

Late Viséan to Early Serpukhovian Rugose Corals from the Yashui Section, Guizhou, South China

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ABSTRACT. Abundant rugose corals are recorded in the Yashui Section in Huishui County of Central Guizhou, South China. The section is mainly composed of light-coloured bioclastic limestone with intercalations of some beds of dolomitized limestone and punctuated by a certain number of unconformities. Totally 20 species belonging to 13 genera are recognized. The composition of the fauna shows resemblance to the Western European faunas of latest Viséan to early Serpukhovian age. Many well-known European taxa such as *Dibunophyllum bipartitum*, *Palaeosmilia murchisoni*, *Lithostrotion decipiens*, *Siphonodendron pauciradiale* and *Aulina rotiformis* appear in Yashui, but with different stratigraphic ranges. There are also some endemic taxa such as *Arachnolasma sinense*, *Yuanophyllum kansuense*, *Kueichouphyllum sinense* and *Stylostrotion petalaxoidae* which can be used for correlations throughout South China. The coral diversity of the Yashui section shows: (1) a diversity decrease in the uppermost part of the Viséan, and (2) a poorly renewed fauna in the Serpukhovian, which is the similar pattern recorded in Palaeotethys. Therefore, a coral based biostratigraphic succession to separate the early Serpukhovian from latest Viséan is difficult to establish. Among the 20 species, 18 are described and illustrated, including 2 in open nomenclature. Two species are omitted from the description due to their bad preservation.

KEY WORDS: Rugose corals, Biostratigraphy, Mississippian, Viséan-Serpukhovian boundary.

1. Introduction

Mississippian rugose corals are relatively diversified and have received much attention in the past decades. Generalized distributional patterns and biostratigraphic successions of the Mississippian rugose corals have been developed and summarized (e.g. Sando, 1990; Sando & Bamber, 1985; Fedorowski, 1981; Mitchell, 1989; Poty et al., 2006; Somerville, 2008). In general, limited information on the temporal and spatial distribution of rugose corals is available for the Serpukhovian. This is probably due to the decrease in coral occurrences caused by sudden change of sedimentary facies from carbonate to siliciclastic

near the Viséan/Serpukhovian boundary (Poty et al., 2006) or/and frequent appearances of subaerial exposure surfaces in shallowing-upwards cycles (Smith & Read, 2000; Al-Tawil et al., 2003). These lithofacies changes are probably linked to global scale glacial and tectonic events. As a result, the rugose corals are often rare in Serpukhovian strata, and furthermore, it is relatively difficult to recognize the Viséan/Serpukhovian boundary by rugose corals.

During the Mississippian, South China had a tropical archipelago layout (Scotese et al., 1979; Scotese & McKerrow, 1990; Torsvik & Van der Voo, 2002). The Mississippian in

Yu(1931)		Wu (1964)			Lo (1984)			Xu and Poty (1997)		Poty et al. (2006)	
Visean	Y.	Visean	Y.	<i>Lophophyllum lophophylloides</i>	Visean	Nam.		Visean	Yuanophyllum	Serp.	Yuanophyllum
						<i>Aulina carinata</i>					
						<i>Heterocaninia tholustabulata</i>					
	T.			<i>Thysanophyllum.-Kueichouphyllum sinense</i>			<i>Thysanophyllum asiaticum</i>		<i>Thysanophyllum (Dorlodotia)</i>		<i>Dorlodotia</i>
								Interval zone			Interval zone
Tournaisian	P.	Tournaisian		P.			<i>Pseudouralinia gigantea</i>	Tournaisian	<i>Keyserlingophyllum</i>	Tournaisian	<i>Keyserlingophyllum</i>
						<i>Uralinia tangpakouensis</i>			<i>Uralinia tangpakouensis</i>		
						C-U interval zone			C-U interval zone		
	C.			C.			<i>Cystophrentis kolaohoensis</i>	Famenian		Famenian	C.
							<i>Caninia dorlodoti</i>				<i>Eocartinophyllum yizhangensis</i>
							<i>Ceriphyllum elegantum</i>				

Table 1. Mississippian coral zonations in China. C.: *Cystophrentis*; P.: *Pseudouralinia*; T.: *Thysanophyllum*; Y.: *Yuanophyllum*; U.: *Uralinia*; Nam.: Namurian; Serp.: Serpukhovian.

most parts of South China consists of shallow-water carbonates intercalated with some terrigenous clastics. Abundant rugose corals occur in the Mississippian, especially in Tournaisian and Viséan strata, which have been intensively studied, starting with the early taxonomic work of Yabe & Hayasaka (1915, 1920) and Grabau (1922, 1928). Yu (1931, 1933, 1937) proposed the first biostratigraphic zonation of rugose corals of the Fengningian System (= Lower Carboniferous) on the basis of collections from southern Guizhou, central Hunan and western Gansu (with additional data by Chi, 1931, 1935). Within the Fengningian System, he established four rugose coral zones in ascending order which are *Cystophrentis* zone, *Pseudouralinia* zone, *Thysanophyllum* zone and *Yuanophyllum* zone. This biostratigraphic zonation has been applied in other parts of South China (Wu, 1964; Luo, 1984; Xu & Poty, 1997; Poty et al., 2006) with some modifications (Table 1). However, despite the relative frequent occurrences of rugose corals during the Mississippian, the resolution of the zonation is still rather low, e.g. the *Yuanophyllum* zone covers a very long range from the middle Viséan to the Serpukhovian.

The main aim of this paper is to describe and illustrate the coral fauna from the Yashui Section in Huishui County of Central Guizhou, which displays a continuous succession from the Upper Viséan through the entire Serpukhovian in shallow water facies.

2. Geological setting and materials

In the Carboniferous, a large carbonate platform developed on the Yangtze Block (South China), with the Upper Yangtze Old

Land to the northwest and the Cathaysia Old Land to the east, together with numerous small intra-continental basins in the western part. The northern part of the Guizhou province belongs to the southern Upper Yangtze Old Land. The Carboniferous sediments in central and southern Guizhou can be subdivided into three distinctive lithostratigraphic regions representing carbonate platform to slope-basin: the Dushan-Weining region, the Puan-Mawei region, and the Langdai-Luodian region.

The Yashui section is located in the south-eastern part of the Huishui County, about 90 km south of the city of Guiyang (Fig. 1). It is mainly composed of light-coloured bioclastic limestone with intercalations of some beds of dolomitized limestone, which is typical for the Dushan-Weining lithostratigraphic region. A certain number of unconformities associated with palaeokarst features and terrigenous clastic deposits that should be considered as palaeosol punctuate the section. Most of the limestone beds of the section are rich in fossils such as corals, brachiopods, chaetetid sponges, foraminifers and calcareous algae.

The Yashui section was first presented during the 11th International Congress on the Carboniferous stratigraphy and geology in 1987. It was selected as the stratotype of the local Chinese stage Dewuan (Wu, 2003). Although the section is a typical representative of the shallow water carbonate facies, it has not been studied in detail in terms of sedimentological and paleontological aspects. Wu (2003) and Wu et al. (2009) published some data of foraminifers from Viséan/Serpukhovian boundary interval, but only few specimens were illustrated. A more recent study on foraminifers in the Yashui section by Groves et al. (in press) uses the first appearance datum (FAD) of *Janischewskina delicata* to suggest a provisional Viséan/Serpukhovian boundary at 41.6m from the base of the section. Other fossil groups have not been studied yet from the section.

