

ON THE STRATIGRAPHY OF THE FENGNIAN SYSTEM

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The corals described by Mr. Yü in the preceding paper came mainly from southern Kueichou, in the districts of Tushan (獨山) and Tat'ang (大塘).

The first fossiliferous section met with in the field (Pl. I, Section 1a) is that between the village of Kolaoho (犛老河), 11 kilometers south of the city of Tushan, and the pass of Heishihkuan (黑石關). North of Kolaoho (犛老河) there is a thick series of thin-bedded siliceous limestone interbedded with brown and gray shale. In spite of careful searches no trace of fossils was found, but from its stratigraphical position, it can be correlated with the *Yunnanella* beds of Yunnan and Kuangsi, which belong to the Upper Devonian. Overlying the last-named formation, which is termed the Maochai (茅寨) limestone, is a series of thin-bedded shaly limestone intercalated with black shale. From the lowest bed Tr81 we obtained, in addition to the corals described by Mr. Yü, numerous other fossils which have been determined by Dr. Grabau as follows:—

- Tr81 *Spirifer chichaensis* Grabau
 S. subduplicosta Grabau
 Schellwienella crenistria Phillips

About 70 m further up we found:—

- Tr82 *Euomphalus* sp.
 Worthenia sp. 1
 Worthenia sp. 2

Immediately above:—

- Tr83 *Goniatites* sp. 1
 Goniatites sp. 2
 Goniatites sp. 3
 Euomphalus sp.

140 m above the last horizon we found the first species of *Pseudouralinia* and in addition:—

- Tr84 *Productus kolaohoensis* Grabau
 Neoproductella kolaohoensis Grabau

Neoproductella tenuistriata Grabau
Schizophoria praeresupinata Grabau
Camarotoechia kinlingensis Grabau
Camarotoechia kinlingensis var. *quadriplicata* Grabau
Spirifer subduplicosta Grabau
Spirifer chichaensis var. *kolaohoensis* Grabau
Reticularia nonconforma Grabau
Martiniella nasuta Grabau
Athyris (*Cleiothyridina*) *profundisinosus* Grabau

Although this is the lowest horizon in which we found *Pseudouralinia* we regard it on stratigraphical grounds as the top of the lowest formation, which we propose to call the KOLAHO Limestone.

70 m above horizon T184 sandy sediments begin to appear; quartzitic sandstone interbedded with black or brown shale now predominates. At horizon T185 near the village of T'angpakou (湯和溝), some 80 m above the base of sandstone, we found in the shaly limestone a few brachiopods as well as the corals described by Mr. Yü:—

T185 *Productus inflatiformis* Grabau
Spirifer chichaensis (mut. β) var. *kolaohoensis* Grabau
Spirifer (*Brachythyris*) *punguis* var. *rotundata* Sow.
Pterinopecten sp.

From T185 upwards the sandy sediments become mingled with limy and shaly material with constant changes of facies within a short distance. The limestone bands form lenses in the shaly and sandy complex, and beds 10–30 m thick thin out laterally a few hundred meters away. About 60 m above horizon T185 we found in the shaly limestone three horizons near together, T186, T187 and T188, with the following faunas:—

T186 (according to Mr. Y. S. Chi):—

Syringopora cf. *reticulata* Goldfuss

T187

Leptaena analoga Phillips
Productus prae Manchuricus Grabau
Productus sp.
Rhipidomella michelini var. *minor* Grabau

Rhipidomella michelini var. *minor* mut. α Grabau

Neoproductella tangpakouensis Grabau

Athyris (*Cleiothyridina*) *profundisinosus* Grabau

Spirifer chichaensis Grabau

Schizophoria sp. 1

Schizophoria sp. 2

Tr88:—

Pseudouralinia irregularis

This is the highest horizon in which *Pseudouralinia* has been found. We therefore classify together the 170 m of strata from Tr88 downwards as one formation and name it the TANGPAKOU SANDSTONE. This together with the Kolaoho limestone form the AIKUAN (岩關) GROUP which is regarded as the lower Division of the FENGNIAN SYSTEM. The last term is applied to the whole of the Chinese Lower Carboniferous, Fengnin (豐寧) being the name of an old Shan kingdom in which the most fossiliferous Lower Carboniferous beds are situated.

