Geology of the Yang-chuan Coal Field Shan-si, North China

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I. Location

The Yang-chuan Coal Field is situated in the eastern part of Shan-si province and forms the northeastern part of the great coal basin of the Tai-hang plateau which occurs widely in southern Shan-si. Yang-chuan station lies midway on the Cheng-tai Railway, which connects Shih-men (Shih-chia-chuang) and Tai-yuan and runs along the Mien-ho, also called Tao-shui. Yang-chuan station is also the center of the Yang-chuan Coal Field. The coal fields of Yu and Shou-yang lie to the northwest and the coal field of Ping-ting lies to the southeast of the Yang-chuan Coal Field. The authors investigated the southern part of the Yang-chuan Coal Field which extends from slightly east of Yang-chuan Station westward 8 km along the railway line to Sai-yu Station and from the railway line to a point 6 km south of that line.

II. Outline of Topography

Shih-nao-shan (1,174 m) which stands in the southwestern part of the field, is the highest mountain peak in this area. A mountain range extends from this peak toward the northeast and its extension reaches to south of Yang-chuan, where its altitude is about 700 m. A mountain range, which extends southward from Shih-nao-shan, occupies the southwestern part of the area (approx. 1,110 m height); it then swings to the east and forms the southern boundary of the Yang-chuan Coal Field. The average height of this range is 1,100 m, but the elevation of its eastern ends is less than 1,000 m. Thus, the mountain range has a shape similar to a horseshoe with its open end facing east. The Hsi-yu-ho flows eastward in the valley embraced by the horseshoe-shaped ridge, and turns to the northeast of I-tung-kou and joins the Mien-ho. A broad alluvial plain is developed along the Mien-ho which flows eastward along the northern border of the investigated area, and its elevation is 720 m in the western part and about 650 m in the eastern. The valleys of Hsi-yu-ho and Mien-ho were buried by loess and by the Mien-ho formation.

The present rivers are deeply entrenched in these deposits forming young valleys and terraces. The river terraces consists of two, the upper and the lower; the upper is more conspicuous and rises to 30–60 m above the flood plain while the lower rises about 10 m. Town of Yang-chuan stands on the lower terrace. The mountains which are not covered with loess and the Mien-ho formation, are generally dissected in the mature stage, and the stepped or table land topography is most characteristic.

III. Geology

The deposits distributed in the Yang-chuan Coal Field are as follows, in descending order:

Diluvium		Loess
		~~unconformity~~~~~
		Mien-ho formation
		~~unconformity~~~~~
Middle & Upper Permian	Tse-shih series	Upper (reddish or yellowish brown rocks), 140 m thick
		Middle (reddish or yellowish green rocks), 160–175 m thick
		Lower (yellowish green rocks), 113 m thick
Lower & Middle Permian	Shan-si series (Upper coal measure), 100–120 m thick	
	~~unconformity~~~~~	
Lower Permian	Tai-yuan series (Middle coal measure), 70–85 m thick	
	~~unconformity~~~~~	
Moscovian	Pen-chi series (Lower coal measure), 50 m thick	
	~~unconformity~~~~~	
Ordovician	Ordovician system	

The Ordovician to Permian formations occur in parallel, lower strata distributed in the east and upper ones in the west, thus assuming a monoclinal structure dipping gently to the west.

A. Ordovician System (Wang and Wang, 1930)

This system is composed of thick-bedded, light gray to gray limestone which is known as the Ki-chou limestone. Though this limestone is widely distributed and constitutes the basement of the coal field, its exposures are very scarce in the area surveyed. However, it does crop out on the right bank of the Mien-ho, about 2 km

east of Yang-chuan near the eastern margin of the field and along the Yang-chuan to Ping-ting highway east of I-tung-kou. It is widely developed further east from these places.

B. Pen-chi Series

This series is limited to two places on a very small scale: the one is near Nan-chuang in the southeastern part of the field and the other is southeast of Yang-chuan city. It is typically developed south of I-tung-kou village along the Yang-chuan to Ping-ting highway, though it is outside the area dealt with here. The main constituents of the series of this region are shale, sandy shale, aluminous shale, limestone and marl, having a total thickness of about 50 m. The stratigraphic succession is as follows (in descending order):

8.	Upper shale	12 – 17 m thick
7.	Upper limestone	13 – 2 m thick
6.	Middle shale	7 – 12 m thick
5.	Middle limestone	1 – 1.2m thick
4.	Lower shale	8 – 12 m thick
3.	Lower limestone	9 m thick
2.	Aluminous shale (G bed)	4 – 6 m thick
1.	Iron ore	2.5m thick

The Pen-chi series rests unconformably upon the Ordovician limestone. This is a parallel unconformity (disconformity); the plane of the unconformity is highly uneven although it is on a small scale.

1. *Iron Ore*

On the top of the old erosion surface of the Ordovician limestone the Pen-chi series begins with layers of yellowish-brown and reddish-brown iron ore about 2.5 m thick. The ore is often deposited in the crevices or the hollow places of the limestone where the thickness often exceeds 3 m.

2. *Aluminous Shale (G bed)*

The Pen-chi series intercalates several layers of aluminous shale. The lowest layer is the thickest and is generally about 4 m thick, but its maximum thickness is 6 m. There is an abandoned mine of aluminous shale about 1 km south-east of I-tung-kou village. The aluminous shale is usually of light gray color and very fine clayey rock. It is very slippery and adhesive when wet. It is easily distinguished from the other rocks by these lithological characters.

3. *Lower Limestone*

This limestone is placed in the horizon 6–9 m above the base of the Pen-chi series and is about 9 m thick. This limestone generally consists of 3 or more separate layers of limestone, intercalating dark gray or black shales, having a thickness of about 30–40 cm. The limestone is gray to dark gray, compact and contains many nodules of chert, especially in the lower part.

4. *Lower Shale*

This shale intercalates one or two layers of marl in its upper part. The upper

one (3.90 m) is thicker than the lower layer. As the result of weathering, the shale easily disintegrates into small fragments of angular polyhedrons and exfoliates to thin pieces of 0.2 to 1.0 cm thick where the rock is sandy or sandy shale. The shale is usually gray, dark gray and black, but occasionally brown when it is associated with thin layers or nodules of ferruginous shale.

5. *Middle Limestone*

This limestone is found in the middle portion of the Pen-chi series. Its maximum thickness is about 1.2 m, and it often lies in a row of nodule having a diameter of 0.25–0.70 m. It is usually dark gray and yields many fossils.

6. *Middle Shale*

This consists mainly of shale and is associated with sandy shale, aluminous shale, coal and iron ore. The shale is generally dark gray to black and well stratified. When the rock is sandy, it weathers easily and exfoliates into thin pieces. The dark-colored shale often contains many poorly preserved plant fossils. The sandy shale is usually gray to dark gray and has a lighter shade than the shale, but it is occasionally bluish gray. Thin layers and nodules of iron ore are often found in the bluish-gray sandy shale. Three beds of light gray to white aluminous shale occur in the upper part of the shale, and attain a maximum thickness of 4.8 m. Two thin coal seams, about 10 cm thick each, are interbedded.