The Yashui section was measured in 2008 and permanent markers (metal pins) have been installed throughout the whole section meter by meter. Rugose corals were sampled for the first time in 2008 and were additionally sampled in 2010 and 2011. All specimens were numbered by the true thickness from the base of the section. The material presented in this study is from the collections of the first sampling, which includes nearly 300 thin sections made from 68 specimens.

3. Composition of rugose coral fauna and discussion

20 rugose species belonging to 13 genera of the families Aulophyllidae, Lithostrotionidae, Palaeosmilidae and Axophyllidae were identified. Seven genera are solitary and six are colonial. In the latter group, three genera are massive and three are fasciculate. The rugose coral association is composed of several endemic taxa and more abundant taxa known in the Palaeotethys. The common abrasion of the dissepimentarium of solitary corals and the fragmentation of the compound corals indicates a shallow water environment with relatively high energy.

Most of the rugose samples were collected from the lower part of the Yashui section (0–25 m). Locally, corals are concentrated at the bottom or top of limestone beds. The rugose coral association in the lower part of the section is dominated by large dissepimented solitary corals such as *Palaeosmilina purchisoni*, *Kueichouphyllum sinense*, *Axophyllum* cf. *lonsdaleiforme*, *Arachnolasma sinense*, *Dibunophyllum bipartitum* and “*Dibunophyllum*” *tingi*, accompanied by some colony fragments of *Siphonodendron pauciradiale*, *Diphyphyllum fasciculatum* and *Palastraea* sp. (Fig. 2). *Aulina rotiformis* is not present in the first sampling from the lower part, but it was found 6 m below the base of the measured section based on the preliminary observation of the later samplings. The occurrence of *Palastraea*, *Dibunophyllum bipartitum*, *Siphonodendron pauciradiale* and *Aulina rotiformis* indicate a late Viséan and early Serpukhovian age. Similar association can be found in zone RC8 (Belgium, France) and RC9 (South France, Poty et al., 2006), faunal divisions H–K in Britain (Mitchell, 1989) and the upper Viséan in North Africa (Aretz, 2010, 2011).

In the middle part of the Yashui section (25–35 m), the abundance of colonial corals increases rapidly with a dominant

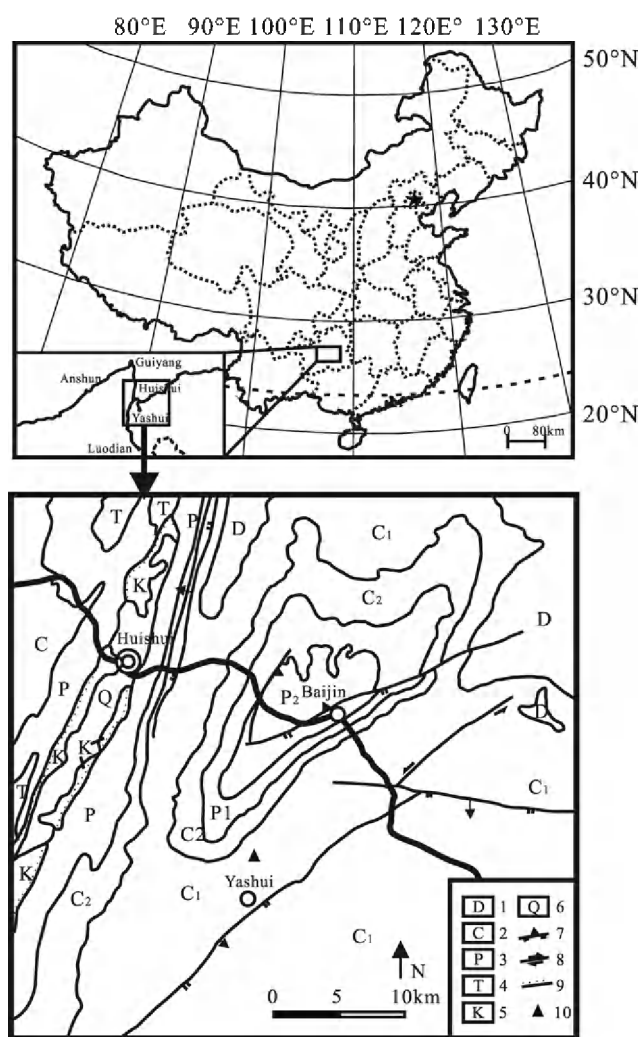


Figure 1. Location and geological map of the Yashui section. Legend: 1. Devonian; 2. Carboniferous; 3. Permian; 4. Triassic; 5. Cretaceous; 6. Quaternary; 7. Dip fault; 8. Strike slip fault; 9. Unconformity; 10. Location of the section (GPS 26°00'47.6"N, 106°45'28"E).

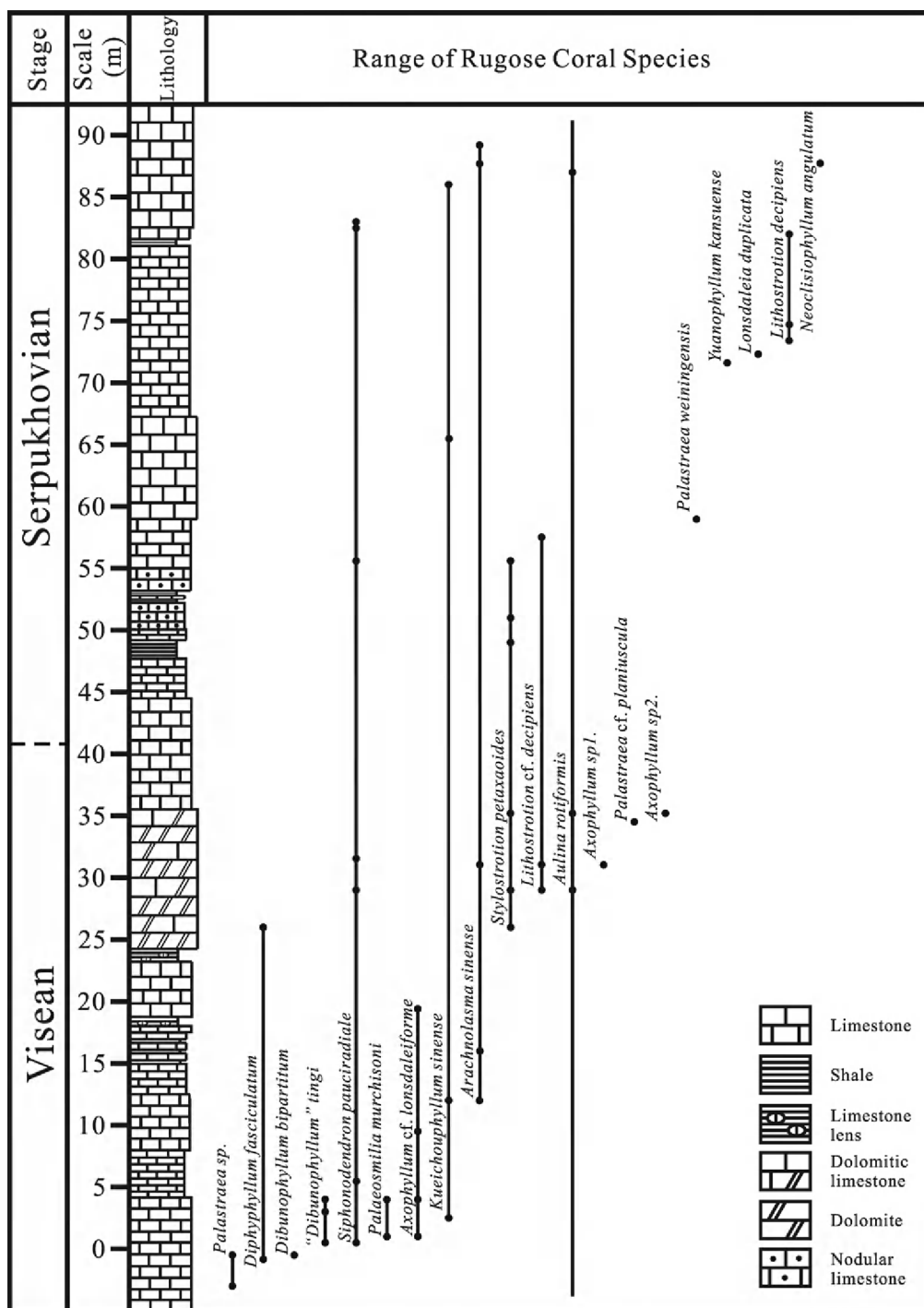


Figure 2. Vertical range of rugose corals from the Yashui section.

