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LUDLOVIAN GRAPTOLITE FAUNAS OF THE YANGTZE GORGES DISTRICT AND THEIR STRATIGRAPHICAL SIGNIFICANCE

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I. INTRODUCTION

The Silurian stratigraphy of the Yangtze Gorges district has been reported by various authors since this century.

Early in 1924 J. S. Lee and Y. T. Chao subdivided the Silurian of Sintan district into two parts—the lower Lungma shale and the upper Sintan formation, thus laying down the fundation of the silurian stratigraphy of China. In the following year C. Y. Hsieh and Y. T. Chao went to Lojoping area of I-Chang district and again subdivided the Silurian of that area into three subdivisions—the Lower Lungma shale, the Middle Lojoping formation and the Upper Shamao formation. They brought back a large collection of fossils from the Middle Lojoping formation which have furnished us the material of the Late Silurian stratigraphy of that region.

But none of the index fossils of the Upper Silurian has so far been known in that area. The type section of Wulungkuan had not been completely measured by them in measuring, so that neither fossil evidence nor the bed of the Upper Silurian had been given. Therefore, the existence of the Upper Silurian in that area remains for a final solution.

The subdivision of the Silurian of I-Chang region is given by Hsieh and Chao as follows:

Permiam: Yanghsin limestone: Chert bearing limestone ..... 800 m thick.
—— disconformity ——
Silurian: Shamao formation: Greenish shale interbedded with sandy shale..... 330 m thick.
Lojoping formation: Greenish shale interbedded with thinbedded limestone containing numerous *Favosites* and *Pentamerus* ..... 80 m thick.
Lungma shale: Mainly greenish shale, black shale in the basal part containg abundant monograptids ..... 360 m thick.
—— disconformity ——
Middle Ordovician: Neichiashan formation.

In 1943. Y. C. Sun summarized the Palaeozoic stratigraphy of China and correlated the Silurian formation of the Yangtze Gorges with that of Yunnan and Kwangtung. Basing upon the stratigraphical position, the principle of sedimentation and also the Lojoping faunas, he suggested that both the Middle and Upper Silurian might be present in the Yangtze Gorges region. Up to 1956, no index fossil of the Upper Silurian had been discovered, hence

the exact correlation of the type Ludlow series with the equivalent formations in China was impossible.

In the autumn of 1956 the institute party led by Prof. Y. C. Sun visited the Yangtze Gorges district and made a detailed study of the Silurian stratigraphy. As a result, they subdivided the Upper Silurian Shamao series (Ludlow) of I-Chang ragion into 3 subdivisions—the upper *Serpulites beds*, the middle *Leperditia beds* and the lower *nilssoni beds*. Particularly from the Wulungkuan area they obtained a rich collection of the Ludlow graptolites comprising 7 species out of which one is new.

The graptolite horizon of Wulungkuan is certainly the equivalent of *Monograptus nilssoni* zone of the Lower and Upper Silurian of Europe.

The writer is very much obliged to Prof. Y. C. Sun under whose direction the present paper is made.

II. Correlation and Classification of the Stratigraphy of I-Chang Region.

The subdivisions of the Upper Silurian formations of I-Chang district is as follows:

(1) Section of the Shamao series (Ludlow) at Wulungkuan, Lojoping (Fig. 1).

Superformation: Devonian Yuntaikuan quartzite.

—— disconformity ——

Upper Silurian: Shamao series (upper Sintan formation). Greygreenish sandstone, with green shale bands ..... 300—350 m thick.

3—*Serpulites* beds:
Greenish-grey argillaceous slaty shale, with thin-bedded calcareous shale containing *Serpulites* sp.

2—*Leperditia* beds:
Interbedded beds of dark green sandstone and of thin-bedded greenish-grey shale containing *Leperditia* sp.

1—*Nilssoni* beds:
Greenish-yellow sandstones interbedded with layers of dark green sandy shale.

Subformation: Lojoping series (Lower Sintan formation).