7. *Upper Limestone*

Though the Upper limestone is dark gray and compact very similar to the Middle limestone, the former is thicker (1.30 to 2.00 m) than the latter. It occurs as a single layer, but is occasionally intercalated with several thin layers of chert. The limestone yields fossils of Foraminifera and Brachiopoda.

8. *Upper Shale*

This is mainly reddish-purple shale, occasionally associated with sandstone and sandy shale. Being very hard the shale often forms steep cliffs along the mountain slopes and characterizes the upper part of the Pen-chi series. The shale is distinctly stratified due to alternation of coarse-grained parts and fine-grained parts. When weathered it easily exfoliates into thin tabular pieces. The sandy shale is usually of light gray color. The sandstone is gray or bluish gray, fine-grained and arkosic, occurring as single or two layers with a total thickness about 80 cm. The reddish-purple shale often contains nodules and lenses of iron ore and yields many plant fossils. Brachiopods and pelecypods were collected from the lower part of this shale at a place about 1 km northeast of Nan-chuang.

The Pen-chi series is divisible into 8 members as stated above, and is easily distinguished from other series by the characteristic limestones. Three thin coal seams, though not workable, are intercalated in it.

The Pen-chi series of this region is well developed in the area from near Nan-chuang to south of I-tung-kou village. The strike and dip of the strata are variable and anticlines and synclines of low angle alternate, with the axes trending not only N–S but also E–W and the maximum dip about 30°. However, at a point about 500 m southeast of I-tung-kou the Lower limestone and the underlying strata are

Columnar section of the Pen-chi Series in descending order
(southeast of I-tung-kou)

	Thickness (m)
1. Reddish-purple shale and sandy shale in alternation	12.00
2. Gray fine sandstone	0.80
3. Dark-gray shale	4.40
4. Yellowish-brown marl	0.60
5. Limestone (Lh_1)	0.80
6. Black chert	0.35
7. Limestone	0.35
8. Black chert	0.35
9. Limestone (Lh_1)	0.20
10. Black chert	0.10
11. Limestone	0.20
12. Black chert	0.20
13. Aluminous sandy shale	0.80
14. Black chert	0.30
15. Coal	0.10
16. Aluminous shale	1.30
17. Aluminous sandy shale	1.80
18. Coal	0.10
19. Aluminous shale	0.90
20. Gray sandy shale	0.20
21. Dark-gray shale	0.90
22. Iron ore	0.10
23. Limestone (Lh_2)	1.20
24. Coal	0.10
25. Aluminous shale	0.60
26. Yellowish-brown marl	1.90
27. Dark-gray or brown shale	2.20
28. Iron ore	0.20
29. Gray or black shale	1.30
30. Black shale	0.80
31. Iron ore bearing limestone	0.40
32. Limestone (Lh_3)	2.20
33. Gray shale	0.40
34. Limestone (Lh_3)	2.30
35. Black chert	0.30
36. Limestone (Lh_3)	2.50
37. Aluminous shale	0.80
38. Light-gray, aluminous sandy shale	1.40
39. Aluminous shale	1.60
40. Iron ore	2.50

intensely folded and dip about 90°. Significant faulting is rare in the area, except for a few faults with a displacement less than 1 m.

The limestones of the Pen-chi series yield many fossils, consisting of Foraminifera, Anthozoa, Brachiopoda, Pelecypoda, Gastropoda, Crinoidea and Trilobita, and the Upper shale contains Brachiopoda and Pelecypoda. We found many plant fossils in the shale of various horizons of the Pen-chi series, but they were not well preserved. The identification of these fossils has not been finished yet, but the Brachipoda are as follows:

Meekella exima EICHWALD
Camarophoria sp. a
Chonetes platti DAVIDSON
Chonetes sp.
Productus gruenwaldti KROTOW
P. gratiosus WAAGEN var. *occidentalis* SCHELLWIEN
Enteletes lamarki F. de WALDHEIM
Enteletes sp.
Linoproductus cf. cora d'ORBIGNY
Marginifera sp.
Choristites wongchichuensis CHAO

Foraminifera (LEE, 1927) are as follows:

Fusulina pankouensis (LEE)
Bradyina nautiliformis Moller

The fossils collected from the Pen-chi series have not yet been fully investigated but there is no doubt that they are equivalent to the fauna of the Pen-chi series of the type locality. Hence it is fairly safe to say that the Pen-chi series of the Yang-chuan Coal Field is Moscovian in age.

C. TAI-YUAN SERIES

The main distributions of the Tai-yuan series are limited to two regions: one is the neighborhood of Nan-chuang in the southeastern part of the field, and the other is the northern marginal portion of the field from south of Yang-chuan city to pit No. 1.

It is composed chiefly of gray to black shale, intercalating sandstone, limestone and coal seam, and its total thickness is 70–85 m. Subdivision of the Tai-yuan series, in descending order, is as follows:

7.	Upper shale and sandstone	1.30 – 5.00 m thick
6.	Upper limestone (Hou-shi)	0.60 – 2.00 m thick
5.	Middle shale and sandstone	9.00 – 40.00 m thick
4.	Middle limestone (Chien-shi)	1.10 – 1.60 m thick
3.	Lower shale and sandstone	21.00 – 25.00 m thick
2.	Lower limestone (Su-chieh)	5.00 m thick

1. Lowest coal-bearing shale and sandstone — 20.00 – 25.00 m thick

1. *Lowermost Coal-bearing Shale and Sandstone*

The main rocks are gray to dark-gray shale and sandy shale to sandstone in alternation, intercalating coal seams. In the lower part, peculiar fine greenish-gray sandstone of 1–3 m thick occurs, containing iron ores of granular or oolitic structure and is overlain by the shale of gray to black color. This shale occasionally becomes reddish where it contains nodules of iron ore. A coal seam 4–8.8 m in thickness occurs in the middle part and is called coal seam E (E bed), or commonly Chang-pa-mei.

Most of the coal of this coal field is exploited from E bed. A dark gray shale 8–10 m thick overlies the coal seam. It is partly reddish purple or partly brown, well stratified, and easily exfoliates to thin pieces. A thin coal seam is occasionally intercalated in the upper part of the shale.

2. *Lower Limestone*

The Lower limestone is about 5 m thick and is usually separated into two layers by a thin intercalation of shale. The lower part is 1.4–1.8 m thick and is also often separated by thin bands of shale. The upper part is 2–2.8 m thick. The shale intercalated between two layers of limestone is gray or black color and often intercalates thin bands of cherty shale 1–1.5 m thick. The limestone is gray or dark gray and contains many fossils that comprise Foraminifera, Anthozoa, Crinoidea, Ammonoidea, Brachiopoda and Trilobita. The limestone is usually divided into three layers, which are called Ku-shih, Su-chieh-shih and Yao-ku-shih in descending order, or collectively called Su-chieh-shih. The limestone has characteristic lithology and remarkable continuity.