Above horizon Tr88 there are another 60 m of quartzose sandstone with some shaly intercalations above which we come to a pure, somewhat thin-bedded, gray limestone with occasional bands of black shale, about 50 m in thickness. A hurried search yielded the following species of *Syringopora* according to Mr. Y. S. Chi's determination:—

Tr89 *Syringopora* cf. *reticulata* Goldfuss

Syringopora geniculata Phillips

Syringopora gracilis Keyserling

This is again overlaid by about 100 m of quartzitic sandstone with some gray shale. Approaching the pass known as Heishihkuan, we come to another limestone. From a distance it looks rather massive forming conical peaks and vertical cliffs. In reality it is somewhat thin-bedded; the individual beds average about 20 cm in thickness. It is gray to dark blue in colour, subconchoidal in fracture and fairly pure, but in the lower part often with black shale partings between the bedding planes. Bands of chert occur also along the latter. It is here we first found specimens of the giant coral *Kueichouphyllum*, lying always with its longitudinal axis parallel to the bedding plane and below a thin parting of black shale. We have from this horizon:—

- T190 *Caninia vesicularis* Yü
Lithostrotionella kueichouensis Yü
Kueichouphyllum jugum Yü
Kueichouphyllum heishihkuanense Yü

and

Composita subtilita var. *sinensis* Grabau.

This does not by any means represent the whole fauna; for the collection was very hurriedly made, towards the evening, when we were still some distance from our night quarters. The limestone is about 120 m thick and is free from both shale and chert in its upper portion.

South of Heishihkuan the limestone is faulted against a quartzose sandstone. The extent of the throw was not determined. The sandstone, dipping in the same direction as the limestone at Heishihkuan, contains numerous bands of brown and black shale, but is almost entirely free from lime until about 170 m in vertical distance from the fault-contact, when shaly limestones begin to appear. In semi-darkness we collected (horizon T191 and T191a) *Syringopora ramulosa* Goldfuss and *Daviesiella productiformis* Grabau, just north of the mart of Shangssu (上叻), one of the capitals of the ancient kingdom of Fengnin.

The shaly limestone soon becomes quite pure, forming massive looking cliffs. It resembles the limestone at Heishihkuan in every detail with exactly the same chert bands and thin black shale partings. The dip is only about 10° and the route between Shangssu and Hsiassu (下叻), our next stopping place, lies along the strike. Unfortunately it rained heavily all day and we collected with difficulty at several points more or less along the strike of the following fossils:—

- T192 *Syringopora geniculata* Phillips
Syringopora gracilis Keyserling
T193 *Cryptospirifer shangssuensis* Grabau
T194 *Productus* sp.
Phanerotinus paradoxiformis Grabau
Meekospira indiciformis Grabau

Bellerophon sp.

Siphonodendron chachaiense Yü

Tr96

Daviesiella llangelliensis Davidson

Productus (*Kansuella*) cf. *maximus* Grabau

Kueichouphyllum heishihkuanense Yü

Dibunophyllum minor Yü

Tr96a

Daviesiella comoides Sowerby

Daviesiella llangelliensis Davidson

Daviesiella cf. *llangelliensis* Davidson

Tr97

Daviesiella comoides Sowerby

Athyris (*Cleiothyridina*) *ingens* de Kon. var. *kansuensis* Grabau

Tr98

Daviesiella comoides Sowerby

Orthotetes sp.

Tr99

Daviesiella cf. *llangelliensis* Davidson

Daviesiella productiformis Grabau

Productus (*Gigantella*) *tingi* Grabau

The horizons listed above probably belong more or less to the same level, as the route lies along the strike, but Tr95-Tr98 may be somewhat higher. The limestone is estimated to be about 160 m thick. The upper part becomes purer and more massive until we come upon a white, semi-crystalline limestone which most probably belongs to the Middle Carboniferous. No fossils were collected because we passed it in semi-darkness, but its stratigraphical position is approximately known, for the next day we found ourselves in the typical Lower Permian which usually overlies the Middle Carboniferous.

