

## MESOZOIC STRATIGRAPHY OF SZECHUAN\*

By C. Y. LEE (李春昱)

(*The Geological Survey of China*)

### INTRODUCTION

The geology of Szechuan and the adjoining regions has been studied by the pioneer geologists such as F. von Richthofen<sup>1</sup>, L. von Loczy<sup>2</sup>, B. Willis and E. Blackwelder<sup>3</sup> and E. C. Abendanon<sup>4</sup> respectively on the northern and eastern parts. In recent years Prof. J. S. Lee<sup>5</sup> and Messrs. C. Y. Hsieh and Y. T. Chao<sup>6</sup> made more detailed study on the geology of Yangtze gorge which is closely related to that of Eastern Szechuan. In 1928, Messrs. Y. T. Chao and T. K. Huang<sup>7</sup> were sent to Shensi and Szechuan by the Geological Survey of China and covered a great area of the latter province in some detail. About the same time Dr. A. Heim<sup>8</sup> made also some observations at several localities such as Omeishan, Tzuliuching and Chungking.

In 1929 to 1931 Mr. H. C. T'an and I worked in the said province and its neighboring Hsikang (Eastern Tibet) for about two years during which

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- \* Read at the 9th Annual Meeting, completed later and received for publication Oct. 1933.
  - 1 Richthofen, F. von. China, Vol. II, pp. 600-604, Vol. III, pp. 53-162.
  - 2 Loczy, L. Wissenschaftliche Ergebnisse der Reise der Grafen Bela Széchenyi in Ostasien, I Bd. pp. 691-693.
  - 3 Willis, B. and Blackwelder, E. Research in China, Vol. I, pp. 265-297.
  - 4 Abendanon, E. C. La Géologie du Bassin Rouge de la Province du Se-Tchouan.
  - 5 Lee, J. S. Geology of the Gorge district of Yangtze, Bull. Geol. Soc. China. Vol. III, No. 3-4, pp. 351-391.
  - 6 Hsieh, C. Y. and Chao, Y. T. Geology of Ichang and neighbouring districts, Bull. Geol. Surv. China, No. 7, 1925, pp. 13-76.
  - 7 Chao, Y. T. and Huang, T. K. The geology of the Tsinlingshan and Szechuan, Mem. Geol. Surv. China, Ser. A, No. 9.
  - 8 Heim, A. The geological structure of Tseliutsin, Szechuan; Studies on tectonics and petroleum in the Yangtze region of Tshungking; Tectonic study of Omeishan, Szechuan, Sp. Pubs. No. VI, VIII, XIII, Geol. Surv. Kwangtung and Kwangsi.

Western Szechuan has especially been widely visited. Mesozoic stratigraphy has been particularly studied in the Chiating and Tzuliuching areas and Chialing-chiang valley. In last summer, 1933, I, as a member of the Szechuan Geological Expedition<sup>1</sup> have extended geological investigation to the Fuling-Peng-shui and Wanhsien-Tahsien regions in Eastern Szechuan which had not been visited before.

By the observations afore-mentioned, the geology of Szechuan Basin is fairly well known. Generally speaking it is almost covered by Mesozoic formations which will be the object of the present paper.

### TRIASSIC

The Triassic strata in Szechuan province vary in facies from east to west which have been designated by different terms of formations applicable to respective rock successions observed in different places. In Eastern Szechuan and the border of Hupeh, Tayeh limestone represents the Lower Triassic and Patung series the upper, while in Western and Central Szechuan the lower and upper Triassic are respectively constituted by Feih sienkuan and Chialingchiang formations. They can be described as below: (Fig. 1)

#### TAYEH LIMESTONE

This is the upper part of Wushan limestone<sup>2</sup> of Willis' nomenclature which is subdivided by Messrs. C. Y. Hsieh and Y. T. Chao into two parts, the lower Yanghsin and the upper Tayeh limestones. The former is undoubtedly of Permian age and the latter, at least the upper part of it, is of Triassic time as has been recently confirmed by the fossils determined by C. C. Tien. In the gorge district the Tayeh limestone consists of thin-bedded marly limestone at the upper and laminated limestone with shaly intercalations at the lower, amounting to a total thickness of about 1,300 m. It lies conformably upon the even surface of Yanghsin limestone and is widely distributed in the border of Szechuan and

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1 The Szechuan Geological Expedition was organized by the Central University, The National Economic Council of China and The National Geological Survey of China.

