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Biodiversity across the Guadalupian-Lopingian Boundary: first results on the ostracod (Crustacea) fauna, Chaotian section (Sichuan Province, South China)

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ABSTRACT
The Middle Permian-Late Permian boundary (Guadalupian-Lopingian boundary, GLB) interval is characterised by important faunal assemblage changes. This extinction-turnover episode is considered by some authors to be the first step of the end-Permian biodiversity drop. The forty-five meters thickness of sediment encompassing the GLB in Chaotian section (Sichuan Province, South China) was sampled and processed for ostracod study. This study presents the first analysis of ostracod faunas in the GLB interval. A total of 154 species belonging to 29 genera are identified. Three species are described as new: *Bairdia chaotianensis* Zazzali, n. sp., *Microcheilinella wujiapingensis* Zazzali, n. sp., *Microcheilinella pagodaensis* Zazzali, n. sp. All the ostracods discovered in the section belong to shallow marine taxa. So these results are not consistent with previous interpretations (lagoonal environment or deep water setting) based on other evidences. Abundance and diversity present a rapid and noticeable decline in the Early Capitanian. Recovery is then recorded about three meters above the GLB. At specific level, a 93% extinction rate and a 96% turnover rate are recorded at the GLB. Moreover, Palaeocopida, straight dorsal border ostracods known to progressively disappear from the Late Permian to the basal Middle-Triassic, are here less abundant and diversified after the GLB. This could reflect the first step of their disappearance at the end of the Palaeozoic.

KEY WORDS
Crustacea,
Ostracods,
South China,
Biodiversity,
Middle-Late Permian,
Guadalupian-Lopingian boundary,
Capitanian-Wuchiapingian,
new species.

RÉSUMÉ

Biodiversité à la limite Guadalupien-Lopingien : premiers résultats sur la faune d'ostracodes, coupe de Chaotian (province du Sichuan, Chine du Sud).

L'intervalle de temps bordant la limite Permien moyen-Permien supérieur (limite Guadalupien-Lopingien, GLB) est caractérisé par d'importantes modifications d'assemblages. Cet épisode d'extinctions-renouvellement est considéré par certains auteurs comme la première étape du déclin de la biodiversité à la fin du Permien. Les échantillons prélevés sur les quarante-cinq mètres encadrant la GLB à Chaotian (province du Sichuan, Chine du Sud) ont été traités pour l'étude des ostracodes. Les travaux présentés ici constituent la toute première analyse des faunes d'ostracodes dans l'intervalle de temps bordant la GLB. 154 espèces appartenant à 29 genres sont identifiées. Trois nouvelles espèces sont décrites : *Bairdia chaotianensis* Zazzali, n. sp., *Microcheilinella wujiapingensis* Zazzali, n. sp., *Microcheilinella pagodaensis* Zazzali, n. sp. Les ostracodes retrouvés au sein de la coupe appartiennent tous à des taxons marins peu profonds. Ces résultats ne sont pas en accord avec les précédentes interprétations (milieu lagunaire ou milieu très profond) basées sur l'étude de divers autres paramètres et taxons. L'abondance et la diversité déclinent rapidement et significativement au Capitanien inférieur. La récupération est ensuite enregistrée environ trois mètres au-dessus de la GLB. Au niveau spécifique, un taux d'extinction de 93 % et un taux de renouvellement de 96 % sont enregistrés à GLB. De plus, les Palaeocopida, connus pour disparaitre progressivement du Permien supérieur à la base du Trias moyen, sont ici moins abondants et diversifiés après la GLB. Cela pourrait constituer la première étape de leur disparition à la fin du Paléozoïque.

MOTS CLÉS
Crustacea, Ostracodes, Chine du Sud, Biodiversité, Permien moyen et supérieur, Limite Guadalupien-Lopingien, Capitanien-Wuchiapingien, espèces nouvelles.

