (1935); Geological reconnaissance between Lungyen and Amoi, Fukien. *BGSC*, vol. 14, no. 5 (E).

Hsieh, C. Y. (1932); Geology of Liuchuan coal field, Tungshan-hsien, Kiangsu. *BGSC*, vol. 11, no. 18 (E).

—— (1935); Microscopic study of aluminous ores from Shantung. *BGSC*, vol. 14, no. 25 (E).

Huang T. K. (1932); Permian formation of Southern China. *Mem. Nat. Geol. Surv. China*, no. 10 (E).

Iida, Kumiji (1942); Report of seismic prospecting in areas adjacent to the southeast Liuhokow coal field, Changtaehsien, Honan Province. Survey report, Investigation Bureau, North China Development Company (J).

Inoue, Kinosuke (1939); Outline of geology and coal reserves of coal fields in North China. *Jour. Geogr.*, vol. 51 (J).

Kadokura, Sanno (1919); Survey report of Tatung coal field, Shansi Province. Oversea mineral survey report, Temporary Industry Investigation Bureau (J).

Kawada, M., and H. Morita

(A) Survey Report of Heishan region, Poshan coal field, Shantung Province,

(B) Survey Report of Wanshan region, Poshan coal field, Shantung Province,

(C) Survey Report of Fangshan coal field, Hopei Province,

(D) Survey Report of Tsitang, Pan-kiao and Ta-an-shan coal field.

Survey report of mines in S. China, Japanese Army in China (J).

Kawada, M., and K. Horiuchi (1937A); Survey report of Hsi-ho region, Poshan coal field, Shantung Province. Japanese Army in China, party no. 3 (J).

—— (1937B); Survey report of Puchi region, Chang-chiu coal field, Shantung Province. Japanese Army in China, party no. 3 (J).

Kawada, M., H. Yoshizawa, I. Matsuzawa, and Y. Onuki (1938A); Survey report of Yihsien coal field, Shantung Province. Coal report. Geological Survey party, Special service facility, Sugiyama detachment, North China (J).

—— (1938B); Survey report of Tzeyao coal field, Ningyang hsien, Shantung Province. Coal report, Geological survey party, Special service facility, Sugiyama detachment, North China (J).

Kawada, M., H. Yoshizawa and I. Matsuzawa (1928); Survey report of Yutzun coal field, Taian hsien, Shantung Province. Coal report, Geological survey party, Special service facility, Sugiyama detachment, North China (J).

Kawada, M., H. Yoshizawa, and Y. Onuki (1928A); Survey report of Tzechuan colliery, Shantung Province. Coal report, Geological survey party, Special service facility, Sugiyama detachment, North China (J).

—— (1938B); Survey report of aluminous shale in the environs of Tzechuan colliery, Shantung Province. Coal report, Geological survey party, Special service facility, Sugiyama detachment, North China (J).

Kawada, M., and Y. Onuki (1938); Survey report of Mentoukou coal field, Wanping hsien, Hopei Province. Coal report, Geological survey party, Special service facility, Sugiyama detachment, North China (J).

KAWASAKI, Hantaro (1931–1934); Plants from Heian system, Korea, *Bull. Geol. Survey* Chosen, No. 6.

KOBAYASHI, T. (1942A); A few Cambrian Trilobites from southwestern Shansi. *JGSJ*, vol. 49, no. 591 (J).

—— (1942B); The Rakuroan Complex of the Shansi Basin and its surroundings. *JJGG*, vol. 18, no. 4 (E).

—— (1950); Overall consideration of geologic history of Far East in Mesozoic era. *Jour. Geogr.*, vol. 59, no. 3 (E).

KONNO, Enzo (1933); Palaeozoic plant fossils, Tokyo, Iwanami Pub. Co. (J).

——, and Kazuo ASAMA (1950A); Palaeozoic plant fossil, Lobatannularia. *Jour. Geol. Soc. Jap.*, vol. 65, no. 656 (J).

—— (1950b); On the Genus *Lobatannularia*, 1927 from Permian Beds in South Manchuria and Shansi, China. *Tohoku Univ. Inst. Geol. Pal. short papers*, no. 1 (E).