3. *Lower Shale and Sandstone*

This member is composed of the alternation of shale and sandstone between the Lower and Middle limestones. Its mean thickness is 23 m. The shales are gray or black and well stratified; the sandstones are medium-grained and are usually gray, often brownish gray or yellowish gray. The thickness of the sandstones is generally several meters, maximum 7.6 m.

4. *Middle Limestone*

The Middle limestone is a single bed 1.1 to 1.6 m thick. It is dark-gray, compact, and yields many fossils. Irregular shaped nodules of black chert are often contained in it. Fossils occur mostly in the upper and lower parts of the limestone and occasionally many Brachiopod and other fossils are obtained from the calcareous shale which overlies the limestone. The fossils are Foraminifera, Brachiopoda, Anthozoa, Bryozoa, Crinoidea, Pelecypoda, Trilobita, and Ammonoidea. The limestone is commonly called Chien-shih.

5. *Middle Shale and Sandstone*

This member consists of shale and sandstone interbedded between the Middle and Upper limestones. It is generally 20 m thick, but the thickness varies with

locality. The main component of the lower half of this member is yellowish-gray, coarse- to medium-grained sandstone. The sandstone east of pit No. 1 is 22 m thick. The lower part of the sandstone is generally massive and coarse-grained and gradually becomes stratified and fine-grained upward. The main rocks of the upper half are gray to black shales and sandy shales with many intercalations of thin bands or lenses of sandstone. The stratification of the shales and sandy shales is usually distinct. A coal seam of 1.0 to 1.5 m thick is intercalated in the upper part of the member, about 8 to 10 m below the base of the Upper limestone.

6. *Upper Limestone*

The Upper limestone is usually about 1 m thick (0.6 to 2.0 m) and often separated into two layers by the intercalation of iron ore or calcareous shale. The limestone is dark gray to black and compact, yielding many fossils such as Anthozoa, Crinoidea and Brachiopoda. Besides these, Foraminifera and Bryozoa have been collected also. The limestone is commonly called Hou-shih. A coal seam usually occurs directly under the Upper limestone, between the limestone and the Middle shale and sandstone. It is 5 to 40 cm thick.

7. *Upper Shale*

The Upper shale, which overlies the Upper limestone, consists mainly of gray or black shale. It is 1.3 to 5.0 m thick and often intercalates thin layers of sandstone and sandy shale. A coal seam 20 to 50 cm thick occurs in its upper part.

The coal seams of the Tai-yuan series occur in the following five horizons (in descending order):

5.	The uppermost horizon of the Upper shale	0.20–0.50 m thick
4.	The horizon below the Upper limestone	0.05–0.40 m thick
3.	The upper part of the Lower shale and sandstone (D bed)	1.00–1.50 m thick
2.	The upper part of the Lower shale and sandstone	0.75–0.80 m thick
1.	The middle part of the lowermost coal-bearing shale and sandstone (E bed)	4.00–5.50 m thick

The Tai-yuan series, overlying the Pen-chi series, crops out in the southeastern and northern margin of the area and generally dips 5 to 30° SW with gentle folding. The axial trend of the folds is diversified, changing from N–W to E–W. The shale of the Tai-yuan series yields many well-preserved plant fossils in several horizons. The investigation on these fossils is not yet finished, but *Cordaites* is the predominant genus among them. The limestones and associated calcareous shales contain many marine fossils such as Foraminifera (Lee, 1927), Anthozoa, Brachiopoda (Ozaki, 1931) and Trilobita. Important species, especially Brachiopoda, are as follows:

On the basis of these fossil contents this series can be correlated with the Tai-yuan series of the Tai-yuan region, and is assigned to the Lowermost Permian (Sakmarian) age.

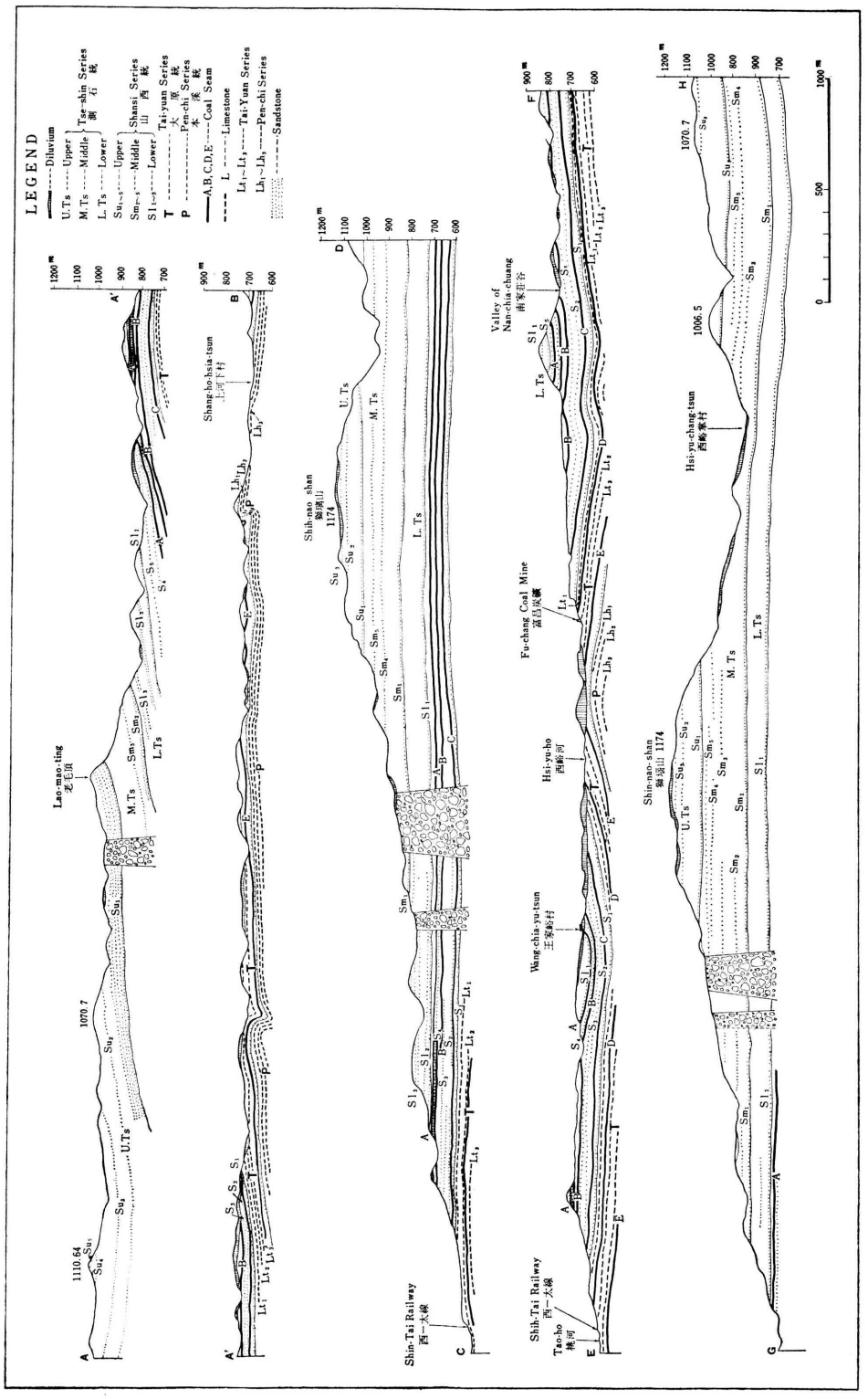

Fig. 1. Geological profiles of the Yang-chuan coal field, Shan-si, North China.