INTRODUCTION

Late Permian (Lopingian) and Early Triassic times are characterised by major global environmental changes and events leading to the most important mass extinction of the all Phanerozoic. Another biological event was evidenced 7.7My before the PTB (Permian-Triassic Boundary) in the upper part of the Guadalupian (Middle Permian), before the Guadalupian-Lopingian Boundary (GLB). It was first demonstrated by a turnover in foraminifera and particularly amongst fusulinids (Stanley & Yang 1994; Jin *et al.* 1994). Stanley & Yang (1994) estimated that 71% of marine species already disappeared at the end of the Capitanian (Late Guadalupian). More recent studies reveal that the extinctions already occurred in the Middle Capitanian within *Jinogondolella altudaensis* conodont Zone, significantly below the GLB (Fig. 1) (Bond *et al.* 2010b). This marine crisis affected also corals, bryozoans, brachiopods, bivalves, calcareous algae and ammonoids (e.g. Jin *et al.* 1995; Wang & Sugiyama 2000; Isozaki & Aljinovic 2009; Shen & Shi 2009; Bond *et al.* 2010b). Bond *et al.* (2010a) highlighted this crisis also on land, with extinction of 24% of plants in South China and 56% in North China. Several geological phenomena have been suggested to be at the origin of this biodiversity drop: regression (Isozaki *et al.* 2008; Wignall *et al.* 2009), volcanism (Emeishan flood basalt Province, Isozaki *et al.* 2007, 2008; He *et al.* 2010), methane release (Thompson *et al.* 2001; Retallack & Jahren 2008) and climatic changes (Veizer *et al.* 2000; Isozaki *et al.* 2007; Isozaki 2009).

The PTB and GLB biodiversity drops are considered by some authors as a double-phased extinction event in the Late Palaeozoic (Yin *et al.* 2007). Some others favor a gradual decrease in diversity from the Wordian (Middle Guadalupian) up to the end of the Permian (Clapham *et al.* 2009). This paper presents the first results on ostracod fauna at the GLB based on the study of the reference Chaotian section (Sichuan Province, P. R. China; Fig. 2).

GEOLOGICAL SETTING

During the Late Palaeozoic-Early Mesozoic period, the South China block (SCB) was located on the eastern part of Pangaea, in equatorial position (Fig. 3A). It was bathed by the Palaeotethys Ocean to the West and by the Panthalassa mega-ocean to the East (Scotese & Langford 1995). The SCB was at this time in a 90° counter clockwise position with regard to the present day location (Fig. 3B). Middle Permian and earliest Triassic (Induan) carbonate sediments are well-exposed along the two banks of the Jialingjiang River, north of Chaotian (north of Guangyuan, NE Sichuan, Figs 2; 4). The Chaotian section (30°23.713N-106°49.615E) mainly consists of marine shelf carbonates deposited on the Palaeo-Tethyan side of South China block (Isozaki *et al.* 2008). Late Guadalupian (Capitanian) sediments of the Maokou Fm consist of thick massive calcareous beds with occasional flint layers notably at base of the section. This informally designed "Unit 1" of Lai *et al.* (2008) and "Main Limestone" of Isozaki *et al.* (2008) was recently named

"Limestone Unit" by Saitoh *et al.* (2013a). It is divided in three subunits, L1 to L3, dated from Wordian to Early Capitanian by conodonts (Isozaki *et al.* 2008; Lai *et al.* 2008; Saitoh *et al.* 2013a). We consider here only the upper part of the last subunit, L3, which is Early Capitanian in age (*Jinogondolella postserrata* conodont Zone, Fig. 1) and is mainly composed of packstones with marine fossils, including calcareous algae, foraminifers and ostracods (Isozaki *et al.* 2008).