LEE, J. S. (1927); Fusulinidae of North China. *Pal. Sinica*, ser. B., vol. IV, fasc. 1 (E).

LEE, J. S. (1931); Distribution of the dominant types of the Fusulinoid Foraminifera in the Chinese Sea. *BGSC*, vol. 10 (E).

—— (1939); Geology of China. (E).

——, and Y. T. CHAO (1926); Classification and correlation of Palaeozoic coal bearing formation in North China. *BGSC*, vol. 5, no. 1 (E).

LI, Y. Y., C. LI, and S. CHU (1935); Geology of Ning mountain range. *Mem. Inst. Geol. Sinensis*; contribution no. 11 (E).

LIU, C. C., and U. T. CHAO (1919); Report of geology and minerals in Hwanpei, North Kingsu. *BGSC*, no. 1 (E).

Mining branch, Investigation bureau, North China Develop. Co. (1942); Investigation report of present states of coal mines in China (J).

MATSUZAWA, Isao (1938A); Survey report of Liuhokow coal field, Chingteh hsien, Honan Province. Report of coal branch, Geological survey party, Special service facility, Sugiyama detachment, North China (J).

—— (1938B); Survey report of geologic structure of Tangshan district, in the western part of Kailan coal field, Lan-hsien, Hopei Province. Report of coal branch, Geological survey party, Special service facility, Sugiyama detachment, North China (J).

—— (1941);
(A) Supposed coal field in the eastern portion of Liuhokow coal field, Changteh hsien, Honan Province, (B) Outline of Liuchuan, Tungshan hsien, Kiangsu Province, (C) Survey report of Yangchiatun coal field, Wangping hsien, Hopei Province, *Monthly report of Kōa-in* (China Affairs Board) (J).

MORITA, H., and H. OZAKI (1937); Estimated reserves of coal, fire clay and limestone in the environs of Kailan coal field, Chitung. Mine investigation team of S. Manchurian Railway Co. no. 2 party (J).

MORITA, H., and Y. ONUKI (1940); Report of 2nd team for 1st Mineral resources survey in Mongolia. Industry Dept. Mongolia Government (J).

MORITA, H., and T. TAKAHASHI (1940A); Explanatory text of Geologic sheet map, Paitungtsun, North Tatung coal field. Mineral resources survey in Mongolia. Industry Dept. Mongolia Government (J).

—— (1940B); Explanatory text of Geologic sheet map, Yufeng colliery. Mineral resources survey in Mongolia. Industry Dept. Mongolia Government (J).

MORITA, H., and M. MUKAI (1940); Explanatory text of geologic sheet map, Paituyao. Mineral resources survey in Mongolia. Industry Dept. Mongolia Government (J).

MORITA, H. (1940); Explanatory text of geologic map, Yungtingchuang. Mineral resources survey in Mongolia. Industry Dept. Mongolia Government (J).

—— (1941); Permo-Carboniferous formation of north Tatung coal field, Mengchiang. *JGSJ*, vol. 48 (J).

—— (1943); Results of investigation of Tatung coal field, Tatung Province, Mengchiang. Outline of investigation in the first half of 1943, Investigation Bureau, N. China Development Co (J).

—— (1944); Hwaijen series of Permian period, North Tatung coal field, Mengchiang. *JGSJ*, vol. 56 (J).

MUKAI, M. (1944); Explanatory text of Geologic Sheet map, Yintangkou, North Tatung coal field. Industry Dept. Mongolia Government (J).

NODA, Mitsuo (1939); Stratigraphical study of Carboniferous system and Permian system in S. Manchuria. *Memoir of National Museum of Manchuria*, no. 1 (E).

—— (1944); Geology of Central portion of Lai-wu coal field, Shantung Province. *Memoir of National Museum of Manchuria*, no. 7 (E).

—— (1950); Carboniferous-permian boundary in North China and South China. *JGSJ*, vol. 56, no. 652 (J).

NORIN, E. (1922); The Late Palaeozoic and early Mesozoic sediments of Central Shansi. *BGSC*, vol. 1, no. 4 (E).