occurrence of *Stylostroton petaxaoides* and *Siphonodendron pauciradiale* in several coral beds. They are often preserved as broken branches. Other associated rugose corals are some small colonies of *Lithostroton cf. decipiens*, *Aulina rotiformis*, and *Palaeosmilium cf. planiuscula*, together with some badly preserved *Axophyllum* and *Arachnolasma sinense*. It is important to note that *Aulina rotiformis* is known from the lower Namurian in Britain (Hill, 1940; Smith & Yu, 1943), but already in the uppermost Viséan of South China (Poty et al., 2011) and in the Yashui section.

Coral abundance decreases slightly in the upper part of the Yashui section (above 35 m). *Palaeosmilium weiningensis*, *Yuanophyllum kansuense*, *Lonsdaleia duplicata*, *Lithostroton decipiens* and *Neocleisiphyllum angulatum* are for the first time recorded in the section (Fig. 2). *Siphonodendron pauciradiale*, *Kueichouphyllum sinense* and *Arachnolasma sinense* have already been found in the underlying beds. *Lonsdaleia duplicata* occurs fairly late in the Yashui section compared to Western Europe (Poty et al., 2011). In Belgium (Poty et al., 2006) and Britain (Mitchell, 1989), it is the index fossil for the latest Viséan. The

genus *Yuanophyllum*, represented by *Yuanophyllum kansuense*, also occurs very late in the Yashui section. Elsewhere in South China it is known from the middle Viséan onward (e.g. Wu, 1964; Wu & Zhao, 1989; Yan 1982). In most parts of Western Europe the Viséan-Serpukhovian boundary is usually marked by a prominent change in the sedimentation style (from carbonate dominated to siliciclastic dominated) resulting in the total disappearance of rugose corals in the lower Serpukhovian. In places where carbonate deposition persisted, a decrease in rugose coral diversity can be seen around the Viséan-Serpukhovian boundary. Earliest Serpukhovian coral associations comprise mainly taxa from late Viséan and only some new taxa, which established the rugose coral Zone 9 of Poty et al. (2006). On the East European Platform and in the Urals, Hecker (2001) defined a Serpukhovian coral assemblage characterized by the appearance of *Turbinatocania*, *Actinocyathus borealis* and *Paralithostroton*. The Yashui section shows similar patterns for the coral diversity around the Viséan/Serpukhovian boundary to the western Palaeotethys: (1) a diversity decrease in the uppermost part of the Viséan, and (2) a poorly renewed fauna in the Serpukhovian.

Aulina rotiformis, though not present in the first collections concerned in this paper, is found as high as 120 m above the base of the Yashui section based on the preliminary observation of later samplings. Since its range covers the whole Yashui section which represents the time interval from uppermost Viséan to early Serpukhovian, it is not as usefully marking the Viséan/Serpukhovian boundary in South China as in Britain. In fact, the exact FAD of *A. rotiformis* in Europe is not well known (see Hill, 1940). In Central Hunan, South China, *Aulina rotiformis* was also found together with many other Viséan rugose corals (Wu, 1964). Thus the FAD of *A. rotiformis* in South China is confirmed as the uppermost Viséan.

4. Systematic description

Nearly all the samples collected from the Yashui section are embedded in limestone blocks and lack well-preserved external structures. Therefore, the external characters will not be described in this paper. Among 20 recognized species, 18 are described and illustrated. The other two species are too badly preserved and are not described here. Specimens are housed in the palaeontological collection of the Nanjing Institute of Geology and Palaeontology (China Academy of Science), under numbers YSR-.

Suborder Aulophyllina Hill, 1981

Family Aulophyllidae Dybowski, 1873

Subfamily Clisiophyllinae Nicholson, 1889

Genus *Neoclisiophyllum* Wu, 1963

Neoclisiophyllum angulatum Wu & Zhao, 1989

(Pl. 1, Figs A-B)

Material. One specimen: YSR-87.7-1-1. One transverse section (ts) and one longitudinal section (ls).

Description. Solitary coral. In transverse section, corallum oval in shape, with a longer axis of 24 mm. 45 septa in two orders. Major septa thin in the dissepimentarium and thickened in the tabularium. The axial ends of some major septa bend to one side and connect to the axial column margin. Minor septa about 1/3 length of major septa. Axial structure occupies 1/3 of the coralla diameter, consisting of a straight median plate with 3.5 mm in length, 37 septal lamellae and numerous concentrically arranged axial tabellae. Dissepiments concentric or herringbone, with the innermost series dilated. Cardinal septum short. Cardinal fossula distinct and narrow.

The longitudinal section does not strictly pass the axial centre. Axial tabellae steeply ascend to the axis. Periaxial tabellae slightly convex, gently descend to the tabularium. Usually there are 6 tabellae per 5 mm. Dissepimentarium partly preserved. Dissepiments convex, deeply incline towards the centre and various in size.

Subfamily Dibunophyllinae Wang, 1950

Genus *Dibunophyllum* Thomson & Nicholson, 1876

Dibunophyllum bipartitum (McCoy), 1849

(Pl. 1, Figs C-D)

Material. One specimen: YSR-(0.5)-1-1; (3 ts, 1 ls).

Description. Large solitary coral. In transverse section, corallum nearly circular, with a diameter of 28 mm. 48 septa of each orders. Major septa thick and thinning at axial ends. Minor septa thin and short, sometimes discontinuous. Axial structure occupies about 1/3 of the coralla diameter. Median plate thin, slightly thickened in the middle. Septal lamellae semi-radially arranged 9, in number, mostly intercept by the axial tabellae and not connected with the median plate. Tabularium wide, about 1/2 of corallite diameter. Dissepiments herringbone.

In longitudinal section, the boundary of the axial column is distinct from the periaxial tabellae. In inner tabularium, the large vesicular tabellae steeply ascend to the median plate. In periaxial area, the tabellae incline gently to the margin,

sometimes becoming concave near the dissepimentarium. There are 8 tabellae per 5 mm. Vesicular dissepiments various in size, counting 7-9 rows.

Discussion. *Dibunophyllum bipartitum* has a very wide intraspecific variation (Hill, 1938-1941; Poty, 1981). This species has been reported from other locations of China, some of them may not strictly in accordance with the diagnosis of *Dibunophyllum*, or their assigning is not very convincing due to poor photographing and simple description.