The correlation of these beds with those north of the fault at Heishihkuan is not quite certain, so the succession is given in a different columnar section (Pl. I, section 1b). Lithologically the limestone Tr92-Tr99 is exactly the same as that of Tr90 at Heishihkuan north of the fault. Again Tr96 and Tr90

both contain *Kueichouphyllum heishihkuanense*. It is probable that the sandstone and limestone south of the fault represent a repetition of similar beds north of the fault line represented at the top of section 1a (Pl. I). The absence of the typical brachiopods found in Tr91a-Tr99 from Tr90 would not necessarily be against this supposition, since, as stated above, the collections at these localities were made under the most unfavourable conditions, and are far from being exhaustive. On the other hand the sandstone series south of the fault is more shaly and is thicker than the corresponding sandstone to the north and the black shales contained therein were not observed in the latter. They may represent some of the thin limestones in the Heishihkuan section. In any case the horizons Tr91a-Tr99 cannot be more than 160 m from the base of the Middle Carboniferous.

In the field we at first considered the beds from 189 upwards as one formation and named it the Shangssu limestone, but as we shall see below, there is reason to believe that the terrain above horizon Tr88 and below Tr90 should be regarded as a separate formation, and that the term Shangssu limestone be restricted to the upper limestone, from Tr90 upwards;

Owing to the cuttings made in building the motor road the outcrops of the section described above are unusually good, but the road lies most of the time along the strike which is crossed only very obliquely over a long distance. The dip is also rather variable. This together with the rapidity of our reconnaissance made accurate measurements of thickness rather difficult. It is believed, however, that the figures given are not far from the truth, and that the order of succession is certainly correct.

The second section (Pl. I, section 2) was observed between the town of Chiussu (舊司) and the village of Liuchai (六樂) via the district city of Tat'ang. The conditions are very favourable for detailed study; the beds dip generally with an angle of 5-12° and the road lies along the strike. From Chiussu to Tat'ang one goes constantly upwards so that the difference in height between the two localities practically gives the thickness of the formations.

The details of the section in ascending order are as follows:—

1. Black shale and shaly limestone. 75 m

From the base of this we collected the following:—

- T296 *Productus inflatiformis* Grabau
Cryptospirifer orientalis Grabau
Cryptospirifer talangensis Grabau mut. α
Cryptospirifer talangensis Grabau mut. β
2. Quartzose sandstone with some dark gray shale. .35 m
 3. Black shaly limestone.37 m

From this horizon we have:—

- T296a *Productus yunnanensis* Lotzy
Alkyris (*Cleiothyridina*) cf. *shangssuensis* Grabau
Worthenia talangensis Grabau
Thysanophyllum sp.
4. Reddish brown sandstone.35 m
 5. Impure sandy limestone.25 m
 6. Reddish sandstone.30 m
 7. Grayish thin-bedded pure limestone.35 m
with black shale partings.

From the base of this horizon we have:—

- T296b *Thysanophyllum pseudovermiculare* (M'Coy) var. *minor* Yü
Thysanophyllum asiaticum Yü
Siphonodendron curvatum Yü
Yabeella cyathophylloides Yü
8. Gray to blue thin-bedded pure limestone with less and less shale partings towards the top.125 m

From the base of this horizon we have:—

- T296c *Daviesiella llangelliensis* Davidson.