North China Development Co. (1943); Text book of resources in North China. (Aluminous ores, coal and iron ores) (J).

ONUKI, Y. (1938); Chichibu system of Kisen gun district, Iwate Prefecture in the Kitakami mountainland. *JGSJ*, vol. 45, no. 532 (J).

—— (1940);

(A) Explanatory text of geologic sheet map, Szelaokow, North Tatung coal field, (B) Explanatory text of geologic sheet map Yen-Ai, (C) Explanatory text of geologic sheet map Weichiakow, (D) Explanatory text of geologic sheet map of Laoyaokow, (E) Explanatory text of geologic sheet map of Changliushui, (F) Explanatory text of geologic sheet map of Meiyukow, North Tatung coal field. Industry Dept., Mongolia Government (J).

ONUKI, Y. (1941);

(A) Outline of Lingshangchen coal field, Chuyanghsien, Hopei Province,

(B) Survey report of Tashe coal field, Tsiyuan hsien, Hopei Province,

(C) Survey report of Chaotso coal field, Honan Province. Investigation Bureau of N. China Develop. Co (J).

—— (1942);

(A) Survey report of Hungyuan coal field (Mengchiayao region) Mengchiang,

(B) Survey report of Kufow coal field, Shantung Province. Investigation Bureau of N. China Develop. Co (J).

—— (1943);

(A) Survey report of Yi-hsien coal field (Chunghsing colliery) Shantung Province. Outline of investigation in the first half of 1943, (B) Survey report of Chinghsing coal field, Hopei Province. Investigation Bureau, N. China Develop. Co (J).

—— (1944A); "Shantung system", upper Palaeozoic formation in Tzechuan, Poshan

and Changchiu coal field, Shantung Province, N. China. Investigation Bureau, N. China Develop. Co (J).

—— (1944B); New division of upper Palaeozoic formation in Tzechuan, Poshan and Changchiu coal field, Shantung Province. *JGSJ*, vol. 51, no. 605 (J).

—— (1945A); Importance of Chunghsing and Liuchuan coal fields, viewed from correlation of coal measures in N. and S. China. Investigation Bureau, N. China Develop. Co (J).

—— (1945B); "Subsidence column" in Chinghsing coal field, Hopei Province. Investigation Bureau, N. China Develop. Co (J).

—— (1941–1945); Survey report of aluminous shale in Tzechuan, Poshan and Changchiu coal field, Shantung Province. Investigation Bureau, N. China Develop. Co.

—— (1943–1945); Survey report of geology of Liuchuan coal field, Hwaihai Province. Investigation Bureau, N. China Develop. Co (J).

ONUKI, Y. (1946); Underground resources of North China. Expropriation Committee, Republic of China.

—— (1951); Palaeozoic coal measures in China. *Mineralogy and Geology*, vol. 4 (J).

—— (1951A); Upper Palaeozoic formation of North China. Paper read before a meeting of Kanto branch, *Geol. Soc. Japan* (J).

—— (1951C); Establishment of Chinghsing series and Pingting series (Upper and Middle Carboniferous system of North China. Paper read before the 58th general meeting, *Geol. Soc. Japan* (J).

—— (1951D); Unconformity of pre-Shansi series and its movement. Paper read before the 58th general meeting, *Geol. Soc. Japan* (J).

—— (1951E); Formation of "A" bed aluminous shale and its geological meaning. Paper read before the 58th general meeting, *Geol. Soc. Japan* (J).

OSUGI, S. (1949); Soil chemistry. Part 1, chemistry of formation of soil (J).

OZAKI, K. (1931); Upper Carboniferous Brachiopods from North China. *Bull. Shanghai Sci. Inst.*, vol. 6 (E).

OZAKI, H. (1937);

(A) Survey report of Shihmenchai coal field, Hopei Province, (B) Survey report of Northwestern Poshan coal field, Shantung Province, (C) Survey report of Liangchiatien colliery in Changchiu coal field, Shantung Province. Jap. Army in China.

SAKAMOTO, T. (1937);

(A) Survey report of Chinghsing coal field, Hopei Province, (B) Survey report of Yi-hsien coal field, Shantung Province. Survey report of mines in North China, No. 4 party, Jap. Army in China (J).