"Dibunophyllum" tingi (Yu, 1933)

(Pl. 1, Figs E-G)

Material. Four specimens: YSR-0.5-1-1, YSR-3, YSR-4-1-1 and YSR-4-2-1; (11 ts, 6 ls).

Description. Large solitary coral. 44 and 48 septa in two orders, at diameter of 20 mm and 28 mm. Major septa thickened in the middle, bending to one side at axial ends. Minor septa never extend beyond the tabularium. Both series of septa become flexuous near the wall. The spider-web-like axial column occupies about 1/3 of corallite diameter. Median plate dilated in the middle, straight or slightly curved, with short "spines" at both sides. Septal lamellae 6-8 in each side of median plate, some discontinuous and become series of spines on the axial tabellae. Dissepimentarium broad, about 1/2 of corallite diameter. Dissepiments concentrically arranged or herringbone when minor septa are short.

In longitudinal section, axial tabellae ascend towards the columella. Periaxial tabellae horizontal or slightly concave, sometimes incomplete and large vesicle shaped, numbering 6-8 per 5 mm. Dissepiments vesicular shape, large, elongated and incline steeply at axial side and small, globose at adaxial side.

Discussion. The appearance of "spines" at each side of median plate is the diagnostic character of this species. The specimens from Yashui differ from Yu's specimens in having much thicker median plates. Though originally assigned to *Dibunophyllum*, this group of rugosa might be a whole new genus. They differ from the typical *Dibunophyllum* in that the latter usually has a long, thin median plate and rudimentary or none minor septa.

Distribution: Uppermost Viséan. At 0.5 m, 3 m and 4 m of the Yashui section.

Genus *Arachnolasma* Grabau, 1922

Arachnolasma sinense (Yabe & Hayasaka, 1920)

(Pl. 1, Figs H-I)

Material. Five specimens: YSR-12-1-1, YSR-16-1-1, YSR-31.2, YSR-87.7-2 and YSR-89.2; (12 ts, 5 ls).

Description. Solitary coral. In transverse section, coralla circular, with diameter of 14-17 mm. 34-26 septa in two orders. Major septa thickened in the middle, attenuating at both ends, slightly flexuous. Minor septa short, about 1/4-1/3 length of major septa. Axial structure occupies 1/5 of the diameter of corallite, consisting of a lens shaped median plate, irregularly arranged septal lamellae and axial tabellae. Dissepiments angulo-concentrically arranged, with the innermost series thickened.

In the longitudinal section, the incomplete, vesicular tabellae ascend to the thick median plate, numbering 7 per 5 mm. Dissepiments 3-6 rows, various in size, inclining steeply towards the tabularium. The innermost series thickened and nearly vertical.

Discussion. The specimens from Yashui are smaller in size and less in septa number than the holotype (Yabe & Hayasaka, 1920; Grabau, 1922), and specimens from Guizhou (Yu, 1933), Poland (Fedorowski, 1971) or Spain (Rodríguez et al., 2001).

Genus *Yuanophyllum* Yu, 1931

Yuanophyllum kansuense Yu, 1931

(Pl. 1, Figs J-K)

Material. Three specimens: YSR-71.6-1-1, YSR-71.6-1-2 and YSR-71.6-1-3; (8 ts, 5 ls).

Description. Solitary coral. Wall of the coralla are missing in many transverse sections due to abrasion. The diameter of the preserved part is not less than 30 mm in mature stage. 46-52 septa in two orders. Major septa thin in the dissepimentarium, thickened in tabularium and attenuate adaxially. Minor septa are fairly short, about 1/5 length of major septa. Median plate thickened in younger stage and thin in mature stage, sometimes connect with the counter septum. Cardinal septum shortened and an open cardinal fossula can be observed. Dissepimentarium broad, with width of 1/2 length of major septa. Dissepiments mostly herringbone or angulo-concentric. Thick layer of stereoplasm coat the innermost series, more obvious in counter quadrant.

In longitudinal section, tabulae incomplete, ascend (more steeply and densely arranged in the axial area) towards the flexuous, sometimes discontinuous columella, numbering 7-10 per 5 mm in the axial part and 4-7 per 5 mm in periaxial part. Dissepiments large, elongated, vesicle shape and incline steeply adaxially. The innermost row nearly perpendicular.

Discussion. The specimens from Yashui are more complex in axial structure compared with the holotype (Yu 1931, 1933). Yu (1937) observed that the axial structure of this species differs considerably in transverse section in different individuals due to irregular arrangement of elongated major septa and tabellae in axial area. Thus the Yashui specimens can be assigned to *Y. kansuense*. Sometimes, the transverse section of this species may resemble *Arachnolasma*, but the latter has a much thicker or oval shaped columella which normally is not connected with the counter septum in mature stage.

Subfamily Heterocariniinae Hill 1981

Genus *Kueichouphyllum* Yu, 1931

***Kueichouphyllum sinense* Yu, 1931**
(Pl. 1, Figs L-M)

Material. Four specimens: YSR-2.4, YSR-12-1-2, YSR-65.5 and YSR-86.2; (10 ts, 5 ls).

Description. Large solitary coral. Wall was missing in all thin sections due to abrasion. 137 septa in two orders in a relatively well preserved specimen with a corallite diameter of 48 mm. Major septa long, thin in dissepimentarium, thickened in the tabularium of cardinal quadrant. Some major septa reach the centre and are flexuous at their axial ends. Minor septa about the 1/3 length of major septa, not extend into the tabularium. Dissepimentarium occupies about 1/5 of diameter of the corallite. Dissepiments dense, concentrically arranged. Cardinal fossula closed, not very prominent.

In longitudinal section, tabular incomplete, large vesicle shaped and slightly ascend to the centre. Dissepiments mostly uniform, incline more steeply inward, numbering 13-15 rows. The innermost series nearly upright.

Discussion. This species strongly resembles *Heterocarinia tholusitabulata* Yabe & Hayasaka, 1920 except the latter has much shorter minor septa. This species also differs from another species of same genus, *K. heishikuanense*, in having (1) a broader dissepimentarium, (2) thickened major septa in cardinal quadrant.

Family Palaeosmiliidae Hill, 1940

Genus *Palaeosmilia* Milne-Edwards & Haime, 1848

***Palaeosmilia murchisoni* Milne-Edwards & Haime, 1848**
(Pl. 1, Figs N-O)

Material. Two specimens: YSR-1-1-2 and YSR-4; (4 ts, 3 ls).

Description. Solitary coral. In transverse section, coralla circular. 71-74 septa in two orders and a diameter of 30-33 mm. Major septa long, straight or slightly sinuous, reach the centre and

curved at the axial end. Minor septa about 1/2 length of major septa, extend beyond the dissepimentarium. Dissepiments mostly concentrically arranged. Cardinal fossula narrow, prominent in one specimen (YSR-1-1-2) but not in another one.

In longitudinal section, tabularium occupies 2/5 of the corallites diameter. Tabulae incomplete, depressed in the axis and upturned at edges. The boundary between tabularium and dissepimentarium not very distinct. Dissepiments globose or elongated, incline more steeply towards the axis, 15-16 rows.

Genus *Palastraea* McCoy, 1851

***Palastraea cf. planiuscula* Wu & Zhao, 1989**
(Pl. 1, Figs P-Q)

cf. 1989 *Palastraea planiuscula*, Wu & Zhao: p. 103, pl. XXI, figs. 4a-b, 6a-b.