From the top we have:—

- T196d *Kueichouphyllum sinense* Yü
Arachnolasma cylindricum Yü
Siphonodendron chachaiense Yü
9. Brown quartzitic sandstone, full of ripple-marks, with occasional shale and shaly limestone.100 m

Here we arrived at the city of Tat'ang whence the road lies in the same formation until it reaches a point 1.5 kilometers west of the village of Touti (斗底). Thence via Touti to a point 1.5 kilometers south of Liuchai we observed the following succession: -

10. Gray to blue thin-bedded pure limestone with black shale partings 90 m

From the base of this formation we collected a very rich fauna. In addition to the 8 species of corals including the genera *Yuanophyllum* and *Kueichouphyllum* we have the following brachiopods:—

- T297 *Schellwienella interstitialis* Grabau
Chonetes papillionacea Phillips var. *shangssuensis* Grabau
Chonetes papillionacea Phillips mut. α Grabau
Productus corrugatus M'Coy
Productus (Gigantella) cf. giganteus Martin
Productus (Kansuella) edelburgensis Phillips
Productus (Kansuella) maximus M'Coy
Echinochonetes elegans (M'Coy)
Martinia shangssuensis Grabau
Martinia sp.
Reticularia sp.
Squamularia sp.
Ambocoelia dubia Grabau
Athyris (Cleiothyridina) shangssuensis Grabau

11. Light gray pure limestone free from shale partings, but with bands of chert between the bedding planes. . . 90 m

From the base of this formation we have: -

T298

- Arachnolasma vesiculare* Yü
Siphonodendron petalaxioides Yü
Daviesiella comoides Sowerby
Daviesiella kueichouensis Grabau
Daviesiella gigas Grabau
Productus (Kansuella) maximus M'Coy

Productus (Gigantella) giganteus mut. β Grabau

Athyris (Cleiothyridina) trigonalis Grabau

From horizon T298b near to the top of 11 we have:—

T298b *Clisiophyllum yenchense* Yoh var. *multiseptatum* Yü

Diphyphyllum convexum Yü

From horizon T298a at the top of the formation:—

T298a *Productus (Gigantella) tingi* Grabau.

This is the highest horizon observed in the section, for the dip now changed and the road followed the strike, and by the time it again turned to cross the strike, it was nearly dark so no more collections could be made, but we observed that it was overlaid, as usual, by the Middle Carboniferous limestone. Again, owing to the zigzagging of the road and frequent changes in dip which was sometimes difficult to measure when the bedding plane was not sufficiently distinct, the thickness given for the beds 10 and 11 is not so accurate as that for 1-9.

The third section (Pl. I, section 3) is that west of the village of Maochai three kilometers WSW from Tushan city. Here the Kolaoho limestone, 220 m in thickness, overlies the typical Maochai limestone of Upper Devonian age. Lithologically it is exactly the same as the corresponding formation described in section 1a. At horizon T280 near the base we found the following fossils:—

T280

Orbiculoidea cf. *nitida* Phillips

Schellwienella crenistria mut. α . Grabau

Schuchertella kolaohoensis Grabau

Schuchertella truncata Grabau

Reticularia imbricata mut. α . Grabau

Composita globularis Phillips

Composita subtilita var. *sinensis* Grabau

Towards the top of the formation we have:—

T280a

Cystophrentis kolaohoensis Yü

Composita globularis Phillips

Composita subtilita var. *sinensis* Grabau.

Then it is succeeded by a series of sandstone, shale, and shaly limestone 60 m thick at the top of which we found *Pseudouralinia tangpakouensis*, so it corresponds to T184 in section 1a which we regard as the top of the Kolaoho series.

This horizon is overlaid by a thick series of sandstones and shale, no less than 340 m thick. We were not able to study the section in detail because the outcrops are rather poor. It can however be divided into two divisions. The lower one, about 190 m thick, consists largely of reddish brown quartzose sandstones with thin shaly beds. This is probably equivalent to the Tangpakou Series. The upper formation, about 150 m thick, is much more shaly, but as far as we could observe, free from limy intercalations. Instead, we have bands of fire-clay locally worked by the villagers. This section is only twenty kilometers from section 1a, yet the shallow water deposits are here partly replaced by fresh water sediments, showing how very inconstant the deposition must have been during the period between the end of Kolaoho limestone and the beginning of Shangssu limestone sedimentation. The occurrence of fire-clay is an important indication of land facies which, as we shall see, will enable us to correlate some of the other sections.