2 Willis, B., op. cit. pp. 274-276.

Hupei provinces. In Icheng and Chungmen, north Hupei, where a bed of conglomerate is found lying at the base of Tayeh limestone, Messrs. C. C. Yü and W. P. Shu collected a number of Lower Triassic fossils which were identified by C. C. Tien<sup>1</sup> as the following:

- Xenodiscus* sp. Nov. ind.
- Xenodiscus* aff. *lilangense* Krafft
- Ophiceras* sp.
- Sibirites* cf. *kingianus* Waagen
- Kashmirites* *obliquecostatus* Tien
- Kashmirites* aff. *subarmatus* Diener
- Kashmirites* aff. *acutangulatus* Welter
- Meekoceras* sp. ind.

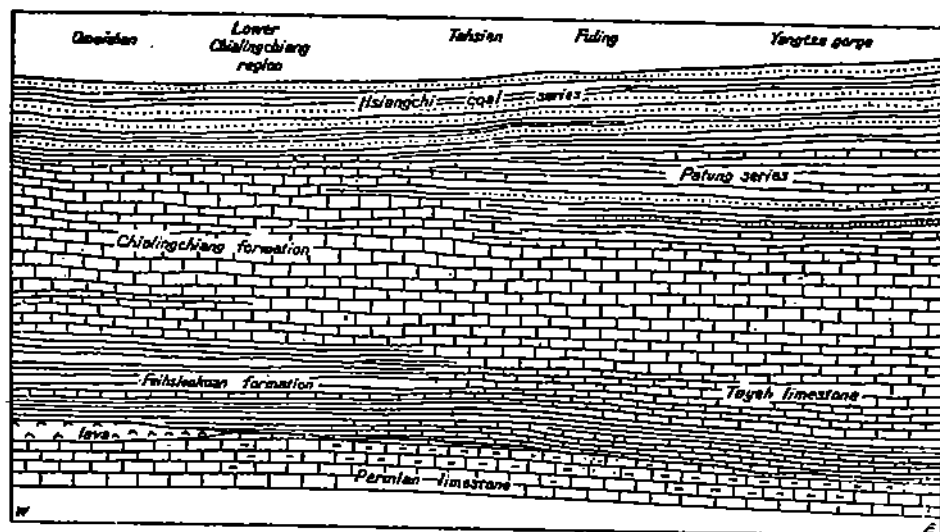


Fig. 1. Diagrammatic section showing variation of Triassic facies.

In Fuling and Pengshui in Eastern Szechuan I have observed a sequence of white-gray thin-bedded limestone lying on the Yanghsin formation which is probably, although not entirely, equivalent to the Tayeh limestone. But in that

<sup>1</sup> Tien, C. C. *Palaeontologia Sinica*, Ser. B, Vol. XV, Fasc. 1, pp. 4, 5, pls. 3, 4.

region it is called the Chialingchiang limestone<sup>1</sup> as it is correlated with the section above Chungking.

In Nanchuan, south-west to the preceding area Mr. L. C. Chang<sup>2</sup> found 100 m. of thin-bedded limestone overlying Loping formation and below Feihsienkuan purple shale and sandstone. This is apparently the same as the lower part of the Chialingchiang formation which we saw in the Fuling-Pengshui region.

#### FEIHSIENKUAN FORMATION.

This represents the lower part of Triassic in Western and Central Szechuan consisting of purple shale, sandstone and purplish impure limestone. At the typical locality, Feihsienkuan, in Kwangyüan, North Szechuan, it lies on a sequence of thin-bedded limestone, which is regarded as Tayeh limestone by Mr. Huang,<sup>3</sup> and has a thickness of more than 700 m. Bivalves have been collected by Loczy<sup>4</sup> from that locality including *Megalodonta* and *Aviculopecten*. Overlying the Feihsienkuan formation is the Chialingching limestone of Upper Triassic.