Material. One colony fragment: YSR-34.5; (2 ts, 2 ls)

Description. Cerioid to aphroid coral. In transverse section, the largest corallite has a diameter of 18 mm. Adjacent corallites are bounded by multilayered, wave shaped wall or without distinct boundary. 29 septa in two orders at diameter of 15 mm. Major septa thin, do not reach the centre, open central space of 1.5-2 mm in diameter. Minor septa about 1/2-3/5 length of the major septa. Both orders of septa not reach the outer wall and intercepted by transeptal dissepiments. Dissepiments concentrically arranged. Cardinal fossula not distinct.

In longitudinal section, tabularium occupies 1/3 of the corallite diameter. Tabulae domed, flat in axial part (about 15 per 5 mm) and vesicular, adaxially inclined at each side. Dissepiments globose, steeply inclined at the inner series, and elongated, arched upward at the outer series. The outmost series may ascend steeply outwards where corallites are bounded by wall.

Discussion. The specimens from Yashui are similar to the holotype of *P. planiuscula*, but differ in having a narrower dissepimentarium and broader axial tabellae.

***Palastraea weiningensis* Wu & Zhao, 1989**
(Pl. 2, Figs A-B)

Material. Two colony fragments: YSR-58-59-1-1 and YSR-58-59-1-2; (6 ts, 7 ls).

Description. Cerioid coral. Corallites diagonal length 12-15 mm. Outer wall are mostly complete. 27-29 septa in two orders. Major septa thin and straight in the tabularium, not reach the centre. Minor septa about 1/2 length of the major septa. Both orders may connect to the wall or intercepted by transeptal dissepiments. They may become flexuous in the dissepimentarium. Dissepiments mostly concentrically arranged.

In longitudinal sections, tabularium occupies 1/2 of the corallite diameter. Tabulae incomplete, flat or slightly depressed at the axis and vesicular, adaxially inclined at each side, with edges upturned, numbering 14 per 5 mm at the axial part. Dissepiments 4-7 row, vesicle shaped and not very uniform in size.

Discussion. Yashui specimens are identical to the holotype of *P. weiningensis* except some small variations: (1) slightly smaller in corallite size and fewer in septal number; (2) more densely arranged axial tabellae. This species differs from *P. planiuscula* in having a more complete wall, wider tabularium and without upwardly arched dissepiments.

***Palastraea* sp.**
(Pl. 2, Figs C-D)

Material. Three colony fragments: YSR-(3), YSR-(0.5)-2-1, YSR-(0.5)-2-2 and YSR-(0.5)-2-3; (6 ts, 4 ls).

Description. Astreoid coral. Wall between corallites usually badly preserved and broken. Corallite diameter 20-30 mm. 33-38 septa in two orders. Major septa long, reach the axis and sometimes meet each other. Minor septa about 2/3 length of major septa. Both orders of septa may thicken slightly at the inner dissepimentarium

and the thickening is more conspicuous in the cardinal quadrant. Dissepiments concentrically arranged in the inner tabularium. Lateral dissepiments usually occur at the outer tabularium.

In longitudinal sections, tabularium narrow, occupies 1/4 of the corallite diameter. The axial tabellae densely arranged, 12-14 per 5 mm. they are flattened in the centre and abruptly turned 90 degree at both ends and rest on the tabellae below. The periaxial tabellae are horizontal or gently inclined outwards, and each may or may not develop an up-turned ends. Dissepiments mostly globose, steeply inclined at the inner part and arched upwards near the margin.

Discussion. The specimens from Yashui resemble *Palastraea regia* (Phillips) in transverse section, but differ from the later in having abruptly turned edges in axial tabellae. This character also distinguishes the Yashui specimens from other species of the same genus, and erection of a new species may be applicable. However, the snapped axial end of major septa and broken corallites boundaries indicate bad preservation of the material, so this species is placed in open nomenclature.

Suborder Lithostrotionina Spasskiy & Kachanov, 1971

Family Lithostrotionidae d'Orbigny, 1852

Subfamily Lithostrotioninae d'Orbigny, 1852

Genus *Lithostrotion* Fleming, 1828

Lithostrotion cf. *decipiens* (McCoy), 1849

(Pl. 2, Figs E-F)

Material. Three colony fragments: YSR-28~29-2-2, YSR-31.2-1-2 and YSR-57.7; (5 ts, 7 ls)

Description. Cerioid coral, lateral offsetting. Corallites polygonal, usually 5-6 sided. The length of the longest diagonal vary from 7 mm to 10 mm in mature stage. 16-19 septa in two orders. Major septa thin, slightly flexuous and sometimes dilated a little in tabularium and/or at the adaxial end. They usually connect to the lens shaped columella but, in less common cases, retreat from the centre. Minor septa about 1/2-2/3 length of major septa, sometimes discontinuous. In rare cases, lonsdaleoid septa occur. Tabularium 2.5 to 4 mm in diameter. Dissepimentarium about as wide as the length of minor septa. Dissepiments concentrically to angulo-concentrically arranged. Very few lateral dissepiments may occur.

In longitudinal sections, axial tabellae ascend to the thickened columella, with downward turned sides which rest on the lower axial tabellae or flat periaxial tabellae (numbered 7-8 per 5 mm). Occasionally, amplexoid septa may occur. Dissepiments vary in size, globose or elongated, numbering 2-4 rows.

Discussion. Although the specimens from Yashui are slightly larger in corallite size compared to most European specimens (Nudds, 1980; Poty 1981, 1993), they are at the limit of the range of variation of *L. decipiens*.

Lithostrotion decipiens (McCoy), 1849

(Pl. 2, Figs G-F)

Material. Four colony fragments: YSR-73.4, YSR-74.7-1-2, YSR-82-1-1 and YSR-82-1-2; (9 ts, 9 ls)

Description. Cerioid coral. Corallites polygonal, 4-7 sided. The length of the longest diagonal vary from 3-8 mm. 15-18 septa in two orders. Major septa connect to the lens shaped columella. Minor septa long, about 1/2-3/4 length of major septa. Both orders of septa may be thickened, reach the outer wall, and no lonsdaleoid form can be observed. Dissepiments concentrically arranged. Diameter of tabularium 2.5-3.2 mm.

In longitudinal section, tabularium occupies about 2/3 of the corallite diameter. Tabulae mostly complete, gently ascend to the columella, numbered 18 per 5 mm. Dissepiments mostly globose, numbering 2-3 rows.

Discussion. The specimens do not differ from specimens of *L. decipiens* in having small corallite size and are assigned to it.

Genus *Siphonodendron* McCoy, 1849

Siphonodendron pauciradiale (McCoy), 1844

(Pl. 2, Figs. I-K; Pl. 3, Figs A-B)

Material. Eight limestone blocks containing colony fragments: YSR-0.5-2-1, YSR-0.5-2-2, YSR-5.5-1-3, YSR-28~29-2-3, YSR-31.5, YSR-55.6-2-1, YSR-82.5 and YSR-83. (38 thin sections) (due to the fragmentation of the coral colonies, some thin sections include both transverse and longitudinal sections of the corallite. The number given here refers to the total amount of the thin sections made. It is the same in the following descriptions if the number of ts and ls are not given separately.)

Description. Fasciculate coral, lateral increase. In transverse section, corallite diameter 3-5 mm. 15-22 septa in two orders. Major septa thin, sometimes connected with the columella, but mostly intercepted by the downward turned edges of tabulae. Minor septa short, or just spine-shaped. Columella often thickened. Dissepiments concentrically arranged.

In longitudinal section, the conical tabula ascend to the columella and bend downward at both edges. Columella thick, straight and continuous. Dissepiments 1-2 rows, vesicular and the innermost series often thickened.