Above the shaly beds just described is a grayish blue thin-bedded limestone about 130 m thick. Near its base occur the following fossils:—

T282

Productus shangssuensis Grabau
Aspidophyllum maochaiensis Yü
Siphonodendron cf. irregulare Phillips
Lophophyllum? sp.
Caminia sp.

Then it is succeeded by a massive, pinkish, semi-crystalline limestone. About 140 m from its base we found some typical Middle Carboniferous fossils. So the first limestone can be roughly correlated with the Shangssu limestone, and the sandstone and shale with the fire-clay beds must be equivalent to the sandstone series between the Tangpakou sandstone and the Shangssu limestone in section 1a.

Let us now correlate the two best sections, 1 and 2. There can be no doubt that 8-11 in the latter is equivalent to the Shangssu limestone in the

former, i.e., the beds from horizon T190 up. Both are characterised by the genera *Daviesiella* and *Productus* of the *giganteus* type, neither of which has been found below horizon T296c in section 2, or horizon 190 in section 1a. Both contain the genus *Kueichouphyllum* not found in the lower beds. Whilst the species are not the same, T194 contains *Siphonodendron chachaiense* which occurs also in T296d. The absence of *Arachnolasma* in section 1 is probably only apparent, due to the unfavourable conditions under which the collection was made.

There is considerable difference in the thickness of the corresponding divisions in the two sections. The Shangssu limestone in section 1 is only 130-160 m thick, whilst in section 2 it is more than 400 m. This however need not trouble us, for we have already seen that after the deposition of the Kolaoho limestone sedimentation became extremely unstable. For example, section 3 which is only 20 kilometers from section 1a cannot be closely correlated with the latter either in its lithological character or in its thickness. Most of the limestones between the Kolaoho and the Shangssu series that have yielded such rich faunas in section 1a are missing in section 3. That this is not entirely due to the lack of good outcrops is clearly shown by the occurrence of fire-clay indicating that in spite of their proximity, the facies are really somewhat different.

The correlation of the strata 1-7 in section 2 is more difficult. Here the formation is characterised by quite definite types of brachiopods and corals. The genus *Thysanophyllum* is entirely confined to it, and that of *Cryptospirifer* nearly so. Only one species, *Productus inflatiformis*, found in the lowest horizon T296, occurs also in horizon T185 in the middle of the Tangpakou sandstone. The genus *Cryptospirifer* occurs again in T193 in the lower part of the Shangssu limestone in section 1b. It is clear therefore that the calcareous and arenaceous complex above T188 and below T190, i. e. between the Tangpakou sandstone and the Shangssu limestone in section 1a, must correspond to the strata 1-7 in section 2, which are represented by shaly and sandy beds containing fire-clay in section 3. We may name these the CHIUSSU SANDSTONE to distinguish them from the Shangssu limestone above and the Tangpakou sandstone beneath. Again the Chiussu Series may be put together with the Shangssu limestone to form the TATANG GROUP, representing the upper division of the Fengninian.

From these considerations we propose the following classification:

The Fengninian System. = The Lower Carboniferous	The Tatung Group = The Viséan.	The Shangssu Series consisting mainly of limestone with occasional sandstones and shales. Thickness. 130-400 m.
		The Chiussu Series consisting of a complex of calcareous, arenaceous and argillaceous sediments. Land facies may prevail. Thickness 200-280 m
	The Aikuan Group = The Tournaisian	The Tangpakou Series consisting of quartzitic sandstone and shaly limestone with subordinate amount of shale. Thickness. 170-190 m.
		The Kolaoho Series consisting of shale and shaly limestone. Thickness. 280 m.

The Shangssu limestone should include the upper part of the *Yuanophyllum* zone of Mr. Yü, for it is certain that it is represented in Kueichou, for the upper part of the Shangssu limestone gradually becomes more and more massive and passes imperceptibly into the Middle Carboniferous, below which no disconformity has been observed. The apparent absence of the genera *Auloclesia*, and *Aulina*, is due most probably to the reconnaissance character of our work. The collection from the upper horizon of the Shangssu limestone is particularly poor, largely because it passes into semi-crystalline beds in contact with the massive limestone of the Middle Carboniferous, which in turn is invariably overlaid by the equally massive Lower Permian limestone. These together form typical karstic country, or may be cut by canyons, both of which types of country are scarcely inhabitable, and we had to march unusually long distance before we could find suitable night quarters for our fairly large caravan with its escort of over one hundred soldiers. The fact that in one of Mr. Y. L. Wang's sections at Ch'iao-tzushih (橋子石) near Kueiyang (貴陽) (TW52-52b) *Heterocaninia* was found a short distance below typical Middle Carboniferous limestone suggests the presence of the uppermost zone.