In Kuanhsien of North-western Szechuan this formation is thrust upon younger strata associated with Palæozoic formations. The outcrops are thus not *in situ*, therefore the succession and thickness can hardly be decided. The constituent rocks are still purple shale and sandstone with occasionally layers of impure limestone. A collection of pelecypod fossils has been made by T'an and myself at Puyangshan, 15 km. N. E. of Kuanhsien city, including the following forms as identified by Dr. T. H. Yin:

*Arca* sp.

*Anoplophora* sp.

*Trochotoma* sp.

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- 1 Parejas, Ed. and Lee, C. Y. The geology of the Territories of Fuling and Pengshui, (not published).
  - 2 Chang, L. C. Geology of the Chungking-Nanchuan area, Contributions Geol. Dep. The Science Institute of West China, (in Chinese) No. 1 p. 38.
  - 3 Chao and Huang: op. cit. p. 88, Sec. Fig. 29, Atlas sheet No. 11.
  - 4 Loczy, L. op. cit. I. Bd. p. 441.

Further west in Ya-an and Yungching, this formation lies on the surface of Permian basaltic lava which is equivalent to the basalt of Omeishan. Purple shale, sandstone and gray micaceous sandstone are the chief constituents, concretions of copper ore, bornite, sometimes occur in certain layers of the sandstone.

The same formation is also found in Omeishan<sup>1</sup> lying between the basaltic lava below and the Chialingchiang limestone above, having the thickness of about 200 m.

In the region of Lower Chialingchiang, the successions of this formation have been studied in Yenchingchi and Kuanyinhsia gorges as will be described in "the Geology of Szechuan and Hsikang".<sup>2</sup> They are as follows in descending order.

8. Purple shale, sandstone and clay, 20 m. thick, yielding *Halobia* (*Daonella*) aff. *bockhi* Mojs, *Myophoria* (internal molds) sp. (T.L. 297).
7. Purplish-gray and gray calcareous shale and limestone with *Pro-spondylus* sp., *Lima* sp. 10 m. (T.L. 293).
6. Brown and purple shale, sandstone and clay interbedded with thin beds of limestone 120 m. thick, yielding *Arca* sp., *Anoplophora* 2 sp., *Nucula* sp., *Trigonodus* sp., *Lima* sp. at its upper part. (T.L. 307).
5. Gray impure limestone and calcareous shale with imperfectly preserved shells, 5 m.
4. Purple shale sandstone and clay 20 m.
3. Purple and gray limestone 20 m.
2. Purple and gray sandy shale, sandstone and clay 20 m.
1. Gray-green and light purple shale and calcareous shale 10-20 m.

In Nanchuan Mr. Chang<sup>3</sup> found the equivalent formation of purple shale and a bed of limestone lying upon Tayeh limestone with a similar thickness of about 200 m. In the territories of Fuling and Pengshui there occurs 50-70 m

1 T'an, H. C. and Lee, C. Y. Geology of Omeishan, Szechuan, Bull. Geol. Surv. China, No. 20, 1933, pp. 42-43.

2 T'an, H. C. and Lee, C. Y. Geology of Szechuan and Hsikang (in preparation).

3 Chang, L. C. op. cit, p. 39.

of purple-red shale intercalated in thin-bedded limestone which is ascribed to the Chialingchiang formation. As far east as to the Yangtze gorge there is no prominent shaly bed equivalent to the Feih sienkuan formation of central and western Szechuan, except the intercalations of shale in the lower part of Tayeh limestone. There is thus a gradual diminution of Feih sienkuan formation to the east where the limestone facies become more prominent.

#### CHIALINGCHIANG FORMATION.

In west and central Szechuan the Feih sienkuan shale is conformably succeeded by the Chialingchiang formation consisting of white-gray thin-bedded and massive limestone. In Kuangyüan it has a thickness of 650 m. while in Yachuan and Yungching only less than 100 m. of argillaceous limestone has been found. The limestone is rather developed in Omeishan where it has a thickness of 380-440 m. and gradually changes from the underlying Feih sienkuan shale. Three fossiliferous horizons have been found at the base, 60 m. higher up and at the top of the formation. The fossils are poorly preserved though some *Halobia*-like and *Avicula*-form shells (TL. 158, 159, 160) can be recognized. Heim<sup>1</sup> has made a collection from the shaly limestone at the top of the formation. The following species were described by Dr. T. H. Yin<sup>2</sup>

*Halobia comatoides* Yin

*Halobia omeishanensis* Yin

*Halobia* sp. A

*Halobia* sp. B

*Posidonomya* aff. *wengensis* Wissmann.