Discussion. The specimens from Yashui can be assigned to *S. pauciradiale* applying Poty's standard (1981, 1993). Though samples from 82.5 m and 83 m have lesser septa number, about 15-17 in average. And they also differ from the specimens from lower part of the section in that their major septa rarely extend into the pseudo-aulos formed by the tabulae.

Genus *Stylostrotion* Chi, 1935

Stylostrotion petalaxoidae (Yu), 1933

(Pl. 2, Figs L-N)

Material. Eleven limestone blocks containing colony fragments: YSR-26-1-1, YSR-28.45-1-2, YSR-28.45-2-1, YSR-28.2, YSR-28~29, YSR-28~29-1-1, YSR-28~29-1-2, YSR-35.2-2-1, YSR-49.1, YSR-50.9, YSR-55.6-1-1; (62 sections).

Description. Fasciculate coral, axial increase. Corallites diameter 5-10 mm. Major septa long, slightly thickened, numbering 20-24. Minor septa rudimentary or not present. Columella long, dilated, usually continuous with cardinal septum and counter septum. Dissepiments concentrically arranged or herringbone.

In longitudinal section, the conical tabulae ascend to the thickened columella, numbering 8 per 5 mm. They incline more steeply outward and upturned near the dissepimentarium. Dissepiments large, elongated, vesicle shape, 1-2 rows, the innermost series may be coated by stereoplasm.

Discussion. This genus was established by Chi (1935). According to the text figure and the photos of the genotype, many resemblances present between this genus and *Siphonodendron*, except that no minor septa are present in Chi's specimens. This character is also present in other specimens from China (Yu, 1933; Wu, 1964; Xu & Poty, 1997). However, the name *Stylostrotion* rarely appears in literatures and this group was always identified as *Siphonodendron*. Fedorowski (2004) questions the validity of this genus name because the definition of this genus does not have a good basis and lack convincing reinvestigation. He points out the Heterocorallia-like arrangement of septa in this genus and suggests using *Donophyllum* for corals with such septal patterns

if synonymy of these two names is proven. In the present author's opinion, it is still questionable if the resemblance in septal arrangement truly represents the similar developing pattern, and considering the priority of *Stylostroton* over *Donophyllum*, the former genus name is applied for the Yashui specimen in this paper.

Subfamily Diphyphyllinae Dybowski, 1873

Genus *Diphyphyllum* Lonsdale, 1845

Diphyphyllum fasciculatum (Flaming), 1828

(Pl. 3, Figs C-D)

Material. Two limestone blocks containing colony fragments: YSR-(0.8)-1-1 and YSR-26; (6 sections).

Description. Fasciculate coral, axial increase. Corallite diameter 5-6 mm. 20-23 septa in two orders. Major septa about half of the corallite radius, mostly not extend to the pseudo-aulos formed by the axial tabellae. Minor septa fairly short, not extended into the tabularium. Dissepiments concentrically arranged.

In longitudinal section, the domed axial tabellae overlapping the preceding one, with sub-horizontal periaxial tabellae on both sides. Dissepiments elongated, vesicle shaped, 1-2 rows.

Subfamily Aulinae Hill, 1981

Genus *Aulina* Smith, 1917

Aulina rotiformis Smith, 1917

(Pl. 3, Figs E-F)

Material. Three colony fragments: YSR-28.45-1-1, YSR-28~29-2-1 and YSR-35.2-1-1; (6 ts, 8 ls)

Description. Astreoid coral. Distance between the adjacent corallites centre 3-6 mm. 10-16 septa in two orders. Major septa intercepted by an aulos of 1-1.5 mm in diameter. Minor septa about 3/4-4/5 length of major septa, extend slightly into tabularium. Carinae may be present on the septa, which sometimes are dilated.

In longitudinal section, tabulae divided in axial and periaxial tabellae. Axial tabellae flat or slightly domed, overlapping the preceding one, numbering 13-15 per 5 mm. The downward turned edges of axial tabellae form an aulos. Periaxial tabellae gently inclined to the dissepimentarium. Dissepiments vesicle-shaped, mostly arch upward. No distinct boundaries between adjacent corallites.

Discussion. The diameter of tabularium and aulos of Yashui specimens is between English specimens of *Aulina rotiformis* and *A. senex*. They more resemble to *A. rotiformis* in having continuous aulos which is a diagnostic character of the later.

Distribution. In the Yashui section, this species range from top to bottom. They are found at 28-29 m and 35.2 m in the first sampling, and at 6 m below the measured base, 87 m and 110 m in the following two samplings. The FAD of this species may extent to the latest Viséan.

Suborder Lonsdaleiina Spaskiy, 1974

Family Axophyllidae Milne-Edwards & Haime, 1851

Genus *Axophyllum* Milne-Edwards & Haime, 1850

Axophyllum aff. *lonsdaleiforme* Salée, 1912

(Pl. 3, Figs G-H)

Material. Five samples: YSR-1, YSR-4-3-1, YSR-9.4-1-1, YSR-9.4-1-2 and YSR-19.3-1-3; (17 ts, 3 ls)

Description. Solitary coral. In younger stage, transeptal dissepiments and columella not developed. In mature stage, septa

in two orders, 28 at diameter of 12 mm, and 34 at diameter of 20 mm. Major septa thickened and thinning adaxially. Minor septa become septal crests, resting on the adaxial surfaces of dissepiments of inner series. Axial structure consists of a thickened, flexuous columella, several irregularly curved septal lamellae and some concentrically arranged axial tabellae. Dissepiments transeptal near the thickened outer wall and concentric at the inner tabularium, with the innermost series coated with stereoplasmic layer.

In longitudinal sections, the three-zonal-structure can be clearly observed. Axial tabellae irregularly ascend to the flexuous median plate. Periaxial tabellae horizontal or incline to the axial region column. Dissepiments very large, vesicle shaped and thickened.

Discussion. The specimens have affinities with *Axophyllum lonsdaleiforme*, but have an axial structure less developed and a wider dissepimentarium.

Genus *Lonsdaleia* McCoy, 1849

Lonsdaleia duplicata (Martin), 1809

(Pl. 3, Figs I-L)

Material. One colony fragment: YSR-72.3; 8 sections.

Description. Fasciculate coral. The colony may show subcerioid habit while corallites are in contact with each other. Corallite diameters from 10 to 20 mm. Wall undulating and thickened by stereoplasm. 28 septa in two orders at a diameter of 10 mm, 32 at a diameter of 15 mm and 36 at a diameter of 20 mm. The major septa are dilated in their middle part and attenuate to both ends. Most of them do not connect with the axial column, which consists of a median plate, several incomplete septal lamellae and concentrically arranged axial tabellae. Minor septa thin, usually as septal crests. The outer dissepiments are transeptal, very large vesicle shaped; there are some inner rings of simple or second-order transeptal dissepiments.

In longitudinal sections, the three-zonal-structure can be clearly observed. Axial tabellae ascend to the flexuous median plate, numbered 8 per 5 mm. Periaxial tabellae inclined to the axis and slightly concave. Dissepimentarium consists of very large vesicular dissepiments and clearly bounded by an inner wall from the tabularium.