(2) Section of the Shamao series (Ludlow) at Wangchiawan (Fig. 2).

Superformation: Devonian Yuntaikuan quartzite.

Upper Silurian: Shamao series (upper Sintan formation). This series consists entirely of interbedded greenish-grey sandstone and greenish yellow sandy shale ..... about 300—350 m thick.

3—*Serpulites* beds:
Dark green and yellowish-brown sandstones alternated with thin-bedded green shale or thick-bedded dark green sandstone, with brachiopods.

2—*Leperditia* beds:
Yellowish-brown and dark green massive fine-grained sandstones, with grey greenish thin-bedded shale containing *Leperditia tingi* and brachiopods.

1—*Nilssoni* beds:
Interbedded slightly green, or greyish-green thin-bedded shale and dark green shaly sandstones.

(3) Section of the Shamao series (Ludlow) at Wulungkuan, Lojoping (Fig. 3).

Superformation: Devonian Yuntaikuan quartzite.

—— disconformity ——

Upper Silurian: Shamao series (upper Sintan shale):
The series consists chiefly of massive sandstone, with thin-bedded sandy shale or massive shale.....300—250 m thick.

3.—*Serpulites* beds:
Greyish-green massive and thick-bedded sandstones, with greyish-green thin shale beds in the upper beds, yellowish-green thin-bedded shales in the lower beds.

2.—*Leperditia* beds:
Brown massive sandstones with abundant trilobites, brachiopods and crinoid stems.

1—*Nilssoni* beds:
Alternating series of yellowish coarse-grained sandy shale and greenish shale, with three layers of graptolites:

iii. Upper layer: Yellowish-green massive sandy shales containing *M. scanicus, M. dubius.*

ii. Middle layer: Grey-green massive sandy shale with green thin-bedded shale containing *M. nilssoni, M. bohemicus, M. dubius, M.* cf *varilius.*

i. Lower layer: Grey and greenish shale about 1—2m thick, containing *Monograptus nilssoni, M. uncinatus* cf. var. *micropoma.*

A correlation table of the Upper Silurian in the Yangtze Gorge

(Y. C. Sun and Y. C. Hong)

			Sintan	Wangchiawan	Wulungkuan	Fanghsiang
Upper Silurian (S_3)	Shamao series	*Serpulites* bed	Greenish-grey argilla ceous slaty shale, with thin-bedded calcareous shale containing *Serpulites* sp.	Dark green and yellowish brown sandstone, with thin-bedded green shale or thick-bedded dark green sandstone, bedding plane full of fragment of mica, containing Brachiopods.	Greyish-green massive sandstone with thin-bedded green shale.	Thick-bedded and thin-bedded dark green sandstone, with greyish-green thin-bedded shale.
		Leperditia bed	Layers of dark interbedded with green sandstone thin-bedded greenishgrey shale, containing *Leperditia tingi.*	Yellowish-brown and dark green massive fine-grained sandstone with greenish-grey thin-bedded shale, containing *Leperditia tingi* and Brachiopods.	Upper part consisting of yellowish-green shale. Lower part consisting of brown massive sandstone.	Green coarse sandstone with green thin-bedded calcareous shale containing *Leperditia tingi* and Brachiopods.
		Monograptus nilssoni	Yellowish - green sandstone, with thin-bedded sandy shale.	Interbedded greenish, greyish-green thin-bedded shale and dark green shale sandstone containing trilobites and *M. nilssoni* (?) zone.	Alternating beds of greyish-green coarse grained sandy shale containing Graptolites fauna of *M. nilssoni* zone.	Alternating beds of greyish-green shale and yellowish-green sandstone.

The total thickness of the *nilssoni* beds is now estimated at 100 to 150 m.

(4) Section of the Shamao series (Ludlow) at Fenghsiang (Fig. 4).

Superformation: Devonian Yuntaikuan quartzite.

—— discontormity ——

Upper Silurian: Shamao series (upper Sintan shale):

Dark green and greyish-green shales interbedded with yellowish green sandstones ..... about 300—350 m thick.