The upper part of the Maokou Fm is represented by a 11 m series called "Unit 2" by Lai *et al.* (2008), "Uppermost Member" by Isozaki *et al.* (2008) and "Mudstone Unit" by Saitoh *et al.* (2013a, b). It is composed of an alternation of thinly bedded black calcareous mudstones, black cherts, black siliceous mudstones, dark grey limestones and dark grey dolostones. Saitoh *et al.* (2013a) subdivided this "Mudstone Unit" in two subunits. The M1 lower carbonate-rich one contains conodonts, fragmented brachiopods, small foraminifera and ostracods. It is Early-Middle Capitanian in age (*J. shannoni* conodont Zone and *Pseudoalbaillella longtanensis-P. globosa* radiolarian assemblage *in* Saitoh *et al.* 2013a). The M2 upper subunit, is dominated by black calcareous mudstones yielding radiolarians, ammonoids and gastropods in some chert layers. The age of M2 is not clearly constrained and it is possible that the Late Capitanian is missing (Saitoh *et al.* 2013a). The "Mudstone Unit" is capped by the Wangpo Bed (Fig. 4), a two-meter-thick deeply weathered air-fall ash bed called "G-L Boundary acidic tuff" (Isozaki *et al.* 2004), and termed Xuanwei Fm in South China (He *et al.* 2007) where volcanoclastic deposits are common at the GLB (Wignall *et al.* 2009; Bond *et al.* 2010a). The volcanic origin of the Wangpo Bed was recently challenged by He *et al.* (2010) who suggest that it corresponds to a clastic deposit originating from the erosion of volcanic rocks from the Emeishan Large Igneous Province. Recent analysis of clay mineral assemblages of the Wangpo Bed (Deconinck *et al.* 2014) precises that they are composed of volcanic particles directly deposited in marine environment reworked with volcanic material first deposited on continent. The base of the Wangpo Bed is directly dated *c.* 260 ± 4My by U-Pb dating of zircons (He *et al.* 2007). The Wangpo Bed is considered by Saitoh *et al.* (2013a, b) to belong to the Wujiaping Fm but it is a distinct "unit" which clearly separates the Maokou Fm from the overlying strata.

The Wujiaping Fm begins by a black argillaceous horizon, called "black level", also referred as coaly mudstone with plant debris (Isozaki *et al.* 2008). The facies drastically change after this interval. Indeed, the overlying sediments are dominantly composed of bioclastic packstones with many foraminifera (but with less diverse populations of fusulinids than in the Maokou Fm), calcareous algae, siliceous sponge spicules, ostracods and brachiopods (Isozaki *et al.* 2008; Lai *et al.* 2008; Saitoh *et al.* 2013a). Numerous centimetric to decimetric yellowish to buff-coloured tuff layers are intercalated in this formation with an upward increasing frequency. We pay attention here to the 27 first meters of the Wujiaping Fm. The presence of *Codonofusiella-Reichelina* small fusuline assemblage in the first levels of this formation, allows Isozaki *et al.* (2008) and Saitoh *et al.* (2013a) to locate the GLB at the base of the bioclastic limestones.

			Conodont Zones	
LATE PERMIAN	LOPINGIAN	WUCHIAPINGIAN	*Clarkina orientalis*	Wujiaping Formation
			C. transcausasia	
			C. guiangyuanensis	
			C. leveni	
			C. asymmetrica	
			C. dukouensis	
			C. postbitteri postbitteri	
MIDDLE PERMIAN	GUADALUPIAN	CAPITANIAN	*C. postbitteri hongshuensis*	Maokou Formation
			Jinogondolella granti	
			J. xuanhanensis	
			J. prexuanhanensis	
			J. altudaensis	
			J. shannoni	
			J. posteserrata	

Fig. 1. — Middle-Late Permian boundary conodont Zones and South China formations (modified after Mei & Henderson 2001; Jin *et al.* 2006).

There is an agreement about the palaeoenvironmental interpretation of "Limestone Unit" of the Maokou Fm and lower part of the Wujiaping Fm which are both deposited on oxic shelf in the euphotic zone. The "black level", at the base of the Wujiaping Fm, is interpreted as near-shore to continental environment sediments deposited after a major regressive event at the end of the Capitanian (Isozaki *et al.* 2008; Lai *et al.* 2008; Saitoh *et al.* 2013a, b). Similar facies are widespread in South China and are referred to the Heshan Fm. These coal seams were deposited in swamps developed on or adjacent to tidal-flats (Shao *et al.* 1998, 2003). The significance of the "Mudstone Unit" is more controversial. Isozaki *et al.* (2008) and Saitoh *et al.* (2013a, b) consider that it represents a two-step deepening (first one during M1 subunit and second one during M2 subunit) up to oxygen-depleted slope/basin environment in the disphotic zone. These authors consider that there is a very sharp sea-level drop during or after the deposition of the Wangpo Bed. According to Lai *et al.* (2008), Unit 2 (="Mudstone Unit") was deposited in a shallow environment close to emergence.