5. Conclusions

The rugose coral fauna in the Yashui section indicate a latest Viséan to Early Serpukhovian age and shows resemblance to the Western European fauna. Many well-known European taxa such as *Dibunophyllum bipartitum*, *Palaeosmilia munchisoni*, *Lithostroton decipiens*, *Siphonodendron pauciradiale* and *Aulina rotiformis* appear in Yashui, but with different stratigraphic ranges. For example, the FAD of *Aulina rotiformis* is usually regarded in earliest Namurian (early Serpukhovian) in Britain while in Yashui, it first appears in latest Viséan strata. There are also some endemic taxa such as *Arachnolasma sinense*, *Yuanophyllum kansuense*, *Kueichouphyllum sinense* and *Stylostroton petalaxoidae* which can be used for correlations throughout South China. The coral diversity of the Yashui section shows: (1) a diversity decrease in the uppermost part of the Viséan, and (2) a poorly renewed fauna in the Serpukhovian, which is the similar pattern recorded in the Palaeotethys. Therefore, a coral biostratigraphic succession which distinguish early Serpukhovian from latest Viséan is difficult to establish.

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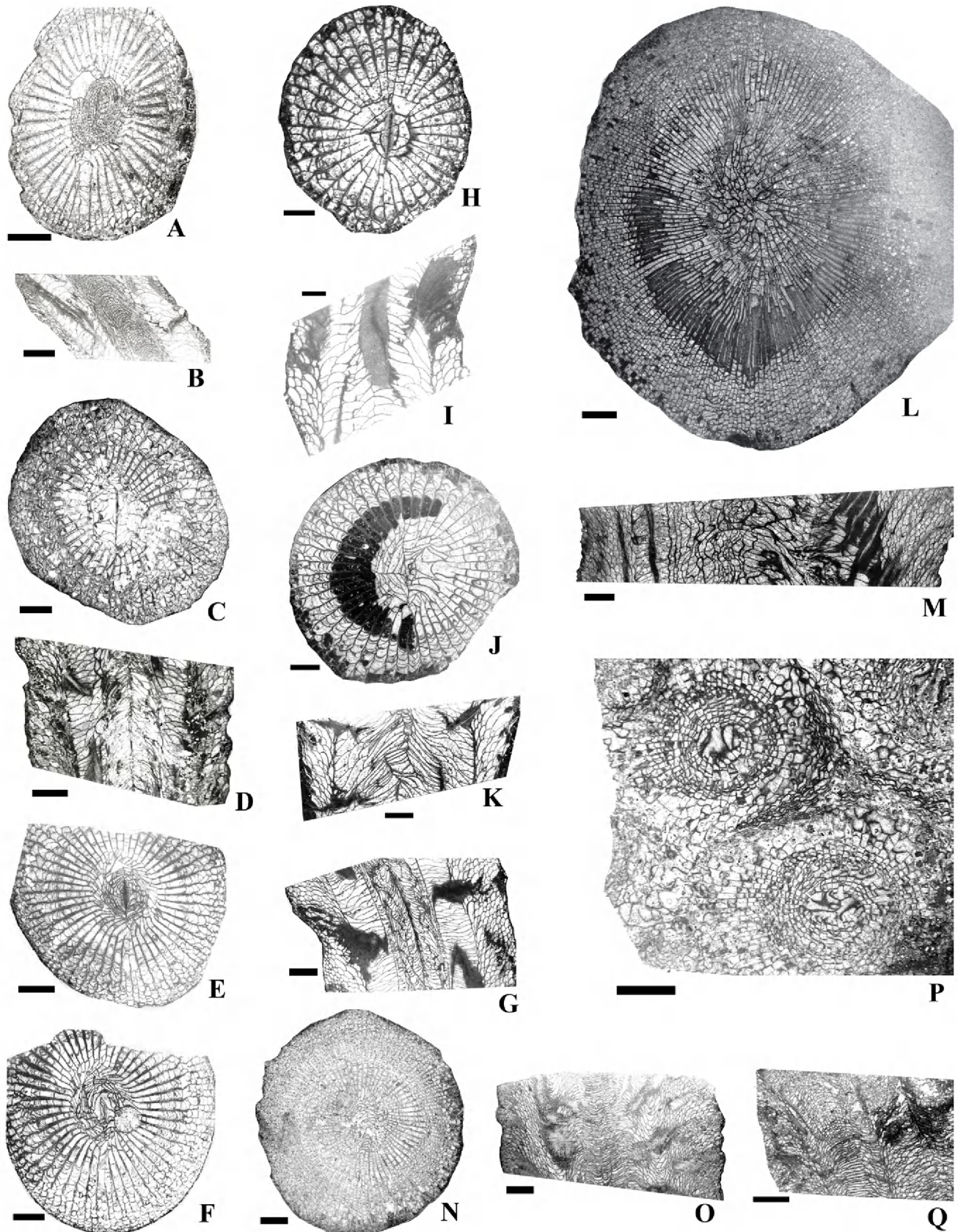


Plate 1. A-B: *Neoclesiophyllum angulatum* Wu & Zhao, 1989. Sample YSR-87.1-1-1, ts and ls. C-D: *Dibunophyllum bipartitum* (McCoy), 1849. Sample YSR-(-0.5)-1-1, ts and ls. E-G: "*Dibunophyllum*" *tingi* (Yu), 1933. Sample YSR-3, ts and ls. H-I: *Arachnolasma sinense* (Yabe and Hayasaka), 1920. Sample YSR-89.2, ts and ls. J-K: *Yuanophyllum kansuense* Yu, 1931. Sample YSR-71.6-1-1, ts and ls. L-M: *Kueichouphyllum sinense* Yu, 1931. Sample YSR-65.5, ts and ls. N-O: *Palaeosmilia murchisoni* Milne-Edwards & Haime, 1848. Sample YSR-4, ts and ls. P-Q: *Palaeosmilia* cf. *planuscula* Wu & Zhao, 1989. Sample YSR-34.5, ts and ls. All the scale bars are 4 mm except H and I, which are 2mm.