Columnar section of the Tai-yuan series in descending order (from south of Hsiao-yang-chuan to southwest of I-tung-kou).

	Thickness (m)
1. Coal	0.40
2. Black or gray shale	2.40
3. Limestone	0.20
4. Iron ore	0.15
5. Limestone (Lt_1)	1.20
6. Coal	0.15
7. Grayish-brown, fine sandstone	0.50
8. Gray shale	2.90
9. Coal	0.30
10. Gray shale	3.50
11. Black shale	1.30
12. Grayish-brown, fine sandstone	6.30
13. Yellowish-gray, medium-grained sandstone	9.00
14. Dark-gray shale	3.00
15. Black shale	0.85
16. Dark-gray, calacareous shale	0.10
17. Limestone (Lt_2)	1.40
18. Dark-gray, calcareous shale	0.40
19. Coal	0.75
20. Clay	0.10
21. Gray shale	1.40
22. Yellowish-gray, fine sandstone	3.00
23. Fine sandstone	4.20
24. Light-gray shale	5.60
25. Bluish-black limestone (Lt_3)	2.80
26. Dark-gray shale	1.30
27. Bluish-black limestone	1.80
28. Gray shale	1.00
29. Calcareous shale	0.30
30. Coal	0.15
31. Reddish-purple or dark-gray shale	6.00
32. Coal (E)	4.00
33. Gray shale	1.00
34. Coaly shale	0.80
35. Dark-gray shale	3.50
36. Gray shale	1.50
37. Grayish-brown, fine sandstone	0.20
38. Black shale	0.60
39. Gray sandy shale	0.20
40. Bluish-gray, fine sandstone	2.00

	Lower limestone	Middle limestone	Upper limestone
Schizophoria indica WAAGEN		×	
Streptorhynchus cf. *pectiniformis* DAVIDSON			×
Chonetes latesinuata SCHELLWIEN	×		
Chonetes cf. *buchiana* de KONINCK		×	
Chonetes cf. *hardrensis* PHILLIPS	×		
Chonetes chonetoides (CHAO)			×
Chonetes sp.	×		
Products uralicus TSCHERNYSCHEW			×
Productus moerri STUCKENBERG	×		
Productus intermedium var. *subplicatilis* FRECH			×
Productus manchuricus CHAO			×
Echinoconchus cf. *punctatus* (MARTIN)		×	
Waagenoconcha sp.	×		
Marginifera typica WAAGEN			×
Marginifera longispinus var. *lobata* SCHELLWIEN			×
Marginifera pusilla SCHELLWIEN	×		
Camarophoria schansiensis OZAKI		×	
Camarophoria meyeri var. *tetraplicata* OZAKI		×	
Spirifer fasciger KEYSERLING		×	
Choristites abnomalis CHAO	×		
Choristites jigulensis STUCKENBERG		×	
Choristites yanghukouensis CHAO	×		
Choristes trautsholdti STUCKENBERG	×		
Choristites paichingiensis OZAKI			×
Choristites pavlovi STUCKENBERG	×		
Choristites cf. *wynnei* (WAAGEN)			×
Choristites cf. *rectangulus* KUTORGA mut. *triplicatus* (MANSUY)	×		
Munella nikitini TSCHERNYSCHEW			×
Munella nikitini var. *tschernyschewi* OZAKI			×
Brachythyris cf. *schansiensis* CHAO	×		
Eliva cf. *mignon* GRABAU		×	
Martinia semiplana WAAGEN		×	
Martinia corculum KUTORGA		×	
Squamularia perplexa MCCHESNEY		×	
Spiriferina cf. *cristata* SCHLOTHEIM	×		

The boundary between the Tai-yuan series and the Pen-chi series is tentatively placed at the base of the coarse-grained sandstone which occurs at about 10 m below E bed. The strata above and below the boundary plane are quite parallel

and no stratigraphic break could be ascertained in the field, but the fossils indicate the age of Lowermost Permian. As the underlying Pen-chi series is Middle Carboniferous (Moscovian) in age, a faunal break should exist between the two series, and consequently the boundary is a disconformity.

D. SHAN-SI SERIES

The Shan-si series is widely distributed from Sai-yu at the northwest end of the report area to the southeast and along the eastern foot of Shih-nao-shan. South of the Tien-lu-kang pit the whole succession of the series can be observed. The Shan-si series consists mainly of sandstone and shale, intercalated with several coal seams. Development of sandstone is especially remarkable, occurring in six beds which are designated S_1, S_2, S_3, S_4, S_5 and S_6 in ascending order. The sandstone forms steep cliffs along the mountain slope as the rock is usually harder than other rocks. By these sandstone beds the Shan-si series, 100 to 120 m thick, is divisible into the following three members:

3.	Upper member (S_5 and above)	25–38 m thick
2.	Middle member (S_3 to base of S_5)	25–38 m thick
1.	Lower member (S_1 to base of S_3)	30–40 m thick

1. *Lower Member*

The sandstone S_1 at the base of the Lower member is 5 to 15 m thick and continues horizontally without much variation of thickness; it is usually underlain by a thin coal seam belonging to the uppermost part of the Tai-yuan series. The sandstone S_2 is 2 to 4 m thick and occurs in the horizon 5 to 8 m above S_1. The rocks occurring between these two sandstones are gray to black shale accompanied by thin sandstone, sandy shale and coal seams. The shale contains many small nodules of iron ore along the bedding plane. Iron ore occasionally forms layers less than 20 cm thick. Coal seam C (C bed) occurs in the upper part of the shale. The upper part of the Lower member, above S_2, consists chiefly of gray to black shale containing thin beds of sandstone, sandy shale and coal seam. Black or dark gray shales often yield plant fossils. In the horizon 4 to 5 m above S_2 a coal seam occurs, and its thickness is about 45 cm south of pit No. 1.

2. *Middle Member*

The sandstones S_3 and S_4 of the Middle member are 6 m and 1–5 m thick respectively and occur in the lower horizons and they are occasionally united into one layer. They are grayish-white, coarse-grained quartzose and occasionally contain small pebbles of quartzite or grade into conglomeratic sandstone. A gray to black shale, which is intercalated between these two sandstones often contains a thin coal seam. The upper horizons of the Middle member above S_4 mainly consists of gray to black shale intercalating sandy shale, coaly shale and coal seams. The coal seams are 0.65–1.70 m thick and can be broadly traced in the field.