MATERIAL AND METHODS

Forty-six samples, distributed through the 45 m thick sequence flanking the GLB (Fig. 4), have been processed for ostracod analysis. The "Mudstone Unit" presents facies (mudstones and cherts) unfavourable for ostracod preservation and release. The M1 and M2 subunit are mainly silicified.

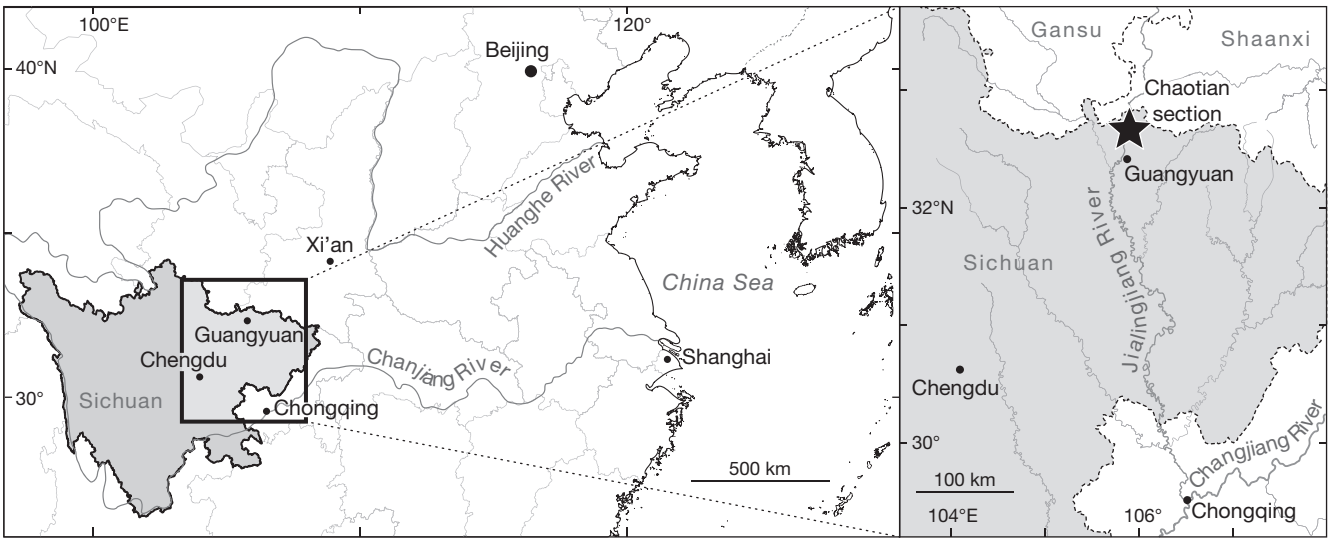

Fig. 2. — Location map of Chaotian section, Sichuan, P. R. China (modified after Isozaki *et al.* 2007).