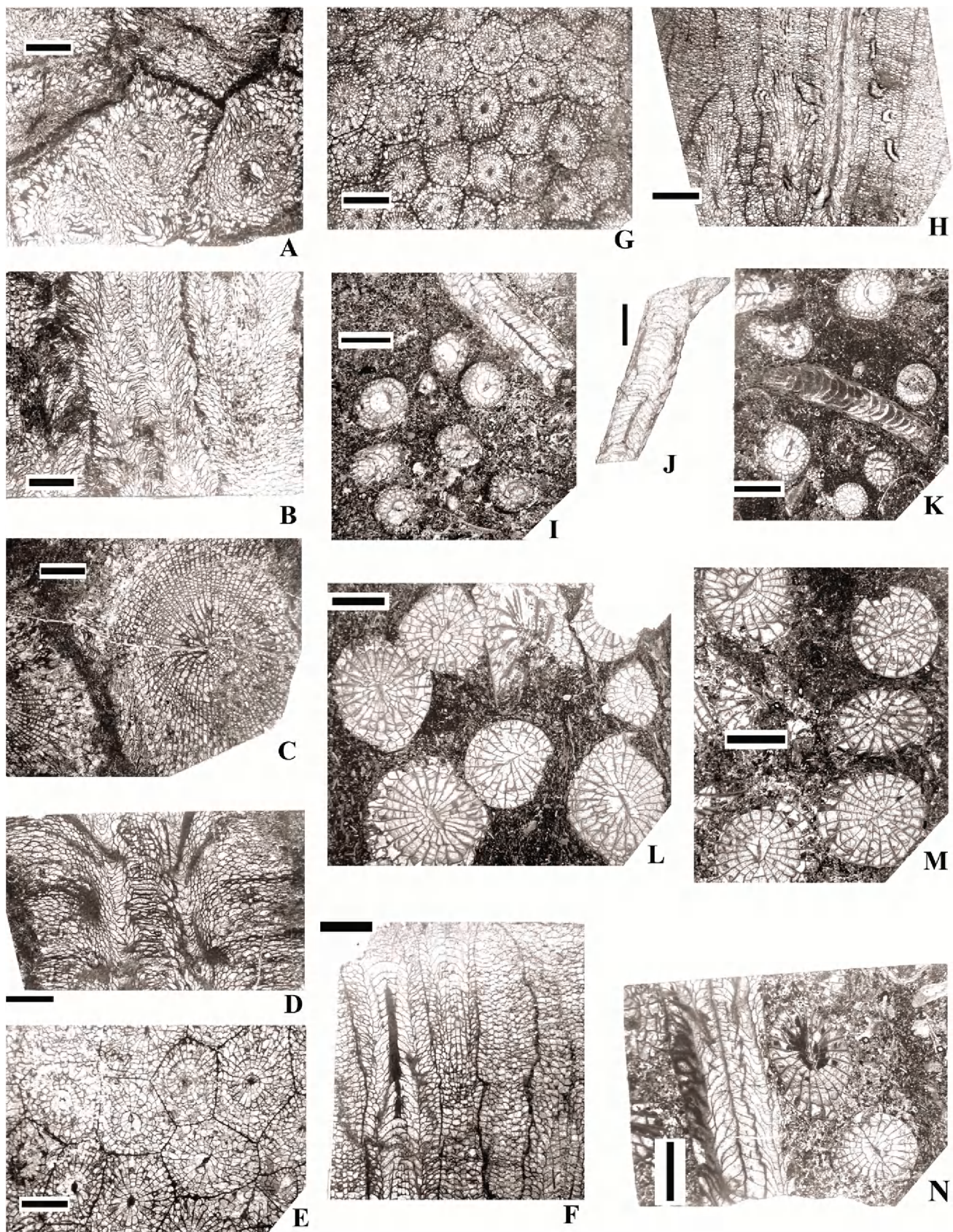


Plate 2. A-B: *Palastraea weiningensis* Wu & Zhao, 1989. Sample YSR-58~59-1-1, ts and ls. C-D: *Palastraea* sp. Sample YSR-(-0.5)-2-1, ts and ls. E-F: *Lithostrotion* cf. *decipiens* (McCoy), 1849. Sample YSR-28~29-2-2, ts and ls. G-H: *Lithostrotion decipiens* (McCoy), 1849. Sample YSR-82-1-2, ts and ls. I-K: *Siphonodendron pauciradiale* (McCoy), 1844. I-J: sample YSR-0.5-2-2, ts and ls. K: sample YSR-5.5-1-3, ts and ls in one slide. L-N: *Stylostrotion petalaxoidae* (Yu), 1933. L: sample YSR-28.45-1-2, ts. M-N: sample YSR-28.45-2-1, ts and ls. All the scale bars are 4 mm.

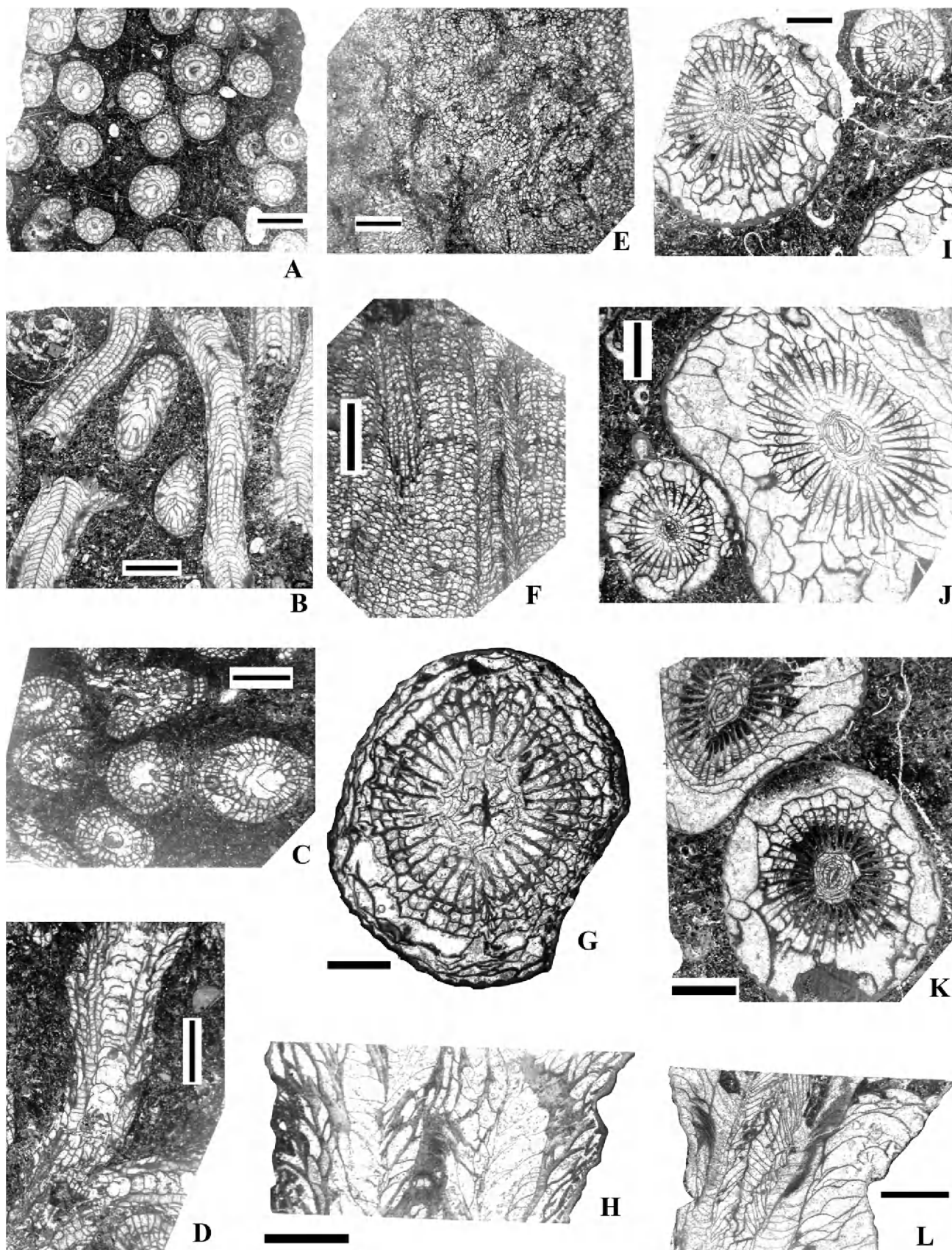


Plate 3. A-B: *Siphonodredon pauciradiale* (McCoy), 1844. Sample YSR-83, ts and ls. C-D: *Diphyphyllum fasciculatum* (Flaming), 1828. Sample YSR-(0.8)-1-1, ts and ls. E-F: *Aulina rotiformis* Smith, 1917. Sample YSR-28-29-2-1, ts and ls. G-H: *Axophyllum* aff. *lonsdaleiforme* Salée, 1912. Sample YSR-19.3-1-3, ts and ls. I-L: *Lonsdaleia duplicata* (Martin), 1809. Sample YSR-72.3, ts and ls. All the scale bars are 4 mm.