? *Ammonites*

In lower Chialingchiang region the limestone was estimated at 650 m. in thickness forming beautiful gorges when crossed by the river. At 100 m. above the base there occurs 20 m. of purple shale. The similar succession has been

1 Heim, A. The structure of Sacred Omeishan, Szechuan, Bull. Geol. Soc. China, Vol. IX, No. 1, 1930, p. 65.

2 Yin, T. H. Sur une petite faune de mollusques provenant de la Merne Triasique d'Omeishan, Szechuan. Bull. Geol. Soc. China. Vol. XI, No. 3, 1931, pp. 247-252.

found in Fuling where the purple shale has a thickness of 50-70 m. lying at 250 m. above the base of the formation and is succeeded by thin-bedded limestone amounting to a total thickness of 800 m. By comparison with the foregoing section the whole sequence is attributed to the Chialingchiang formation.

The upper part of the Tayeh limestone of the Gorge district is equivalent to the lower Chialingchiang formation. This can be confirmed by the intermediate sections between Chungking and Fengchieh (Kueichoufu).

#### PATUNG SERIES.

This series is typically developed in the environs of Patung of Western Hupeh, consisting of purple and gray shale and limestone and lying conformably on the Tayeh limestone up to a thickness of 800 m. At the horizon 350 m. above the base there occurs abundant *Spiriferina* in a bed of limestone. Going to north-west its thickness is gradually decreased and, at the same time, the purple shale becomes gray and more calcareous until finally it is replaced by Chialingchiang limestone. This is clearly shown along the route from Wanhsien to Tahsien.

In Fuling and Pengshui this series is only 200 m. thick composed of purple shale and gray earthy limestone and lying conformably on the Chialingchiang limestone. A fragment of pelecypod shell has been found from a limy bed, it is however, insufficient for determination. Further west only a thin seam of red shale has been seen in the western limb of Mutung anticline lying between the Chialingchiang limestone and Hsiangchi coal series.

Judging from the position of this series as lying between the Hsiangchi series and Tayeh limestone, it is unquestionably of Triassic age and most probably of Upper Triassic.

#### PRE-HSIANGCHI SERIES EROSION.

On account of the irregular distribution of Patung series in the gorge district on the east, and entire absence of Triassic formations in Hanyuan on the west, it is believed that there was an erosion interval before the Hsiangchi coal series was deposited. However as the Hsiangchi series is regarded as representing Rhaetic to Liassic and Patung series of Triassic, probably Upper Triassic, the time interval between the two can not be very long.

The total thickness of Triassic formations is 2100 m. in the Yangtze Gorges, 900 m. in the Lower Chialingchiang region, 600 m. in Omeishan and reduced to less than 300 in Yungching and Ya-an districts. Further west the Trias is entirely absent in Hanyuan with Jurassic coal series directly overlying Permian limestone or lava. The gradual reduction of the Triassic strata in thickness from east to west is probably due partly to erosion and partly to the originally unequal deposition which is also confirmed by the more shaly facies of Trias to the west.

### JURASSIC

#### HSIANGCHI COAL SERIES.

This is the widely distributed formation which specially occurs in anticlinal regions in Szechuan basin and occurs also widely in Hsikang province where it is however strongly metamorphosed. It overlies Patung series in the Gorge region, on Chialingchiang limestone in Szechuan basin and on Permian limestone or lava in Hanyuan district of Western Szechuan.

The constituent rocks are mainly gray sandstone and shale with thin coal seams; sandstones are abundant in the east and shales become the chief component in the western districts. The thickness is very variable, in Yangtze Gorge it is only 200 m. as estimated by Messrs. Hsieh and Chao, 550 m. in average in Central Szechuan, and up to about 1,000 m. in Penghsien and Kuanhsien. It seems to be also thicker in the metamorphosed region of Hsikang province.