From the fossil lists given above it is interesting to note that each subdivision of the Fengninian system contains its characteristic brachiopods though the latter have a greater range than the corals and have somewhat less zonal value. The following are the horizons established by Dr. Grabau:—

1. The Shangssu limestone is characterised throughout by the genera *Daviesiella* and *Productus* (*Gigantella*) of the *giganteus* type. *Daviesiella liangeliensis* seems to have the lowest range, *Gigantella edelburgensis* next, *Daviesiella comoides* still higher, and *Cleiothyridina ingens* the very top of the formation, as it has been found in the Choniukou section in Kansu which Mr. Yü considers the highest zone of the Fengninian. The same species of *Cleiothyridina*, however, occurs in T19 in Kuangsi together with *Pseudouralinia*. These species have not the same zonal value as the corals, but it is believed that at each horizon mentioned above certain types predominate.

2. The Chiussu sandstone is definitely characterised by the genus *Cryptospirifer*. Three species or mutations occur in the lowest horizon at the type locality. Only a single occurrence is known from the base of the overlying series, namely that of T193, but the species is different.

3. The Tangpakou sandstone is characterised by *Rhipidomella michelini* and *Athyris* (*Cleiothyridina*) *profundisinus*. This horizon seems to be absent from all the neighbouring provinces, Hunan, Kuangsi and Yunnan. Nor is it known in the Nanking region.

4. The fauna of the Kolaoho limestone falls into 2 zones. The upper zone is characterised by *Camarotoechia kinlingensis*, *Martiniella nasuta*, and *Neoproductella kolaohoensis*. This is the most wide-spread fossiliferous horizon in China, for identical species are found near Nanking and in Central Hunan. The lower zone consists almost exclusively of two genera, *Schuchertella* and *Composita*, each occurring in several specific forms. *Composita globularis* Phillips and *Composita subtilita* var. *sinensis* are equally characteristic. Both range into the division above, but are certainly the dominant forms in the lower formation. *Composita subtilita* var. *sinensis* has also been found in horizon T190, at the base the Shangssu limestone, *Schuchertella kolaohoensis* and *Schuchertella truncata* are characteristic of this horizon, but *Schuchertella lianglukouensis*, found by Mr. Y. L. Wang in another section containing the two typical species of *Composita*, occurs also in the division above.

As stated by Mr. Yü, the other localities in Kueichou from which corals have been found can be easily correlated with the standard sections. We may add that his conclusion agrees with the field observations and the evidence furnished by brachiopods. In the section containing horizon T249, the bed with *Pseudouralinia tangpakouensis* is directly overlaid by the Shangssu limestone. In another section from P'iaochai (瓢寨) to Chich'ang (鷓鴣) 188 km east of Tushan, which yielded many *Syringopora*, and a rich brachiopod fauna (T274) there is between the Tangpakou series and the Shangssu limestone, a thin series of sandstone containing poorly preserved plant fossils, which must represent the fire-clay series of section 3. It is clear therefore that the Chiusssu and the Tangpakou series were formed in a very unstable sea near the shore, and are elsewhere, even in localities near to our type sections, represented by land conditions. This important fact will enable us to understand some of the unfossiliferous deposits north of Tushan which belong undoubtedly to the Fengninian, as well as the sections observed in Hunan, Kuangsi and Yunnan.