3. *Upper Member*

The Upper member is the part above S_5 and consists of sandstone and shale

intercalating coal seams. The sandstone S_5 is white, medium- to coarse-grained, quartzose and 1.3–8.0 m thick. The upper and lower parts of the sandstone are stratified, medium-grained, and has a maximum thickness of 8 m while the middle part is massive, coarse-grained and often shows good cross-bedding. The sandstone S_6 is gray, fine- to medium-grained, stratified and is 3–7 m thick with intercalations of thin gray to black shale, sandy shale and coal seams. The shale and sandy shale, associated with the coal seams, yield many *Annularia* and other plant fossils. A coal seam 0.75–1.20 m thick occurs in a horizon about 2–5 m above S_5 and can be broadly traced. The part above S_6 consists mainly of shale.

Columnar section of the Shan-si series in descending order (south of Tien-ku-kang pit).

	Thickness (m)
1. Gray shale	4.50
2. Yellowish-green sandstone	0.20
3. Gray shale	0.80
4. Sandy shale	0.80
5. Gray shale	4.10
6. Coal	0.10
7. Clay	0.10
8. Gray shale	3.00
9. Sandstone	0.40
10. Coal	0.10
11. Clay	0.15
12. Gray shale and sandy shale in alternation	5.20
13. Yellowish-brown marl	0.15
14. Sandy shale	1.50
15. Gray shale	0.60
16. Coal	0.50
17. Clay	0.10
18. Gray shale	0.30
19. Stratified sandstone (S_6)	3.00
20. Gray shale	0.25
21. Coal (A)	0.50
22. Dark-gray shale	0.20
23. Coal	0.15
24. Gray shale	1.60
25. Yellowish-gray sandstone (S_5)	1.30
26. Dark-gray or light-gray shale	0.80
27. Coal	0.07
28. Dark-gray shale	0.60
29. Light-brown, sandy shale	0.50

	Thickness (m)
30. Dark-gray or light-gray shale	1.00
31. Gray sandy shale	8.00
32. Light-gray or dark-gray shale	0.80
33. Coal (B)	0.90
34. Dark-gray or brownish-gray shale	1.60
35. Coal	0.07
36. Dark-gray shale	6.00
37. Coal	0.10
38. Gray sandy shale	2.50
39. Grayish-white coarse sandstone (S_4)	5.00
40. Gray or black shale	1.80
41. Grayish-white sandstone (S_3)	5.80
42. Gray shale and sandy shale in alternation	4.40
43. Stratified sandstone	1.00
44. Gray-sandy shale	1.00
45. Black shale	15.00
46. Coal	0.12
47. Coaly shale	0.70
48. Coal	0.20
49. Black shale	1.00
50. Gray-sandy shale	0.60
51. Grayish-brown, sandy shale and gray shale in alternation	4.20
52. Black shale	0.30
53. Coal	0.45
54. Gray shale and sandy shale in alternation	3.20
55. Gray medium-grained sandstone (S_2)	2.00
56. Coal (C)	0.20
57. Coaly shale	0.15
58. Coal (C)	0.25
59. Coaly shale	0.15
60. Coal (C)	0.18
61. Black shale	2.30
62. Sandy shale	0.30
63. Gray shale	2.00
64. Grayish-white, medium-grained sandstone (S_1)	6.20

The shales of the Middle and Lower members of the Shan-si series are gray to black, but the color gradually changes to yellowish-brown toward the Upper member. The yellowish-brown shale occasionally intercalates several thin coal seams and sandstones which are not extensive. Sandstones are fine-grained, well stratified and yellowish gray to grayish brown.

Considering the relation between the Shan-si series and the Tai-yuan series, the former always overlies the latter with sandstone S_1 at its base. The boundary plane is distinct at every outcrop and both strata are usually parallel and apparently conformable. The top bed of the Tai-yuan series, which is overlain by the Shan-si series with sandstone S_1 at its base, is not always uniform lithologically and its stratigraphic position is variable. Sandstone S_1 is conglomeratic in places and often contains many pebbles of shale and sandstone which probably have been derived from the Tai-yuan and the Pen-chi series. Judging from these facts it is probable that the relationship between the two series is a disconformity rather than being conformable.

E. Tse-shih Series

The Tse-shih series, which overlies the above-mentioned Shan-si series, consists of yellowish-green to yellowish-brown or reddish-purple rocks and was named by us (Fujimoto, 1943) after the type locality Tse-shih on the Cheng-tai Railway. It is widely distributed from the west to the southwestern part of the field. The series is a continuous deposit, but is divisible into Lower, Middle and Upper according to lightological characteristics.

1. *Lower Member*

The Lower member is typically developed 20–120 m above the level of the Cheng-tai Railway along the northern slopes of the Shih-nao-shan and westward from pit No. 5 (Tsai-wa-keng). It is about 100 m thick at this place and is composed of the alternation of dark gray to black shale and yellowish-green shale, intercalated with quartzose coarse-grained sandstone (3 layers), a thin coal seam at the lower part, and iron ore and aluminous shale in several horizons. Three layers of sandstone, Sl_1, Sl_2 and Sl_3, are 3–10 m thick each, horizontally continuous, usually coarse-grained, quartzose, and white to light-gray. They occasionally show conglomeratic texture and cross-bedded structure here and there. The quartzose sandstones are very hard and massive, so that they usually form steep cliffs along the slopes. The base of these sandstones is usually very clear, so that the distinction between the sandstone and the underlying shale is easy, but the upper part grades into sandy shale.

Considering the color of the shale of this member there are two types; one is gray to black and the other is yellowish green to yellowish brown. The former is predominant in the lower part and the latter in the middle and the upper parts. The latter is also usually massive and shows a tendency to be yellowish green in the middle portion and becomes yellowish brown in the upper portion. The shale often grades into sandy shale which consists chiefly of finely alternating yellowish-green, finegrained sandstone and light-gray shale.

2. *Middle Member*

This member, which overlies the Lower member, is about 175 m thick and consists chiefly of the alternation of yellowish-brown to yellowish-green shale, and speckled brown to reddish-brown shale with five layers of quartzose and coarse-

grain sandstones. These sandstones are called Sm_1, Sm_2, Sm_3, Sm_4 and Sm_5, in ascending order. The member often intercalates thin layers of iron ore and aluminous shale, and sometimes gray shale in the lower part, while the coal seam and the black shale cannot be observed. The above-mentioned sandstones are quartzose, coarse-grained and conglomeratic like those of the underlying series. They are 3–10 m thick, and generally white to light gray, but sometimes yellowish green. Sandy shale is occasionally found; it is not thick and merges into yellowish brown shale. There are two types of shale, yellowish brown to yellowish green and speckled brown to reddish brown, the latter is characteristic of this member and gradually increases upward.