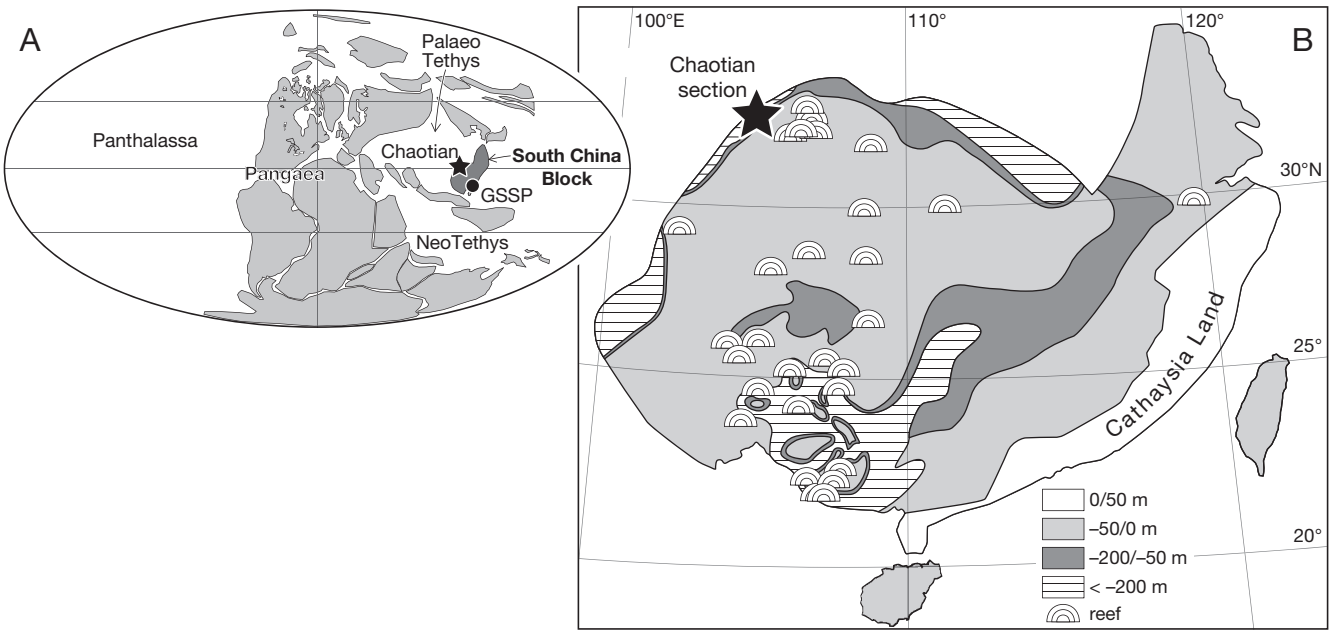

Fig. 3. — **A**, Palaeogeographic map of the Middle-Late Permian (modified after Golonka 2002); **B**, distribution of Capitanian palaeoenvironments in South China (map in present day latitudes, modified from Wang & Jin 2000).

Only the lower part of the M1 subunit, more calcareous, was sampled (11CHAO153 to 11CHAO158). Due to the facies, the Wangpo Bed composed of ashes and the coaly "black level" were not taken in consideration in this study (11CHAO159 to 11CHAO162).

The extraction of calcareous ostracod carapaces from calcareous rocks is achieved by hot acetolysis (Lethiers & Crasquin-Soleau 1988; Crasquin-Soleau *et al.* 2005). An average of 15 grams from the sediment fine fraction (between 530 and 140 µm) has been studied for each sample. Six samples are barren, five from the Maokou Fm (11CHAO152, L3 subunit; 11CHAO153/154/155/157, M1 subunit) and one from the Wujiaping Fm (11CHAO78). From the 40 productive samples (Fig. 4), three yielded only unidentifiable specimens (11CHAO75/76/77).

A total of 154 species belonging to 29 genera are identified and figured (Table 1; Figs 5-17). Three new species are described, 11 species are formally recognized and one is compared to a previously described one. With regard to the poor preservation and/or the low number of specimens, all the other species are presented in open nomenclature but are nevertheless figured (Figs 5-17).

All specimens are deposited in the Université Pierre et Marie Curie, Paris (UPMC) collection (numbers: P6Mxxxx).

TABLE 1. — Stratigraphic distribution of Capitanian-Wuchiapingien ostracods in Chaotian section. Abundances are indicated by numerical values (number of specimens).