Before discussing the correlation of the sections outside of Kueichou province, we propose to give first a section near the city of Tuyün (都匀) from which practically no fossils have been obtained. It was first observed by Mr. S. S. Yoh in his trip to the high peak of Mangshan, west of the city of Tuyün 50 kilometers north of Tushan. We revisited his section together with Mr. Y. L. Wang and noted the following detail (Pl. I, section 4) in descending order:—

SUPRA-FORMATION: Lower Permian limestone

Disconformity

- | | |
|---|-------|
| 1. Reddish brown quartzite | 200 m |
| 2. Massive light gray semi-crystalline limestone . . | 85 m |
| 3. Hard brown quartzite | 250 m |
| 4. Quartzitic sandstone intercalated with gray and
black shale in which is a seam of bad coal
0.6 m thick | 120 m |
| 5. Dark gray limestone, slightly shaly | 50 m |
| 6. Light gray massive limestone | 80 m |
| 7. Thin-bedded siliceous limestone | 40 m |
| 8. Hard reddish and brownish quartzite | 500 m |

Disconformity

SUB-FORMATION: Ordovician limestone and shale.

In spite of careful searches no fossils were found except ostracods which occur at the base of 5 in great abundance as already noted by Mr. Yoh. Although these ostracods may be difficult to determine, they form an important horizon marker, for in all the unfossiliferous Fengninian beds observed further north they were invariably found in similar limestone at the corresponding level. Moreover, in the section west of Tushan (Pl. I, section 3) they reappear at horizon T280 at the base of the Kolaoho series. So there is no doubt that bed 5 belongs to the same formation. This conclusion is strengthened by the correlation of the beds 6-7. In 2 sections, one south and the other north of Tuyūn, we found all the corresponding beds, but bed 7 yielded *Spirifer sinensis* which is the index fossil of the Chinese Upper Devonian. Bed 6 certainly corresponds to the Maochai limestone which is regarded as equivalent to the *Yunnanella* bed of Kuangsi and Yunnan which overlies the *Spirifer sinensis* horizon, forming together with it the Upper Devonian.

The occurrence of a coal seam in bed 4 makes it certain that it is equivalent to the fire-clay horizon in section 3, representing the land facies of the Chiussu series. The overlying quartzite 3 would be the equivalent of the Shangssu limestone, and 2-3 the Middle Carboniferous. The Tangpakou series is here either wholly or partly wanting, as the bed with the coal seam rests directly on the Kolaoho limestone which is here only 50 m in thickness.

Further north to about the latitude of Kueiyang, the Kolaoho formation is everywhere present, always with abundant ostracods. It is always overlaid by a sandstone containing fragments of *Lepidodendron* together with *Lingula lungsungensis* Grabau, which must be the equivalent of the Chiussu series, the Tangpakou being probably absent. The Shangssu limestone is again usually represented by quartzose sandstone.

In north-western Kueichou in the district of Weining (威寧) the Shangssu limestone with *Productus* of the *giganteus* type is well-developed and is overlaid by the *Spirifer mosquensis* limestone and underlaid by sandstone, shale and and shaly limestone containing species of *Composita*. So here the Chiussu series is entirely wanting; so is probably the Tangpakou sandstone. But to the south, in the districts of Chütsing (曲靖) and Chanyi (盐津) in eastern

Yunnan, a sandstone containing *Lepidodendron* and *Sigillaria*¹ occurs between the Shangssu limestone containing *Productus giganteus* and a shaly limestone with a fauna similar to that of Kolaoho.

In Kuangsi the shaly limestone overlying the Upper Devonian has yielded *Composita globularis* proving the presence of the Kolaoho series. The occurrence of *Pseudouralinia gigantea* in locality 1619 indicates the presence of the Tangpakou sandstone. In the same limestone we found *Productus praemanchuricus* which occurs in horizon T187 in type section 1a. This limestone is directly overlaid by a series of soft reddish sandstones and shales containing poor coal seams, which would be the equivalent of the Chiussu sandstone. Locality 1621 and 1622a containing *Siphonodendron petalaxioides* correlated by Mr. Yü with the upper Shangssu limestone, lies in a complex series of limestones, soft sandstones and shales, lying stratigraphically well above the coal series just mentioned. The stratigraphical position of the *Arachmolasma* beds of localities 1601, 1602, and 1633 is a little uncertain, but Mr. Yü is probably right in correlating it with the upper Shangssu limestone.