3. *Upper Member*

The Upper member, which overlies the Middle member, consists chiefly of the alternation of yellowish brown shale and speckled brown or reddish brown shale, and constitutes the summit part of Shih-nao-shan. It also intercalates four layers of thick, coarse quartzose sandstones which are called Su_1, Su_2, Su_3 and Su_4 in ascending order; of these, Su_1 is thickest, about 10 m, and forms precipices at the summit. Thin aluminous shale occurs in the upper part of the member.

The Tse-shih series extends from the western part of the area southward and forms the mountains including the Shih-nao-shan and its extensions. The strike is on the whole NW–SE, with a dip of 5–15°S or E, presenting a monoclinic structure. The series locally dips to the north or west and is gently folded.

This series yields many plant fossils in the Lower and Middle members. The important fossils collected from the Lower, especially in the gray to dark-gray shale, are *Pecopteris* sp., *Cordaites* sp., *Tingia* sp., and *Plagiozamites*; those from the Middle, mainly in the gray or dark-gray shale and sometimes in the yellowish-green, sandy shale are *Cordaites* sp., *Taeniopteris* sp., *Pecopteris* sp., *Annularia* sp., *Neuropteris* sp., *Gigantopteris* sp., and *Lepidodendron* sp. These fossils have not yet been fully investigated, but there exists little doubt that the series is equivalent to NORIN's Shih-ho-tzu series (NORIN, 1922) and is thought to be Middle Permian in age, according to lithic character and the order of succession of beds.

The location of the boundary plane between the Tse-shih series and the Shan-si series is a difficult question, because field observations show that the former conformably overlies the latter. For convenience' sake, we classified the Tse-shih series mainly on the basis of distribution of coal seams and yellowish-green to yellowish-brown rocks, and of good continuity of sandstones.

F. CHIN-CHUAN SERIES AND SI-LO-CHEN SERIES (FUJIMOTO, 1943)

After the geological survey along the Cheng-tai Railway, the writers suggested that the Tse-shih series is overlain by the Chin-chuan series, which in turn is covered conformably by the Si-lo-chen series.

The Chin-chuan series consists mainly of reddish-purple shale and reddish-purple, sandy shale; the Si-lo-chen series consists of reddish-purple sandstone and reddish-purple shale and yields *Lepidodendron* sp. and other plant fossils in its upper-

Columnar section of the Lower Tse-shih series in descending order (south of Yen-tzu pit).

	Thickness (m)
1. Yellowish-brown shale	2.60
2. Aluminous shale	0.25
3. Yellowish-brown shale	0.80
4. Yellowish-green sandstone	0.20
5. Reddish-purple shale	0.30
6. Yellowish-brown shale	3.00
7. Yellowish-brown sandstone	0.50
8. Gray aluminous shale	0.50
9. Yellowish-brown shale	5.00
10. Yellowish-green, coarse sandstone	2.50
11. Yellowish-green, sandy shale	4.90
12. Dark-green sandstone	0.60
13. Yellowish-green, sandy shale	6.00
14. Yellowish-brown, fine sandstone	2.20
15. Yellowish-green shale	10.40
16. Yellowish-green, coarse sandstone (Sl_3)	5.80
17. Gray aluminous shale	0.02
18. Yellowish-brown shale	22.50
19. Yellowish-green sandstone (Sl_2)	8.50
20. Yellowish-green, sandy shale	1.60
21. Dark-gray shale	0.20
22. Yellowish-green, sandy shale	1.20
23. Dark-gray shale	0.20
24. Yellowish-green, sandy shale	1.80
25. Black shale	0.20
26. Gray shale	1.00
27. Yellowish-green shale	1.50
28. Gray shale	2.80
29. Yellowish-gray sandstone and yellowish-green sandy shale in alternation	1.80
30. Gray shale	1.50
31. Yellowish-brown sandstone	0.30
32. Gray shale	2.00
33. Yellowish-brown sandstone	0.60
34. Coal	0.10
35. Black shale	0.20
36. Yellowish-green, sandy shale	4.50
37. Yellowish-green, quartzose sandstone	1.00
38. Gray shale	7.30
39. White or light gray sandstone (Sl_1)	5.50

Columnar section of the Middle Tse-shih series in descending order (along the north slope of Shih-nao-shan).

	Thickness (m)
1. Reddish-purple shale	2.00
2. Yellowish-brown shale	2.50
3. Reddish-purple shale	2.30
4. Yellowish-green shale	3.20
5. Dark-gray shale	0.50
6. Gray shale	0.80
7. Yellowish-brown shale	1.00
8. Reddish-purple shale	0.50
9. Yellowish-green shale	1.20
10. Reddish-purple shale	4.90
11. Yellowish-green sandstone (Sm_5)	10.00
12. Gray-shale	3.20
13. Yellowish-brown, stratified sandstone	1.00
14. Yellowish-brown shale	3.00
15. Reddish-purple shale	1.00
16. Yellowish-brown shale	3.00
17. Reddish-purple shale	8.70
18. Yellowish-brown shale	7.20
19. Reddish-purple shale	1.50
20. Yellowish-green, sandstone (Sm_4)	8.70
21. Yellowish-brown shale	3.00
22. Grayish-white, coarse sandstone	0.40
23. Yellowish-brown shale	3.50
24. Reddish-purple shale	2.00
25. Yellowish-green shale	4.30
26. Reddish-purple, sandy shale	0.20
27. Yellowish-green, sandy shale	2.60
28. Dark-green, fine sandstone	0.40
29. Yellowish-brown shale	3.70
30. Yellowish-green, sandy shale	0.70
31. Reddish-purple, sandy shale	0.30
32. Yellowish-green shale	2.20
33. Iron ore	0.20
34. Yellowish-green shale	0.50
35. Yellowish-brown, sandy shale	1.50
36. Dark-gray shale	1.00
37. Gray aluminous shale	0.15
38. Yellowish-brown shale	3.60
39. Yellowish-brown sandstone (Sm_3)	2.80
40. Yellowish-brown shale	1.80

	Thickness (m)
41. Yellowish-brown, sandy shale	0.80
42. Yellowish-brown shale	1.20
43. Yellowish-brown sandy shale	1.50
44. Yellowish-brown shale	2.00
45. Reddish-purple shale	1.80
46. Yellowish-brown sandy shale	1.20
47. Yellowish-green fine sandstone (Sm_2)	7.00
48. Reddish-purple shale	1.50
49. Yellowish-brown shale	3.50
50. Reddish-purple shale	0.40
51. Yellowish-brown shale	2.80
52. Grayish-white, aluminous shale	0.10
53. Yellowish-brown shale	0.60
54. Reddish-purple shale	0.30
55. Yellowish-brown shale	0.70
56. Reddish-purple shale	0.20
57. Yellowish-brown shale	0.30
58. Reddish-purple shale	4.00
59. Yellowish-brown shale	2.70
60. Reddish-purple shale	1.20
61. Iron ore	0.30
62. Yellowish-brown shale	1.00
63. Reddish-purple shale	3.20
64. Gray-shale	0.10
65. Reddish-purple shale	0.90
66. Grayish-white, quartzose, fine sandstone	1.00
67. Yellowish-brown shale	10.30
68. Yellowish-brown, sandy shale and gray sandy shale in alternation	4.70
69. Yellowish-green shale	6.00
70. Reddish-purple shale	4.10
71. Yellowish-brown shale	0.70
72. Gray shale	0.60
73. Yellowish-green, sandy shale	3.00
74. Dark-green, fine sandstone	0.30
75. Yellowish-green sandstone (Sm_1)	4.70

Columnar section of Upper Tse-shih series in descending order (South of Siyu Ho).