—— (1939); Quality and reserve of coal in Tatung coal field (attached with Quality and reserve of Kaolin). Industry Dept., Mongolian Government (J).

—— (1950); Ore deposits of bauxite and aluminous shale. Consideration on weathering and deposition of clays from the standpoint of historical geology *JGSJ*, vol. 56, no. 653 (J).

SASA, K. (1942); Report of Seismic prospecting in Lincheng coal field, Hopei Province. Report of N. China Develop. Co. (J).

SEMICHATOV (1930); Contribution to the question concerning the boundary between the Upper and the Middle Carboniferous in North China, in European Russia. *Mem. Nat. Res. Inst. Geol.* Academia Sinica, no. 9 (E).

SHIIDA, K. (1941); Border plane of Permo-Carboniferous system in Yangchuan coal field and Taiyuan-Sishan, Shansi Province. *JGSJ*, vol. 48 (J).

—— (1942A); Table of coal reserves and quality of coal fields, North China and Mengchiang. Investigation Bureau, N. China Develop. Co (J).

—— (1942B); Survey report of coal field in the environs of Hsienkangchen in Ningwu coal field. Report of N. China Develop., no. 1 (J).

—— (1944); Geological characteristics of Upper Palaeozoic coal fields in North China. *JGSJ*, vol. 51, no. 605 (J).

SHIMAKURA, M. (1939); Plant fossils from Hwainan coal field, Anhwei Province. *Journal Shanghai Sci. Inst.*, vol. 9 (E).

—— (1950); Geology of Hwainan coal field, Anhwei Province. *JGSJ*, vol. 56, no. 656 (J).

SUN, C. C. (1934); Geology of the Yuhsien-Mihsien coal field, Honan, *BGSC*, vol. 13, no. 24 (E).

SZE, H. C. (1934); Problem on the age of the distribution of plants in the end of Palaeozoic era. *Sci. Quart. Nat. Univ.*, Peking, vol. 4, no. 1 (C).

—— (1935); Ueber das Vorkommen von Callipteris conferta Sternb. in der unteren Shihhotze Serie in Central Shangsi. *BGSC*, vol. 14, no. 4 (G).

TAKAHASHI, T. (1944);
(A) Horizon of Hunglohsien coal field and Yangchia Chiangtzu coal field, Chinhsi hsien, and Hsingchenghsien, Chinchou Province, (B) Stratigraphical division of upper Palaeozoic formation in the bore—log at Tafotou, Kailan coal field, Hopei Province. *Bull. Ore deposit and Geology*, S. Manchuria Railway Co., No. 1 (J).

TAKEYAMA, T. (1937); Survey report of Tatung coal field in the environs of Yungtingchuang, Tatung hsien, Shansi Province. Survey report of mines of North China, B team, no. 4 party, Jap. Army in China (J).

TAN, H. C. (1922); The Geology of Tsuchuan—Poshan coal field, Shantung. *BGSC*, vol. 1, no. 4 (E).

—— (1923); New research on the Mesozoic and Early Tertiary Geology in Shantung. *BGSC*, vol. 2, no. 5 (E).

TANAKADATE, S. (1922); Geology and mines of Shantung Province (J).

TIEN, C. C. (1929); Study of Upper Palaeozoic formation in Central Hunan. Memoir of the Institute of Geology; Sinensia; Contribution no. 7 (E).

TOKUDA, T. (1941); Survey report of Hwainan coal field, Hwaiyuan hsien, Anhwei Province. Survey report of major mineral resources of China, Kōa-in (China Affairs Board) (J).

TOMITA, T. (1942); Table of correlation of strata in North China. Peking University (J).

UEDA, F., H. MORITA, and H. YOSHIZAWA (1938); Survey report of the geology of northeastern part of Tatung coal field, Shansi Province. Mining & Industry Dept., S. Manchuria Railway Co (J).

WANG, C. C. (1921); Geology of Tatung, Tsoyun, Hwaijen, and Yuyu coal fields. *Geological Bulletin* no. 3 (E).