The stratigraphy of the Fengninian in Central Hunan is given by Mr. Tien in great detail in a paper following this. It remains for me to emphasise that his Tzeshui coal series is evidently the continental equivalent of the Chiussu sandstone, and that a disconformity lies just above the Kolaoho series, as is probably also the case everywhere.

In the Nanking region the Kinling limestone of Prof. J. S. Lee represents undoubtedly the Kolaoho series. The reported occurrence of *Productus giganteus* at the base of the Huanglang limestone² can only mean that the Tangpakou and the Chiussu series are both wanting. Elsewhere in Kiangsu, southern Anhwei, N. W. Chekiang, Kiangsi, N. Hunan and Kwangtung the Fengninian is largely continental, and has been hitherto classed together with the Devonian. The widespread occurrence of the fire-clay, which I regarded in 1919¹ as Devonian, has been since proved to be Carboniferous. The plant fossils collected by members of the Geological Institute of the Academia Sinica from the fire-clay beds at Wusieh have been submitted to Dr Halle who

1. Halle: Plant Fossils from S. W. China

2. J. S. Lee and S. Chu, Note on Chhsia limestone and its Associated Formations. Bull. Geol. Soc. China, Vol. IX, No. 1.

considers them to be probably Lower Carboniferous. I think that there is little doubt that this is the same fire-clay horizon seen in section 3, and is to be correlated with the marine facies of the Chiussu sandstone. The correlation of the various sections is shown in Plate II, Sections I-VII.

We may thus summarise the history of the Fengninian. In the beginning of the period the whole of S. W. China was covered by the sea of shallow depth in which the limestones and shales of the Kolaoho series were deposited. Some of the sediments was certainly formed close to the shore, for sun-cracks can often be observed. At first the fauna was not rich in species, but towards the end of the period it became more and more varied and the large coral *Pseudouralinia* began to appear. Soon after the sea became still shallower, and sandy sediments more and more predominated. During the Tangpakou period shore conditions began to prevail. From a large part of the country sea water was withdrawn, as in central Hunan, north-western and central Kueichou, and eastern Yunnan. Only southern Kueichou and Kuangsi remained under water, but even here sedimentation was unsteady, so that deposition varied a great deal in thickness and in the character of the sediments. After the closing of the Tangpakou period, the withdrawal of the sea became still more pronounced, for eastern Kuangsi now emerged from water. Swamps not far from the shore existed here and there in which thin coal seams were formed. Marine conditions continued, however, in southern Kueichou where the Chiussu sandstone was deposited. Soon after the sea again advanced and in most places the water was probably deeper than it ever had been since the beginning of Fengninian time so that purer limestone everywhere came into existence. The advance probably did not take place at the same time over the whole area, so that the Shangssu limestone varies greatly in thickness and seems to begin with a slightly different fauna in different localities. In some places, as for example at Tat'ang, shore facies alternated with deeper water so that sandstones, bearing ripple-marks, were deposited between pure limestones. One peculiar feature of the fauna is the gigantic size of some of the brachiopods and corals. It is the age of *Productus giganteus* and *Kueichouphyllum*. In most part of the area under consideration the sea continued to deepen until, at the close of the Fengninian,

1. V. K. Ting: The Orogenic Movements in China Bull. Geol. Soc. China Vol. VIII, p. 155. (1929)

massive limestones were everywhere in predominance. This Shanssuan sea continued right into the Middle Carboniferous and was probably only withdrawn at the Upper Carboniferous.

In the country to the east of Hunan and the north of Kueichow land conditions prevailed during the greater part of the Fenginian time. In the north there seems to have been no deposition, whilst several hundred meters of quartzite and sandstone of fresh water origin accumulated in the east. Only in the extreme east near Nanking and the adjacent area of Northern Anhwei the Fenginian sea made some invasion, but here again it was only in the beginning and towards the end that the land was under water.