Age	Middle Permian Late Guadalupian Capitanian																	Upper Permian Early Lopingian Wuchiapingian																						
Formations	Maokou Formation																	Wujiaping Formation																						
	Limestone Unit (L3)													Mud stone Unit (M1)		Wangpo bed and Black level																								
Samples	11CHAO173	11CHAO172	11CHAO171	11CHAO170	11CHAO169	11CHAO168	11CHAO167	11CHAO166	11CHAO150	11CHAO165	11CHAO164	11CHAO151	11CHAO163	11CHAO156	11CHAO158		11CHAO72	11CHAO74	11CHAO79	11CHAO80	11CHAO81	11CHAO82	11CHAO83	11CHAO84	11CHAO85	11CHAO86	11CHAO87	11CHAO88	11CHAO90	11CHAO91	11CHAO92	11CHAO95	11CHAO96	11CHAO97	11CHAO98	11CHAO99	11CHAO100	11CHAO101
Knightina sp. 1	1																																							
Mirabairdia sp. 1	1																																							
Bairdia sp. 1	1	1																																						
Acratinella sp. 1	2	4																																						
Permoyoungiella? sp. 1	1	1																																						
Basslerella sp. 1	2	3	5																																					
Bairdiacypris sp. 1	1	1	4																																					
Silenites? sp. 1	1	2	4																																					
Knoxitidae sp. 1	3	–	2																																					
Silenites? sp. 2	1	2	4																																					
Microcheilinella sp. 1	3	1	1	1	2																																			
Bairdia sp. 2	5	3	1	–	–	–	1																																	
Bairdia sp. 3	7	2	18	1	–	–	2																																	
Acratia sp. 1	2	–	3	–	–	–	1																																	
Healdianella sp. 1	1	–	2	–	–	–	1																																	
Cyathus caperata? (Guan, 1978)	4	–	3	2	–	–	1																																	
Hollinella martensiformis Crasquin, 2010	1	–	–	–	–	–	1	1																																
Neoamphissites sp. 1	1	1	–	–	2	–	1	2																																
Bairdiacypris sp. 2	2	–	1	–	–	–	2	1																																
Basslerella sp. 2	6	5	7	–	–	–	–	1																																
Acratinella? sp. 2	1	–	–	1	–	–	–	–	–	1																														
Waylandella sp. 1	3	4	2	2	3	1	6	4	–	2																														
Basslerella sp. 3	6	3	12	2	1	2	8	3	–	3																														
Basslerella? sp. 4	1	5	5	–	–	1	–	–	–	1																														
Roundyella? sp. 1	1	1	–	–	–	5	2	5	–	–	1																													
Fabalicypris sp. 1	5	2	7	–	2	4	3	–	2	1	1																													
Basslerella sp. 5	10	5	18	2	–	–	3	1	–	1	1																													
Basslerella sp. 6	3	2	7	–	–	–	1	–	–	–	–	2	3																											
Basslerella sp. 7	4	6	13	1	1	1	1	4	–	–	–	1	1																											
Bairdia chaotianensis Zazzali, n. sp.	1	2	–	3	8	6	2	1	–	1	1	1	–	–	–	–	–	–	–	–	–	–	–	–	–	1	19	–	–	4									
Microcheilinella pagodaensis Zazzali, n. sp.	3	1	2	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	1	–	1	–	–	5	–	7	4			
Samarella viscusforma Chitnarin, 2012	3	1	6	–	1	–	–	–	–	–	–	1	–	–	–	–	–	–	–	7	8	–	6	1	–	–	–	1	–	–	5	–	–	–	–	–	1	1		
Kirkbya sp. 1		1																																						
Bairdia sp. 4		1	–	–	1																																			
Microcheilinella sp. 2		1	3	–	–	–	1																																	
Bairdiacypris sp. 3		1	1	–	–	–	–	1																																
Bairdia sp. 5			1																																					
Bairdia sp. 6			1																																					
Acratia sp. 2			1	–	–	–	1																																	
Kirkbyoidea sp. 1			2	–	–	–	1	2																																
Bairdia sp. 7			7	–	–	–	–	–	–	–	–	–	1																											
Bairdiacypris? sp. 4				1	1																																			
Bairdia sp. 8				1	–	–	–	–	–	1	–	–	1																											
Kirkbya sp. 2					1	–	–	–	–	–	3																													
Bairdiacypris sp. 5					1	1	–	3	–	–	–	–	1																											
Bairdia sp. 9						1																																		
Kirkbyoidea sp. 2						1	–	1	–	3	1																													
Kirkbyoidea sp. 3							2																																	
Knightina? sp. 2							1																																	
Bairdia sp. 10							3	–	–	1																														
Reviya cf. *subsompongensis* Chitnarin, 2008							2	1	–	–	–	1																												
Bairdia sp. 11								1																																

Table 1. — Continuation.