—— (1924); Geology of southwestern part of Hwaiyuan hsien, Anhwei. *BGSC*, vol, 3, no. 6.

—— (1927); Geology of Wu-an, She Hsien, Ling Hsien and An Yang Districts, Northern Honan. *BGSC*, vol. 6, no. 9 (E).

—— (1927); Geology of the Ja-Ching-shan range and its coal fields. *BGSC*, vol. 6, no. 10 (E).

—— (1930); A study on the Hsueh-Hua-Shan basalt lava and its underlying fossiliferous sediments in the Chinghsing district. *BGSC*, vol. 9, no. 15 (E).

—— (1932A); Study of Poshan coal, Shantung. *BGSC*, vol. 11, no. 18. (E)

—— (1932B); Study of aluminium ores from Poshan and Tzechuan, Shantung, *BGSC*, vol. 11, no. 18 (E).

—— (1938); Geology of North Chinghsing coal field. *Geological review*, vol. 1, no. 3.

——, C. C. TIEN, and Y. T. CHAO (1924); Stratigraphy of Lin-chen-hsien. S. Chihi.

——, and Y. S. CHI (1933); The coal field of Mentoukou, west of Peiping. *BGSC*, vol. 12, (E).

WANG, C. T., and Y. L. WANT (1930); A study of general and economic geology along the Chang-jai (Shansi) railway, *BGSC*, vol. 9, no. 15 (E).

WATANABE, K. (1923); Survey report of Changchiu coal field. Overseas mineral survey report. *Geol. Surv. Japan*, no. 10 (J).

—— (1923); Survey report of mineral localities in Shantung. Overseas mineral survey report. *Geol. Surv. Japan*, no. 15 (J).

—— (1924); Survey report of Poshan coal field. Overseas mineral survey report. *Geol. Surv. Japan*, no. 12 (J).

—— (1931); Survey report of Tzechuan coal field. Overseas mineral survey report. *Geol. Surv. Japan*, no. 11 (J).

—— (1940); Outline of Geology of China, No. 3. *Jour. Geogr.*, vol. 52 (J).

WILLIS, B., and E. BLACKWELDER (1907); Research in China (E).

YABE, H. (1939, 1940); Fossils and palaeontology of China. *Jour. Geogr.*, vols. 52, 53 (J).

YAMANE, S. (1918);

Survey report of minerals in the western part of Shantung; Survey report of minerals in the eastern part of Shantung; Survey report of the Sishan coal field, Taiyuan, Shansi Province; Survey report of southwestern coal field, Shansi Province; Survey report of coal fields in the basins of Fen Ho and Tsin Ho. Overseas Mineral Survey report, Temporary Industry Investigation Bureau, nos. 1, 2, 6, and 10 (J).

—— (1920); Survey report of coal in the environs of Tzehchow, Shansi Province. Overseas mineral survey report. *Geol. Surv. Japan*, no. 1 (J).

—— (1923); Survey report of eastern coal field, South Shansi. Overseas mineral survey report. *Geol. Surv. Japan*, no. 13 (J).

—— (1923); Survey report of Chinghsing coal field, Chihli Province. Overseas mineral survey report. *Geol. Survey Japan*, no. 14 (J).

—— (1924); Survey report of coal fields in the southern part of Chihli Province and the northern part of Honan Province. Overseas mineral survey report. *Geol. Surv. Japan*, no. 16 (J).

—— (1931); Geologic history of China, Tokyo, Iwanami Pub. Co. pp (J).

YEH, L. F. (1920); Geology of Sishan of Peiking. *Mem. Geol. Surv. China*, no. 1 (E).

——, and T. Y. YU (1933); Outline of geology of Hwainan coal field. 21st General report. *Nat. Res. Inst. Geol.* Academia Sinica (E).

YIH, L. F., and C. C. LIN (1919); Coal field of Lingyu-hsien, Chihli. *BGSC*, no. 1 (E).

YOSHIZAWA, H. (1938); Survey report of coal field in the west of Wangpingtzun, Wangpinghsien, Hopei Province. Survey report of coal branch, Geological survey team, Special Service facility, Sugiyama detachment, Jap. Army (J).