	Thickness (m)
1. Grayish-white, quartzose sandstone (Su_4)	10.00
2. Gray aluminous shale	0.05
3. Reddish-purple shale	7.25
4. Reddish-purple, sandy shale and yellowish-brown sandy shale in alternation	1.30
5. Yellowish-brown, sandy shale	5.00
6. Reddish-purple shale	3.50
7. Reddish-purple, sandy shale	2.50
8. Reddish-purple shale	5.00
9. Yellowish-brown, sandy shale	1.50
10. Yellowish-brown shale	1.50
11. Reddish-purple shale	2.70
12. Yellowish-brown shale	0.70
13. Yellowish-green sandstone	1.00
14. Reddish-purple shale	2.00
15. Reddish-purple, sandy shale	1.10
16. Reddish-purple shale	2.10
17. Reddish-purple, sandy shale	2.10
18. Reddish-purple shale	2.80
19. Yellowish-brown shale	0.90
20. Reddish-purple shale	1.50
21. Yellowish-brown shale	1.10
22. Reddish-purple shale	0.90
23. Reddish-purple, sandy shale	0.60
24. Reddish-purple sandstone	0.60
25. Reddish-purple shale	4.20
26. Reddish-purple, sandy shale	1.00
27. Reddish-purple, stratified sandstone	1.00
28. Yellowish-brown shale	3.20
29. Reddish-purple shale	1.00
30. Reddish-purple, stratified sandstone	0.60
31. Reddish-purple shale and yellowish-brown, sandy shale in alternation	2.20
32. Yellowish-green, sandy shale	1.00
33. Grayish-white, quartzose sandstone (Su_3)	7.80
34. Reddish-purple shale	13.00
35. Reddish-purple, sandy shale	1.90
36. Yellowish-brown, quartzose sandstone	1.40
37. Reddish-purple shale	1.00
38. Yellowish-brown shale	2.00

	Thickness (m)
39. Reddish-purple shale	6.00
40. Grayish-white, quartzose sandstone	2.50
41. Reddish-purple shale	2.30
42. Reddish-purple sandstone	0.20
43. Reddish-purple, sandy shale	1.20
44. Grayish-white, quartzose sandstone (Su_2)	5.80
45. Reddish-purple shale and yellowish-brown shale in alternation	2.30
46. Grayish-quartzose sandstone (Su_2)	3.10
47. Yellowish-brown, sandy shale	1.90
48. Yellowish-brown sandstone	1.90
49. Reddish-purple shale	2.30
50. Yellowish-green, sandy shale	1.20
51. Sandstone and shale in alternation	0.90
52. Grayish-white, quartzose sandstone	1.00
53. Reddish-purple shale	1.60
54. Yellowish-brown, sandy shale	1.90
55. Yellowish-brown shale	2.30
56. Grayish-white, quartzose sandstone (Su_1)	8.50
57. Yellowish-green, sandy shale	1.20
58. Grayish-white, quartzose sandstone	1.50
59. Yellowish-brown shale	1.60
60. Yellowish-green sandstone and yellowish-green, sandy shale in alternation	2.10
61. Grayish-white, quartzose sandstone (Su_1)	8.60

most horizon. The stratigraphical relation between the two series was not ascertained on account of the Shou-yang basin between them. Afterwards we had the good fortune to study the Liu-chu-tsun to Shan-yen-shan district south of Tse-shih and to clarify this question. Mt. Shan-yen is about 500 m above the level of the Cheng-tai Railway. The boundary between the Tse-shih series and the Chin-chuan series can be determined at Lang-yu village south of Tse-shih, and the boundary between the Chin-chuan series and the Si-lo-chen series can be determined south of Liu-chu village which is the entrance to Mt. Shan-yen. The Chin-chuan series observed along the route is an extension from its type locality; and lithologically, the Si-lo-chen series is certainly correlated with the type section west of Shou-yang basin.

When the Chin-chuan series and the Si-lo-chen series are compared by means of the lithological and paleontological data and the sequence of coal seams in the Tai-yuan district, they seem to correspond to the Shih-chien-feng series of NORIN (1922).

IV. Coal Seams

The workable coal seams occur in the Tai-yuan and the Shan-si series.

A. Coal Seams of the Tai-yuan Series

There are four workable coal seams. The Horizons of these coal seams are easily identified by means of three characteristic limestones (Su-chieh, Chien-shi and Hou-shi) as key beds. Thickness, distance between the coal seam and the limestone, and between the coal seams are enumerated as follows:

	thickness	distance between coal seam and limestone	distance between coal seams each other
Hou-shi limestone (Lt_1)			
		0.00–0.20 m	
Hou-shi coal seam	0.04–1.00 m		
		9.90–11.02 m	5.00–9.70 m
Coal seam D	0.85–1.75 m		
		3.60–31.05 m	
Chien-shi limestone (Lt_2)			5.20–31.85 m
		0.00–1.50 m	
Chien-shi coal seam	0.10–1.30 m		
		11.10–30.80 m	
Su-chieh limestone (Lt_3)			29.30–40.05 m
		9.30–13.39 m	
Coal seam E	3.65–8.80 m		
		7.55–10.20 m	
Basal sandstone			

Coal Seam E.

Commonly called Chang-pa-mei, this is the thickest and the most important coal seam of the field; its areal distribution is also the greatest. The thickness varies from 3.65 to 8.80 m and the average thickness is 5.00 m. The variation of thickness is not notable over the whole area and the partings are comparatively small. (Percentage of thickness of the workable coal to that of the coal seam as a whole is 88%).

Chien-shi Coal Seam

This coal seam lies below the Chien-shi limestone with gray shale about 1.5 m thick in between. The thickness is highly variable (0.10–1.30 m), and it gradually decreases east and southeastward. Outcrops of this coal seam trend in the same direction as the Chien-shi limestone.

Coal Seam D

This coal seam, commonly called Hsiao-tan or Ssu-chih-mei, is 0.85–1.75 m in thickness; it occurs between the Chien-shi limestone and the Hou-shi limestone, that is, at a horizon 3.61–31.05 m above the former and 9.90–11.02 m below the latter.