3—*Serpulites* beds:

Thick-bedded and thin-bedded dark green sandstone, with greyish-green thin-bedded shale.

2—*Leperditia* beds:

Green coarse grained sandstones, with green thin-bedded calcareous shale containing *Leperditia tingi* and brachiopods.

1—*Nilssoni* beds:

Alternating beds of greyish-green shales and yellowish-green sandstones.

Subformation: Lojoping series (Lower Sintan formation).

III. Composition of the Upper Silurian (Ludlow) Graptolite Faunas of I-Chang.

The graptolite assemblages of the Shamao series (Ludlow) obtained from the type locality Wulungkuan near Lojoping, I-Chang region consist of the following species:

Monograptus nilssoni (Barrande) Elles & Wood.
Monograptus colonis (Barrande) Elles & Wood.
Monograptus bohemicus (Barrande) Elles & Wood.
Monograptus dubius (Suess) Elles & Wood.
Monograptus uncinatus cf. var. *micropoma* (Jaekel) Elles & Wood.
Monograptus scanicus Tullberg.
Monograptus changi Hong, sp. nov.

Monograptus dubius ranges from the Middle Silurian to Upper Silurian; *Monograptus scanicus* is a zone fossil of the overlying zone of *M. scanicus* zone although it first appears in the zone of *Monograptus nilssoni.*

Monograptus nilssoni, rather abundant in *nilssoni* zone and associated with *Monograptus colonus* and *Monograptus bohemicus,* is generally selected as a zone fossil of that zone.

Therefore, the graptolite-bearing horizon of Wulungkuan is certainly of *Monograptus nilssoni* zone of early Ludlovian age, and corresponds to *M. nilssoni* zone of Europe and Australia.

IV. Description of Species.

Family Monograptidae Lapworth, 1873

Genus *Monograptus* Geinitz, 1852

The monograptids fall into two main groups:

Group I. Thecae simple with straight ventral edges and even apertural margins.

M. nilssoni (Barrande) Elles & Wood;
M. bohemicus (Barrande) Elles & Wood;
M. colonus (Barrande) Elles & Wood;
M. dubius (Suess) Elles & Wood.

Group II. Thecae tubular with ventral edges and concave, convex, oblique or sigmoid curvature of apertural margins.

M. scanicus Tullberg;
M. uncinatus cf. var. *micropoma* (Jaekel) Elles & Wood;
M. changi Hong sp. nov.

Monograptus nilssoni (Barrande) Elles & Wood.

(Pl. I, Figs. 1a—f)

Polypary slender and long, 5 cm or more in length, widening from 0.4 mm to a maximum breadth of 0.8 mm. Thecae 8—10 in 10 mm overlapping $\frac{1}{3}$ of their extent. The ventral edge of thecae curved, but apertural margins even. Sicula small with conspicuous virgula.

Description: The polypary is small and very slender, the proximal portion being marked by a ventral curvature, but it may show the double curvature like that seen in *Monograptus scanicus*. The straight distal portion and concave middle portion of the polypary are highly characteristic with a width of 0.4 mm at the proximal protion and a maximum breadth of 0.8 mm at the distal end.

The sicula is small, measuring 1 mm or more in length, and the first thecae arises near its apex, and it has a conspicuous virgella 0.5 mm in extent.

There are 8—10 thecae in 10 mm. Simple tubes show slight tendency to sigmoid curvation about 2 mm, four to five times as long as wide, and with an inclination of 20—30°. The apertural margins are even and normal but those of the concave portion appear to be somewhat oblique to the general direction of the polypary.

Horizon and Locality: Upper silurian Shamao series (Ludlowan), Wu-Lung-Kuan, Lojo-Ping, I-Chang, Hupei.

Monograptus bohemicus (Barrande) Elles & Wood.

