CARBONIFEROUS STRATIGRAPHY OF NORTHWESTERN KANSU.§

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The geological reconnaissance in the northwestern part of Kansu was undertaken during the five months from the end of June to the beginning of December, 1923. The area covered is along the graben trough between Nan Shan and Pei Shan, formerly a part of the prefectures of Liang Chow Fu(凉州府)and Kan Chow Fu(甘州府)and now of the administrative region of Kan Liang Tao [under which are the *hsiens* of Wu Wai (武威), Yung Chang(永昌),Shan Tan(山丹),Tung Lo(東樂), Chang Yeh(張掖),Fu I (撫彝) etc] together with a part of Kao Tai Hsien (高台縣) further west. The route follows mainly the northern slope of the Nan Shan Range. The distance covered is about 500 li, or 180 miles, if measured in a straight line from S by E to N by W.

The coal-bearing formations have a wide geological range from the Carboniferous to the Jurassic. However, the most interesting part of the study is the Carboniferous stratigraphy.

(1) For, in the first place, the area, as we know it, was in the Carboniferous time a part of the Nanshan geosyncline. The various marine and continental facies show that the sea must have been fluctuating quite a number of times, probably in the form of gulfs or bays, with either a quickly fauna or some isolated ones. From the Viséen, the lowest fossiliferous beds discovered in this region, to the Lower Permian, the uppermost marine strata, the sedimentation, the dominant fossils, and fossil associations at one locality, differ from every other locality.

(2) But, on the other hand, many localities have distinctly close relation to far distant places as shown by their fossils. For instance the fossils found in the small area of the Choniukou (臭牛溝) Series bear many characteristics of the European Viséen forms. The same are with the Taiyuan Series. For whereas the Taiyuan Series of several localities differ

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among themselves, they bear similarities to some of the Taiyuan beds in the type region in Shansi. The study of Fusulinidæ by Professor J. S. Lee and that of Productidæ by Mr. Chao will throw more light on this problem.

(3) The stratigraphic succession clears up to a certain extent the upper and lower limits of the Taiyuan age. The Taiyuan series in N.W. Kansu is clearly underlain by the typical Visèen and overlain by the lower Permian beds. And most of the Fusulina beds are quite separable from the typical Taiyuan which carries the brachiopod facies. All of them are, however, in apparent conformity and nowhere there is found any unconformity.

While the detail correlation can not be attempted at this early stage of the laboratory work, the following six sections may be taken for illustrating the results so far ascertained. Thanks are due to Professor Grabau, Messrs. Chao and Tien who have kindly made the preliminary determination of the fossils.

Choniukou Section

Of five exposures where the Visèen is clearly shown, the thickest and most fossiliferous is that at Cho Niu Kou (臭牛溝), 70 li W. by S. from Wu Wai Hsien (武威縣), the site of former Liang Chow Fu (涼州府). The Choniukou formation is preceded by a continental formation, 67 meters thick, bearing plant remains and resting unconformably on the pre-Cambrian Nanshan series. The marine facies of the said formation itself attains a thickness of 68 meters and consists of interbedded blue and grey limestones and shales. Fossils are abundant throughout the whole formation. They present the typical European facies and thus indicate a close intercommunication between western Europe and northwestern China Visèen time.

These beds are overlain disconformably by a greenish grey micaceous hard thin-bedded sandstones, 5 meters thick, with fossil plants, indicating a change to the continental facies. This, in turn is succeeded by 15 5 meters of fossiliferous shales and limestones carrying the typical Taiyuan fauna. Further up, the Taiyuan beds are overlain disconformably by inter bedded quartz-sandstones and clay-shales of lower Permian age.

The Viséen formation occupies an area not more than 50 sq. li S. and W. by S. of Wu Wai Hsien. Further west it is overlapped by the Tai-yuan which lies directly unconformably on the Nanshan Series (pre-Cambrian)

The fossils that have been determined are:—

Productus giganteus Martin var. *maximus* M'Coy
P. giganteus Martic var. *depressa* Chao
P. undatus Defrance
P. elegans M'Coy
P. cf. *concinnus*
P. cf *semireticulatus* Martin
P. tenuistriatus Vern.
P. scabriculus Martin.
Spirifer striatus Mart.
Rhipidomella michelini l'Ev.
Orthothetes crenistria Phillips
Spiriferina laminosa M'Coy
Leptaena analoga Phillips
Athyris igens d'Kon.
Schizophoria resupinata Martin
Chonetes sp.
Phillipsia sp.
Fenestella sp.
Aviculopecton sp.
Lithostrotion portlocki (Bronn.)
simple corals, and
bryoz as.