Plant fossils have been collected from many parts and have been studied by more than one palaeobotanist. The plants found by Richthofen from Kuan-yuan were considered by Schenk<sup>1</sup> as Middle Jurassic. From the same formation in Kuanyuan Chao and Huang collected a number of plants which have been recently described by Dr. H. C. Sze<sup>2</sup> as of Liassic in age. From the neighboring Chaohua district, Yokoyama<sup>3</sup> has described some forms which he considered to Lower Cretaceous. It is difficult to reconcile with the fossils so far known and it is little possible that coal seams may occur in the Cretaceous.

<sup>1</sup> Richthofen, China, Vol. IV, pp. 256-258, Taf. Li

<sup>2</sup> Sze, H. C. Palaeontologia Sinica, Ser. A, Vol. 1, Fasc. 3

<sup>3</sup> Yokoyama, Mesozoic plant from China, Journ. Coll. sc. Imp. Univ. Tokyo, Vol. XXI, Art 9, pp. 11, 12.



Plant fossils have also been collected by Chao and Huang from the surroundings of Ipin (Suifu) in S. Szechuan and also identified as Liassic by Dr. Sze who thus concluded that all coal series in Szechuan is of that age and thought that Schenk's comparison of *Tæniopteris richthofeni*, with *T. major* of England was likely mistaken.

Dr. V. K. Ting has found a number of plant fossils from Hueili, southwestern corner of Szechuan. Those fossils were studied by Dr. T. G. Halle<sup>1</sup> who considered them as of Rhætic age and possibly of Liassic.

Two species *Neocalamites carrerei* Zeiller and *Schizoneura hoerensis* Hisinger obtained from Lungwangtung, northeast of Chungking, by G. Kobayashi<sup>2</sup> were also taken to indicate the Rhætic age of the coal bearing formation.

In the Gorge region Willis made a collection of plant fossils which were determined by David White<sup>3</sup> as probably not older than Rhætic and not younger than Oolite. At Hsiangchi from which the present name of the coal series is derived, Hsieh and Chao<sup>4</sup> collected fossils both from the lower and upper parts which were respectively referred to Rhætic and Lias.

The collections made by Mr. H. C. T'an and myself from different localities contain the following forms as identified by Mr. C. H. Pan:

1. From the upper part of the coal series at Erhyai, Chiangpei district (T. L. 302).

*Neocalamites carrerei* (Zeiller)

*Equisetites sarrani* Zeiller

2. From the middle part of the coal series at Tafuti, Weiyuan district (T. L. 223).

*Equisetites cf. lateralis* (Phyll.) Morris

*Clathropteris meniscoides* Brongn.

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1 Halle, T. G. *Palæontologia Sinica*. Ser. A. Vol. 1, Fasc. 2. pp. 16-21.

2 Kobayashi, G. *Geographical Research in China*, Vol. II, p. 414.

3 Willis, op. cit. pp. 280-283.

4 Hsieh and Chao: op. cit. pp. 58-63.

3. From the environs of Ching kanglin in Penghsien (T. L. 252-254).  
*Cladophlebis denticulata* Brongn.  
*Podozamites lanceolatus* (L. & H.) Braun
4. At Fuhussu in Omeishan (T. L. 161)  
*Neocalamites carrerei* (Zeiller)  
*Equisetites sarrani* Zeiller  
*Phyllothea* sp.  
*Cladophlebis* sp.  
*Podozamites lanceolatus* (Lind & Hutt)
5. From the lower part of the coal series at Lungchih, south of Omeih sien (T. L. 194).  
*Clathropteris meniscoides* Brongn.  
*Teniopteris jourdyi* Zeiller  
*Pterophyllum (Anomozamites) inconstans* (Braun.)  
*Pterophyllum (Anomozamites) minor* Brongn.  
*Pterophyllum* sp.  
*Cladophlebis* sp.
6. From the upper part of the coal series at the opposite side of Ipia city (T. L. 211).  
*Cladophlebis denticulata* Brongn.  
*Dictyophyllum* sp.
7. From the upper part of the coal series at Motzuchang, Chienwei district (T. L. 203).  
*Pterophyllum aequale* Brongn.
8. From the lower part of the coal series in the environs of Huangtao Pingshan district (T. L. 204-205).  
*Podozamites lanceolatus* (L. & H.) Braun

9. From the middle and upper part of the coal series in the environs of Shaping and Kuanyinpu, Ya-an district (T. L. 2, 3, 6, 8).