(Pl. I, Fig. 2a—d)

Polypary several cm in length, with incurved proximal portion, straight distal portion and with a maximum breadth of 1.5 mm. Thecae 10 in 10 mm overlapping $\frac{1}{2}-\frac{1}{3}$ of their length with an average inclination of 25—30°. Virgula conspicuous. Apertural margins convex.

Description: The robust and broad sweeping form of the polypary is very characteristic of this species. The thecae are short and broad; the tubes are simple, with a maximum length of 2 mm, two to three times as long as wide, with average inclination of 30°. Apertural margins are wide, convex, oblique, occupying about $\frac{1}{3}$ of total breadth of the polypary.

Horizon and Locality: Same as the preceding.

Monograptus colonus (Barrande) Elles & Wood.

(Pl. II, Fig. 2a—f)

Polypary 9 cm or more in length, widening gradually to a maximum breadth of 1.5 mm. Thecae 10—12 in 10 mm and overlapping 2/3 of their length Aperture concave or even. Virgula stout and conspicuous.

Description: The polypary is robust and straight with slight ventral curvature near the proximal end, widening gradually till the maximum breadth of 2 mm is attained. The thecae margins are nearly parallel. There are 10—12 thecae in 10 mm overlapping 2/3 of their length, with an average inclination of 30—45°. The early four proximal thecae are short and relatively broader with the goose-like curvature and retroverted apertural extremities. The adult thecae are uniform in breadth, with straight walls and concave or even apertural margins, gradually increasing in length until it reaches fully four or five times of the breadth.

Affinities: In general form, *M. colonus*, approaches to *M. tumescens*, *M. variaus* and *M. vulgaris*, but the proximal thecae and the general character of the proximal end of this spacies serve to distinguish it.

The polypary is very long and wide and the thecae of the distal portion is with more everlapping (2/3 of their length) than that in *M. variaus*.

The polypary of this species is straight, but its proximal end is curved at the ventral side. The shorter and wider thecae of the proximal end distinguish it from *M. tumesceus*, *M. carians* and *M. dubius*.

Horizon and Locality: Same as the preceding.

Monograptus dubius (Suess) Elles & Wood.

(Pl. II, Fig. 1a—d)

Polypary very long, 9 cm or more in length, widening gradually untill a maximum breadth of 2 mm is attained. Thecae 10—12 in 10 mm, overlapping $\frac{1}{2}-\frac{1}{3}$ of their length, average inclination 30°. Apertural margins even, virgula on spicuous and robust.

Description: The polypary is very long and robust, 9 cm or more in length, straight distally, parallel-sided with the slight ventral curvature in the proximal portion and with a maximum breadth of about 2 mm. There are 10 thecae in 10 mm of the proximal portion, while those of the distal portion increase to 12 in 10 mm. The thecae is 2.5 mm in length, but the average length of the adult thecae is 3 mm, overlapping $\frac{1}{2}$ in proximal portion, but $\frac{1}{3}$ in the distal portion, the slight ventral curvature of the proximal portion is characteristic of this species.

The apertural margins are even, but often deformed after compression.

Affinities: In the general character *M. dubius* somewhat resembles *M. vulgaris*, *M. tumescens*, *M. bohemicus*, and *M. colonus*, but it is readily distinguished from the other three species in the ventral curvature of the proximal portion, and the character of thecae—long and wide, three or four times as

long as wide. From *M. colonus* it is distinquished by the shorter and broader thecae (often been confused with *M. colonus*). From both these species it may be readily separated by the characters of the thecae in proximal portion—the thecae of *M. dubius* is not retorversed, but that of *M. colonus* is retorversed.

Horizon and Locality: Same as the preceding.

Monograptus scanicus Tullberg

(Pl. III, Fig. 1a—b)

Polypary very slender and flexuous, 5 cm or more in length, widen in from 0.3 mm to 0.6 mm, 10 thecae in 10 mm, overlapping $\frac{1}{3}$ of their length. Virgula conspicuous. Apertural margins inclined and undulated.

Description: The polypary is considerably long, strongly flexuous, with conspicuous ventral curvature in the proximal portion, but with a slight curvature in the more distal end. The thecae are curved downward and hook-like.