Samples	11CHAO173	11CHAO172	11CHAO171	11CHAO170	11CHAO169	11CHAO168	11CHAO167	11CHAO166	11CHAO150	11CHAO165	11CHAO164	11CHAO151	11CHAO163	11CHAO156	11CHAO158	Wangpo bed and Black level
Age	Middle Permian Late Guadalupian Capitanian															
Formations	Maokou Formation															
	Limestone Unit (L3)													Mud stone Unit (M1)		
Kirkbya sp. 3								2								
Sulcella suprapermiana? Kozur, 1985								1	–	–	–	–	–	–	–	–
Kindlella sp. 1									8							
Roundyella sp. 2									7	–	–	–	–	–	7	
Bairdia sp. 12													1			
Microcheilinella? sp. 3														8		
Knoxiella sp. 1														10		
Microcheilinella? sp. 4															10	
Kirkbya sp. 4															5	
Hollinella sp. 1																
Cyathus elliptica? Shi, 1987																
Acratia sp. 3																
Geffenina posterodorsospina? Chitnarin, 2012																
Knoxiella sp. 2																
Fabalicypris sp. 2																
Microcheilinella sp. 5																
Acratia sp. 4																
Microcheilinella sp. 6																
Microcheilinella rectodorsata? Forel, 2010																
Basslerella sp. 8																
Basslerella sp. 9																
Bairdiacypris sp. 6																
Bairdia sp. 13																
Microcheilinella sp. 7																
Acratia nagyvisnyoensis? Forel, 2013																
Bairdia sp. 14																
Microcheilinella sp. 8																
Microcheilinella sp. 9																
Kegelites sp. 1																
Microcheilinella sp. 10																
Bairdia sp. 15																
Bairdia sp. 16																
Bairdiacypris sp. 7																
Acratinella sp. 3																
Acratia recurvata? Cordell, 1952																
Silenites? sp. 3																
Bairdia sp. 17																
Petasobairdia sp. 1																
Acratinella sp. 4																
Bairdia sp. 18																
Fabalicypris sp. 3																
Basslerella sp. 10																
Petasobairdia sp. 2																
Microcheilinella sp. 11																
Bairdia sp. 19																
Bairdia sp. 20																
Silenites? sp. 4																
Bairdia sp. 21																
Bairdia sp. 22																
Microcheilinella sp. 12																
Bairdia sp. 23																
Bairdia sp. 24																
Bairdia sp. 25																
Bairdia sp. 26																
Bairdia sp. 27																
Bairdiacypris sp. 8																