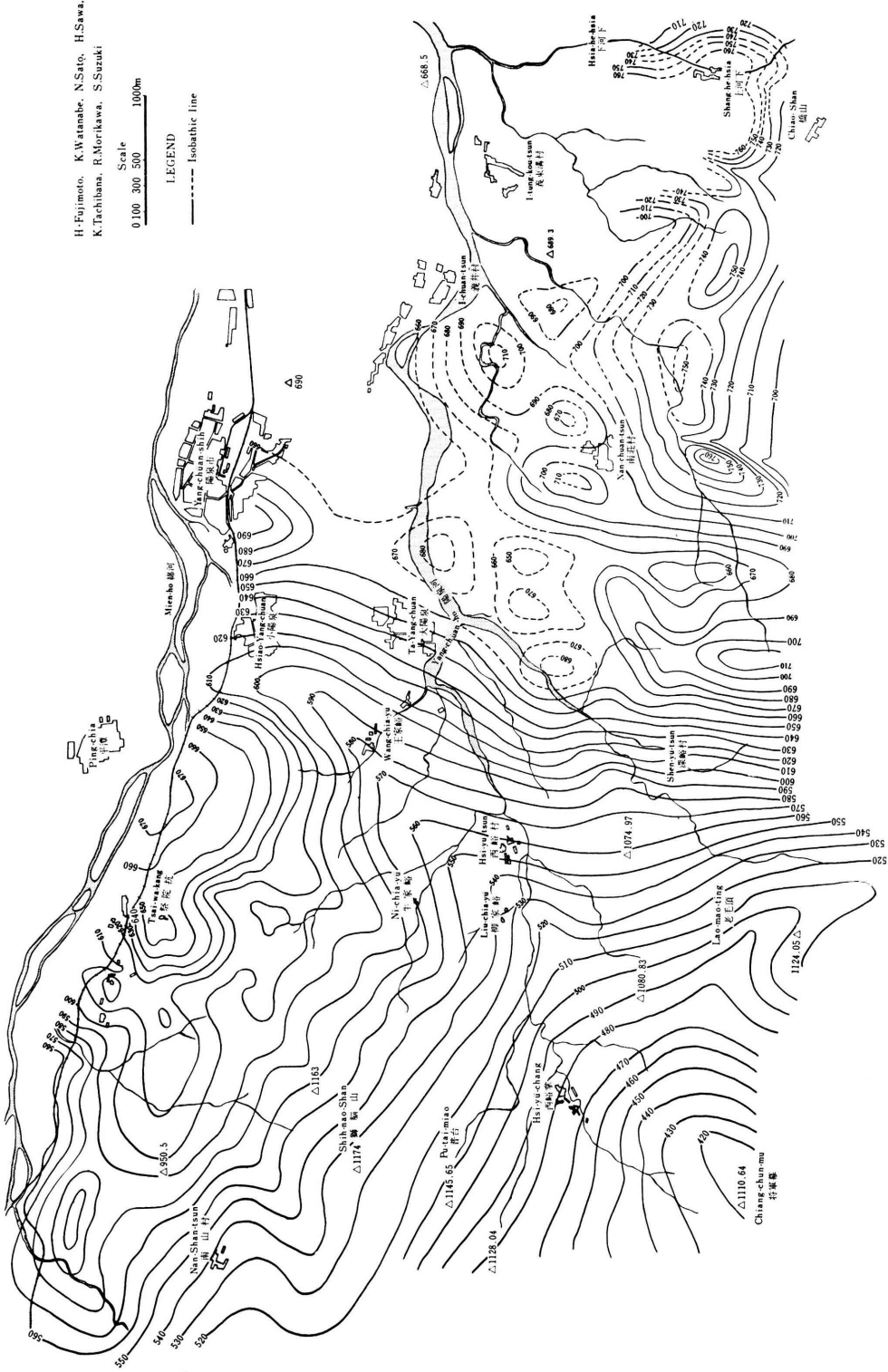

Fig. 2. Map showing the isobathic line of coal seam E in the southern area of the Yang-chuan coal field, Shan-si, North China

Hou-shi Coal Seam

This coal seam, commonly called Hsiao-tan or San-chih-mei, lies beneath the Hou-shi limestone, with thin shale about 0.20 m thick in between. It is usually 0.10–0.40 m and often 0.70–1.00 m thick.

B. Coal Seams of the Shan-si Series

There are five coal seams. The horizons of these coal seams are easily identified by means of the characteristic sandstones S_1, S_2 and S_3 which are intercalated in the lower part of the series and the basal sandstone (Sl_1) of the Lower Tse-shih series. Thickness, distance between coal seams and the sandstones, and the distance between the coal seams are as follows:

	thickness of coal seam	distance between coal seam and sandstone	distance between the coal seam
Basal sandstone Sl_1			
		0.00–32.18	
S_6			
Coal seam A	0.50–2.70	32.98–48.70	
S_5		26.16–36.07	12.30–20.70
Coal seam B	0.90–3.29	10.21–20.40	
S_3			37.95–56.93
S_2		0.00–8.60	
Coal seam C	0.30–1.40	3.00–8.00	
S_1			

Coal Seam C

This coal seam is not important, because it is usually about 0.5 m thick with many intercalations and does not have horizontal continuity.

Coal Seam B

This coal seam is uniform in thickness and has horizontal continuity, so that it is workable and is now being worked at Ta-nan and Hsiao-nan.

Coal Seam A

This coal seam has many intercalations and the aggregate thickness of the workable coal is 0.34–1.30 m. The percentage of the thickness of the workable coal to that of the coal seam as a whole is 53.7–73%. This coal seam is generally workable because it is uniform in thickness and has horizontal continuity.

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GEOLOGICAL MAP OF YANG-CHUAN COAL FIELD, SHAN-SI.

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LEGEND

- Alluvium
- Diluvium
- Upper $Su_1 - Su_4$
- Middle $Sm_1 - Sm_3$
- Lower $Sl_1 - Sl_4$
- Tse-Shini Series
- Shan-Si Series $S_1 - S_5$
- Tai-Yuan Series $Lt_1 - Lt_3$
- Pen-chi Series $Lh_1 - Lh_3$
- Ordovician system (Or)
- Sandstone
- Limestone
- Coal Seam A, B, C, D, E
- Strike and dip
- Anticline and syncline
- Quoqua Versal and Basin Shaped Structure
- Normal and Reverse fault
- Depression
- Shaft and Inclined gallery

0 200 500 1000 m

A B C D E F G H

Ping chia
Nan Shan tsun
Yang chuan shin
Hsiao yang chuan
Ta yang chuan
I-chuan tsun
Yang Chuan-ho
Shin nao Shan
Pu tai miao
Ni Chia yu
Wang Chia yu
Hsi Yu tsun
Liu chia yu
Hsi yu chang
Chiang chun mu
Lao mao ting
CShen Yu tsun
Nan chan tsun
I tung kou tsun
HSia-he hsia

△ 1163 △ 1174 △ 950 5 △ 690 △ 668 5 △ 689 3 △ 1145 05 △ 1128 04 △ 1080 83 △ 1074 97 △ 1110 64 △ 1124 05

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