Affinities:

(1) It is distinguished by thecae overlapping $\frac{1}{3}$ of their length.

(2) The very flexuous polypary, the conspicuous ventral curvature in the proximal portion serve to distinguish it from *M. irfonensis*, but the straight form of the distal portion of the polypary of this species resembles that of *M. uncinatus*.

Horizon and Locality: Same as the preceding.

Monograptus uncinatus cf. var. *micropoma* Elles & Wood

(Pl. III, Fig. 2a—j)

Polypary straight and long, 16 cm or more in length, widening gradually to a maximum breadth of 2 mm. Thecae 9 in 10 mm overlapping $\frac{1}{2}$ their length. Virgula conspicuous and robust. Apertural margins undulated.

Description: Polypary is very straight and long, and its breadth is commonly uniform for the greater part of the length of the polypary and with parallel margins. The thecae of this species are usually situated on the concave side and generally resemble *M. scanicus* and *M. uncinatus*. In scalariform view the average inclination is 20—30°. The adult thecae are usually marked by ventral curvature with a length of about 2 mm and hook-like.

Affinities: In general outline our form resembles that of *M. uncinatus* var. *micropoma*, but differs from the latter in the size of the polypary.

Horizon and Locality: Same as the preceding.

Monograptus changi Hong sp. nov.

(Pl. III, Fig. 3)

Polypary very small and slender, 3 cm in length, widening to 0.4 mm. Thecae 6 in 5 mm, and overlapping $\frac{1}{3}$ their length. Virgula and nema conspicuous. Apertural margins even or retroversed. Average inclination 20°.

Description: The polypary is very slender and small, with slight ventral

curvature in the proximal portion. The sicula measures 1.2 mm and extents to the end of the Th_3. There are only four thecae in our speciemen. Two different forms of the thecae are observed: (1) Th_{1-3} straight and extending upward 1 mm in length, widening 0.2 mm. It is represented by a simple tube. Apertural margins even and broad, occupying about $\frac{1}{2}$ or more the width of the polypary. (2) Th_4 1 mm in length, widening 0.4 mm. The overlapping portion of the thecae seems to be curved and very narrow, but the free portion of the thecae is wider and hook-like. Nema conspicuous, 1.2 mm in length.

Horizon and Locality: Same as the preceding.

Specific characters of graptolites belonging to the zone of *M. nilssoni* of Upper Silurian (Ludlow) of the Yangtze Gorges District

	Character of polypary	Width (mm)	Length of sicula (mm)	Length of vigella (mm)	Character of thecae						Length of thecae (mm)
					No in 10 (mm)	Over-lap	Aperture margins	Proportion length to wide	Average inclination	Form of thecae	
M. nilssoni	Curvature of the proximal portion straight.	0.4-0.8	1.	0.5	8-10	1/3	even	4 : 1	25-30	simple tubes	2
M. bohemicus	Straight, robust or broad, rounded proximally.	1.5+			10	1/2 - 1/3	wide, and slightly concave	2-3 : 3	30	simple tubes	2
M. dubius	Straight, with proximal ventral curvature.	1-2			10-12	1/2 - 1/3	even or slight oblique	3 : 1	30	simple tubes	3
M. colonus	Straight, with slightly ventral proximal curvature.	1-1.5			10-12	2/3	Concave and undulate with *flered spicies*	4-5 : 1	30-45	simple tubes	1.6
M. scanicus	Very slender and flexuous, with conspicuous proximal ventral curvature.	0.36-0.6			10	1/3	Oblique and excavate	2 : 1	10	hook-like	1-
M. uncinatus cf. var. *micropoma*	Straight and very long.	1.5-2			9	1/2	everted or excavate	2 : 1	20-30	hook-like	2
M. changi	Small and slender, with slight dorsal curvature.	0.4	1.2	0.5-0.7	11-12	1/3	even and slightly everted	2 : 1	20	simple tubes and hook-like	1