The section can be summarized in descending order as follows:—

Permian:

10.	Sandstones of great thickness.	
9.	Shales and coal seams	40 m
8.	Sandstones and shales, unfossiliferous	10 m
7.	Sandstones and shales, fossiliferous	26 m

Disconformity

Carboniferous:

Taiyuan Series:

6.	Limestones and shales, richly fossiliferous	15.5 m
5.	Sandstones with fossil plants (W)	5 m

Viséen—the Choniukou formation:

4.	Limestones and shales, richly fossiliferous	68 m
3.	Sandstones and shales, unfossiliferous	5 m
2.	Sandstones and shales—"basal shale", fossil plants.	12 m
1.	Quartzite and shales	50 m

Unconformity

Subformation—Nanshan Series.

Hungshanyao Section.

While the Taiyuan occupies only 15.5 meters of marine sediments at Cho Niu Kou, it is much more developed in Hung Shan Yao (紅山窯). 250 li N.W. of Cho Niu Kou, and 50 li W. of Yung Chang Hsien (永昌縣). But the limestones and shales are thin and are often interrupted by their sandstone beds. The lower part of the section occupying 41.7 meters in thickness are yellow clayey shales and limestones with intervening thin sandstones and are termed as the Hungshanyao formation. Its fossils are:—

Productus punctatus Martin
P. taiyuanfuensis Grabau
P. cora d'Orligny
P. juresanensis Tschernyschew (rare)
Marginifera loczyi Chao
Reticularia roundata Gr.,
Chonetes cf. *pseudovaiolata* (Nikitin) Loczy
Spirifer bisulcatus Sow. mut.
Spirifer pankouensis Gr.
Rhipidomella michelinoides Gr. & Chao
Orthothothetes crenistria Phill.
Orbiculoidea sp., nov.
Conularia sp.
Phillipsia kansuensis Loczy
Euomphalus sp.
Hustedia bella Gr.

Higher up the section is more distinctly exposed at a ravine, T'a Erh Kou (塔兒溝) and is therefore termed the Taerhkou formation which has a total thickness of 13.7 meters. It consists of three fossiliferous limestones, the lowest of which the, "Lower Fusulina bed", has *Fusulina* and *Spirifer bisulcatus* occuring together.

Above this is the Yanglutsao (陽路橋) formation of 21 meters thick, the top of which is a limestone of 2.5 meters full of *Fusulina* with a few *Phillipsia, Lonsdaleia* sp. and crinoidal stems.

The section can be summed up in the following:—

Super-formation—Permian:—

IV. 13. Variegated sandstones of great thickness.

Disconformity

Carboniferous, equivalent to the Taiyuan series:

III. Yanglutsao formation

12.	Fusulina limestone with *Fusulina*, *Lonsdaleia* sp., *Phillipsia*.	2.5 m.
11.	Sandstones, shales, and coal	13.5

II. Taerhkou formation

10.	Fossiliferous limestones	0.8
9.	Fossiliferous shales	5
8.	Fossiliferous limestones	0.8
7.	Sandstones and shales	2.

I. Hungshanyao formation.

6.	Bluish grey shale	2.
5.	Black limestone with *Chonetes*, *Productus*, and *Conularia*	2.
4.	Sandstones and shales	7
3.	Yellow limestones and shales, most fossiliferous.	9.6
2.	Sandstones	3.4
1.	Yellow shales and limestones, fossiliferous	17.7

Base covered.

Lichiachuan Section

The locality, Li Chia Chuan (李家泉), is about 65 li west of Hung Shan Yao; and is the next important section which has a good exposure. But lying between Li Chia Chuan and Hung Shan Yao is the prolific fossiliferous locality, Yang Hu Kou (羊虎口) which had been visited by Loczy, Obrutchev and Hsieh. From the abundant fossils collected it seems to be higher than the Hungshanyao and probably corresponds to the Taerhkou formation.

The same is true with the age of the Lichiachuan formation which is about 19 meters thick. It overlies unconformably on the Nan Shan series and is succeeded by sandstones and shales of later beds. Of the 19 meters, only the upper half is fossiliferous. The fossils bear the same general appearance as those from Yang Hu Kou, except no Fusulina being found. It is remarkable, too, that a Fusulina bed lies 21.7 meters higher above the limestone and immediately overlies a coal seam. The Fusulina limestone is dark blue, but the fossils are badly weathered into reddish clay and no collection was made of them.

Triassic or Permian:

Variegated Sandstones eroded.