*Thaumatopteris elongata* Oishi.

*Pterophyllum æquele* Brongn.

*Pterophyllum* sp.

*Podozamites lanceolatus* (L. & H.)

*Neocalamites carrerei* (Zeiller).

10. From the middle part of the coal series in Tienchuan (T. L. 147).

*Tæniopteris nahaensis* Oishi

*Podozamites* sp.

11. From the lower part of the coal series at Huayaiping and Huetzupa of Yungching district (T. L. 23).

*Podozamites lanceolatus* (L. & H.) Braun

*Neocalamites carrerei* (Zeiller)

12. From the lower part of the coal series at Lihsūkou of Hanyüan (T. L. 25).

*Pterophyllum contiguum* Schenk

*Equisetites* sp.

Of the 14 species from the foregoing list according to Mr. Pan, most are known since Rhætic time and some from Lias when compared with the flora of other regions in Asia.

The opinion of palæobotanists seems to hesitate between Rhætic and Liassic. But while many species are common to both ages, the most typical Rhætic one as *Lepidopteris oftonis*, according to the opinion of Dr. Sze, is conspicuous by its absence. It seems therefore reasonable to refer the fossiliferous beds of the Hsiangchi coal series mainly to the lower Jurassic including possibly a part of Rhætic at the base and a part of middle Jurassic at the top. On account of the identification of plant fossils from the upper part of the coal series such as the fossils collected by Chao and Huang in the surroundings of Ipin which Sze has determined as of Liassic age. It is therefore little possible that this series can extend in age into the upper Jurassic or still less to Lower Cretaceous.

In fact the rock characters change gradually from the upper Hsiangchi series to Lower Red-beds and no remarkable demarcation can be distinguished

in the field. From this fact Dr. Heim<sup>1</sup> concluded that the coal bearing series represents the whole Jurassic period. But the same fact can be explained as that the "red-beds" facies begun with the later Jurassic time.

#### CRETACEOUS

The Cretaceous formations are represented by red-beds which occur in the well known Szechuan red basin and its adjacent regions such as Kueichow (Tzukuei) basin in the Gorge district. They were previously divided, in western Szechuan by Heim<sup>2</sup> and Chao and Huang<sup>3</sup> into three divisions with different names. Their divisions however were not complete as they have not included the upper part of the red-beds. The strata observable at Mengshan in Mingshanhsien of Western Szechuan, for instance, cannot be included in any of their upper divisions. Therefore a new subdivision is necessary. Three formational names have therefore been proposed, namely Tzuliuching, Chiating and Mengshan for the lower, middle and upper divisions respectively.

The main criterion of these divisions is the rock character and chiefly the distinctive color of the strata, since there is no other feature which could be used for this purpose. The relation between the different stratigraphic nomenclatures proposed can be shown in the following table.

A. Heim	Y. T. Chao & T. K. Huang	H. C. T'an & C. Y. Lee
		Mengshan formation
Tshiating series	Ch'êngts'iangyen formation	Chiating formation
Tshungking series	Kuangyüan formation	Tzuliuching formation
Tseliutsin series	Ts'ienfuyen formation	

1 Heim, A. Sp. Pub. No. VIII, op. cit. pp. 13-14.

2 Heim, A. Sp. Pub. No. VI, op. cit. pp. 2-11.

3 Chao and Huang: op. cit. pp. 160-164.

TZULIUCHING FORMATION.

This is the lower division of the red beds. It consists of alternative red clayey shale and sandstone red or yellowish-gray in color. The sandstone, when it is comparatively massive, is generally cross-bedded as can be easily observed in the valleys of Chialingchiang and Yangtze. Fossil shells are usually found in calcareous beds which are occasionally intercalated. Some critical sections will be briefly described.