Disconformity

Carboniferous:

Formation II

(6)	Covered	5.0 m.
	Fusulina limestone	2.0
	Shale and coal	5.0
	Coarse sandstone	0.6
(5)	Shale and thin coal	3.0 m.
	Fire clay	0.3
	Red sandstone	0.3
	Blue shale	10.0
	Grey and yellow sandstones	2.5

Formation I.—The Lichiachuan formation

(4) Black shale and limestone nodules, fossiliferous 5.0

(3)	Limestones, fossiliferous	0.8
	Shale	0.8
(2)	Buff limestone, fossiliferous	1.5
(1)	Blue shale	4.0
	White sandstone	1.8
	Brown sandstone	5.0
	Unconformity	

Sub-formation: Nanshan Series.

Hsinho Section

Hsin Ho (新河) is 40 li W. of San Tan Hsien (山丹縣) and about 50 li N.W. of Li Chia Chuan. The Fusulina limestone 2 meters thick is the lowest fossiliferous bed exposed here and carries a rich fauna of Fusulina as well as brachipods, gastropods and a few corals. About 22 meters higher than this is another bed, which carries also Fusulina and is designated as the "Upper Fusulina limestone."

The complete section is as follows:

10.	Variegated sandstones of great thickness	
9.	Sandstones, shales, and thin coal seam	60.0 m.
8.	White quartzite sandstones	1.8
7.	Blue shale.	3.2
6.	"Upper Fusulina limestone"	0 45
5.	Grey, blue and white shales	22.0
4.	Fusulina limestone	2.0
3.	Blue to gray shale	25.0
2.	Coal seam	0.25
1.	Sandstone, partly covered	

Mokou—Heishihhsia Sections.

Mo Kou (墨溝) is 70 li S. of Fu I Hsien, (撫彝縣). The Taiyuan Series here is 16.5 meters thick and rests directly on the Nanshan Series (pre-Cambrian), thus overlapping the Viséen. The Ballerophon beds are characterized by *Bellerophon* sp. nov, *Loxonema*, ? *Naticopsis* and other gastropods, and small corals. The sections is as follows:—

Triassic?

Formation 4.

11. Red sandstones of great thickness

Disconformity

Permian

Formation 3.

10.	Green and purple sandstones	60 m.
9.	White and grey sandstones	60
8.	Shale (bed Q with fossil plants)	1
7.	White and grey sandstones	100

Formation 2.

6.	Shale (bed P with fossil plants)	1.5
5.	Sandstones and coal	120

Carboniferous

Formation 1.—the Mokou formation

4.	Bellerophon shale, richly fossiliferous	6.0
3.	Shale, unfossiliferous	6.0
2.	Fossiliferous limestone with *Sp. bisulcatus* and a large Nautilus species	0.5
1.	Conglomerates and sandstones	4.0

Yaokou Section

Yao Kou (窯溝) is about 45 li W. of Mo Kou and 60 li S. of Kao Tai Hsien (高台縣). The Taiyuan Series here is 20.5 meters thick, resting unconformably on pre Cambrian granite and being succeeded disconformably by Permian beds. There are only two limestone beds totalling 3.5 m. in thickness; the lower, 2 m. thick contains large compound corals and brachiopods (Spirifer, etc) and, after an interruption of 6 meters of continental sandstones and shales, the upper, 1.5 m. thick, contains a rich accumulation of Fusulina.

Super-formation

Permian and later beds 250 m.

Disconformity

Carboniferous

Formation II

Red sandy limestone	2.0
Shale	3.0
Fusulina limestone	1.5
Shale	3.0
Sandstone	3.0

Formation I—Yaokou formation.

Calcareous shale with large corals and brachiopods.	2.0
Thin coal	0.5
Sandy shale and clayey shale	2.5
Sandstone and quartzite	3.0

Unconformity

Sub-formation—Pre-Cambrian granite.

Correlation table of the Carboniferous strata in N.W. Kansu.

Localities	Cho Niu Kou 卓牛溝	Hung Shan Yao 紅山窯	Li Chia Chuan 李家泉	Hain Ho 新河	Mo Kou 墨溝	Yao Kou 窯溝
Super-formation: Permian, or Triassic	Lower Permian 76 m.	Variegated Sandstones	Variegated Sandstones	Variegated Sandstones	Permian 342 m.	Permian 260 m.
Fusulina Beds: Taiyuan and upper Carb.	.....	Yanglu-tsao f. 21 m.	Fusulina beds 26 m.	Fusulina beds 114.7 m.	.....	Fusulina bed 12.5 m.
Taiyuan Series	.....	Taerhkou f. 8.6 m.	Lichia-chuan f. 19 m.	Covered	Mokou f. 16.5 m.	Yaokou f. 9 m.
	Taiyuan beds (X—Z, and W) 20.5 m.	Hungshan-yao f. 41.7 m.	.....	.....	.....	.....
Viséen	Chonhukou f. 135 m.	.....	.....	.....	.....	.....
Sub-formation: Pre-Cambrian	Nanshan System	Nanshan System	Nanshan System	.....	Nanshan System	Nanshan System