At Tzukei the Tzuliuching formation is represented by the lower 1,500 m. of the Kueichou series and consists of purple shale and yellowish-gray shale alternating with sandstone yielding fresh water molluscs, which were considered as of typical Lower Cretaceous fauna. Similar rock succession is found in Fuling where pelecypod shells have also been found from a clayey shale at about 100 m. above the base. Traces of plant remains were observed but too poorly preserved for determination.

In the lower Chialingchiang region this formation is represented by about 1,200 m. of purple shale, clay and sandstone with 25 m. of limestone about 350-450 above the base. The latter yielded abundant pelecypod shells similar to those found at Tzuliuching. At Tsaochiehtzu about 50 li or 22 km. below Hochuan, fragments of fossil bones have been found from this limestone and considered by Dr. C. C. Young as belonging to a kind of dinosaurs which are now under study by Prof. Broili. This is the first time that dinosaurs have been found in Szechuan. The first find was made by Dr. W. H. Wong in 1930.

The rock characters and succession of Tzuliuching formation at its type locality Tzuliuching have already been described in previous publication<sup>1</sup> so that no repetition is needed here. Suffices it to remember that there are two beds of limestone, each of which contains plenty of shells including *Unio* and *Cyrena* (T. L. 212).

<sup>1</sup> T'an, H. C. and Lee, C. Y. Oil field in Szechuan province. Bull. Geol. Surv. China, No. 22, p. 5 and pl. III. See also in the same Bulletin. Salt deposits of Szechuan.

Farther west at Ipin the rocks amounting to a thickness of 800 m., are purple shale, clay and gray sandstone with calcareous nodules in the place of limestone.

On the north-western border of the red basin the facies is entirely changed. In Kuanhsien and Lushanhsien this formation is represented by more or less 700 meters of conglomerate. However it is still apparently conformable with the underlying Hsiangchi series.

So far the age determination of the Tzuliuching formation has been entirely based upon the pelecypods *Cyrena* and *Unio* which have been referred to Wealden by Frech<sup>1</sup>, Grabau and Chao<sup>2</sup>. No stratigraphic break can be, however, observed in the Szechuan basin and its adjoining parts between this and its underlying Hsiangchi coal series of Liassic age. The question therefore rises whether the Upper Jurassic is entirely unrepresented in the sequence or it may be represented by the lower and unfossiliferous part of the Tzuliuching formation which ranges in thickness from 100 to 400 m.

#### CHIATING FORMATION

This formation is characterized by the brick-red color of the sandstone and clayey shale. The transition from the Tzuliuching formation upward is very gradual and no definite boundary can be established. The sandstone is more usually red and seldom gray and yellow. It is also often cross-bedded. The shale is generally soft and shows no cleavage. Chiating with the characteristic cliff of brick-red sandstone is taken as the type locality, while the middle division, the Tshungking series of Heim, is included by us, Mr. T'an and myself, in our Tzuliuching formations being all characterized by purple-red color. The Chiating formation thus defined has a thickness of about 500 m.

Besides the type region of Chiating, this formation is well developed between Chienyang and Suining in the northern part of the red basin forming rolling hills of low and smooth relief. It occurs also in some synclinal basins in eastern Szechuan. It is likely that the upper part of the Kueichou series of Hsieh and Chao in the Gorge region is equivalent to this formation.

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1 Richthofen, China. Vol. V. pp. 222-225, Taf. XXXI.

2 Hsieh and Chao: op. cit. pp. 65, 66.

MENGSHAN FORMATION.

The upper division of the red-beds is named from Mengshan in Ming-shan district near Ya-an where it consists of brownish-gray sandstone and clay with occasional intercalations of conglomerate. The thickness of the exposed part is not less than 800 m.

In Jenzhou district, north-west of Tzuliuching, the Mengshan formation constitutes the north-western limb of the Jenzhou anticline where it is folded up to 60° conformably with the underlying Chiating formation. The transition between the two formations is also very gradual. But the Mengshan formation is characterized by the predominance of brown-gray sandstone and shale both very soft, and less conspicuousness of the red color.

No fossil has been found from the Mengshan formation. But as it is gradually passing from and conformably folded with the underlying Cretaceous formations, it is highly probable that it is still of the same period thus making the whole Cretaceous red beds in Szechuan up to about 2,800 m. thick.