Samples	11CHAO72	11CHAO74	11CHAO79	11CHAO80	11CHAO81	11CHAO82	11CHAO83	11CHAO84	11CHAO85	11CHAO86	11CHAO87	11CHAO88	11CHAO90	11CHAO91	11CHAO92	11CHAO95	11CHAO96	11CHAO97	11CHAO98	11CHAO99	11CHAO100	11CHAO101
Age	Upper Permian Early Lopingian Wuchiapingian																					
Formations	Wujiaping Formation																					
Kirkbya sp. 3																						
Sulcella suprapermiana? Kozur, 1985	–	–	–	–	1																	
Kindlella sp. 1																						
Roundyella sp. 2																						
Bairdia sp. 12																						
Microcheilinella? sp. 3																						
Knoxiella sp. 1																						
Microcheilinella? sp. 4																						
Kirkbya sp. 4																						
Hollinella sp. 1	18	1																				
Cyathus elliptica? Shi, 1987			1	–	1																	
Acratia sp. 3			1	–	–	–	–	–	–	–	–	–	–	1	–	3	–	–	–	4		
Geffenina posterodorsospina? Chitnarin, 2012				7																		
Knoxiella sp. 2				3																		
Fabalicypris sp. 2				7	1	1	–	2														
Microcheilinella sp. 5				1	–	–	–	–	–	–	–	–	–	1	–	–	–	4				
Acratia sp. 4				4	–	–	–	1	–	–	–	1	1	3	2	7	1	2	1	1		
Microcheilinella sp. 6				1	–	–	–	–	–	1	–	–	–	–	–	1	–	2	–	–	2	
Microcheilinella rectodorsata? Forel, 2010				1	2	–	–	–	1	–	–	–	–	–	–	1	–	–	–	2	1	
Basslerella sp. 8				4	–	–	–	1	–	–	7	–	1	3	4	5	1	2	1	2	1	
Basslerella sp. 9				15	11	2	1	2	–	–	–	–	–	1	2	1	–	1	1	3	2	
Bairdiacypris sp. 6				13	3	1	–	–	–	–	–	–	1	–	–	–	–	–	–	–	1	
Bairdia sp. 13					3																	
Microcheilinella sp. 7					2																	
Acratia nagyvisnyoensis? Forel, 2013					5	–	–	1														
Bairdia sp. 14					3	1	–	–	–	1												
Microcheilinella sp. 8					2	1	2	–	–	–	–	–	2	–	1							
Microcheilinella sp. 9					2	–	–	–	–	–	1	–	–	–	–	1	–	1				
Kegelites sp. 1					1	1	–	–	–	–	–	–	–	–	–	1	–	1	–	1		
Microcheilinella sp. 10					1	–	–	–	–	–	2	–	–	–	–	1	–	–	–	–	1	
Bairdia sp. 15					1	1	–	1	–	1	–	–	–	–	5	13	–	2	2	9	7	
Bairdia sp. 16					1	–	–	–	1	–	–	1	1	1	–	–	–	1	–	1	1	
Bairdiacypris sp. 7					2	–	–	–	–	–	5	1	–	4	–	2	–	–	1	1	4	
Acratinella sp. 3					1	–	–	–	–	–	–	–	–	1	1	2	1	1	–	3	2	
Acratia recurvata? Cordell, 1952					1	–	–	–	1	–	–	–	1	–	–	7	–	3	1	1	1	
Silenites? sp. 3					1	–	–	–	–	–	–	–	–	–	–	1	–	2	3	3	1	
Bairdia sp. 17						1																
Petasobairdia sp. 1						1	–	–	–	–	–	9										
Acratinella sp. 4						1	–	–	–	–	–	–	–	–	1	1	–	–	–	1		
Bairdia sp. 18							6															
Fabalicypris sp. 3							1	–	–	–	1	–	–	–	–	1	–	1	–	–	2	
Basslerella sp. 10								1	1	–	3	1	–	1	2	2	–	1	–	4	3	
Petasobairdia sp. 2										1	1	2	–	–	–	–	–	–	–	1		
Microcheilinella sp. 11										1	1	–	–	–	–	6	–	5	1	3	4	
Bairdia sp. 19											3	–	–	–	1	–	–	–	–	–	1	
Bairdia sp. 20											2	91										
Silenites? sp. 4											2	4										
Bairdia sp. 21											3	–	–	–	–	4						
Bairdia sp. 22											1	2	–	1	–	1	2					
Microcheilinella sp. 12											1	1	–	–	–	1	–	1				
Bairdia sp. 23											2	–	–	–		2	–	4	1	1		
Bairdia sp. 24											1	–	–	–	2	–	–	6	2	5	2	
Bairdia sp. 25											1	–	1	–	–	3	–	2	–	–	1	
Bairdia sp. 26											3	2	–	–	2	–	–	1	1	4	5	
Bairdia sp. 27											2	–	–	1	1	–	–	1	–	4	2	
Bairdiacypris sp. 8											1	6	1	1	–	6	1	3	3	2	3	

TABLE 1. — Continuation.

Age	Middle Permian Late Guadalupian Capitanian																Upper Permian Early Lopingian Wuchiapingian																					
Formations	Maokou Formation															Wangpo bed and Black level	Wujiaping Formation																					
	Limestone Unit (L3)													Mud stone Unit (M1)																								
Samples	11CHAO173	11CHAO172	11CHAO171	11CHAO170	11CHAO169	11CHAO168	11CHAO167	11CHAO166	11CHAO150	11CHAO165	11CHAO164	11CHAO151	11CHAO163	11CHAO156	11CHAO158		11CHAO72	11CHAO74	11CHAO79	11CHAO80	11CHAO81	11CHAO82	11CHAO83	11CHAO84	11CHAO85	11CHAO86	11CHAO87	11CHAO88	11CHAO90	11CHAO91	11CHAO92	11CHAO95	11CHAO96	11CHAO97	11CHAO98	11CHAO99	11CHAO100	11CHAO101
Fabalicypris sp. 4																											1	–	–	1	–	6	–	1	2	1	1	
Basslerella sp. 11																											2	–	–	2	2	1	1	1	–	1	6	
Microcheilinella sp. 13																											1	3	–	–	–	2	–	–	–	4	–	1
Microcheilinella wujiapingensis Zazzali, n. sp.																												7										
Bairdia sp. 28																												1										
Ceratobairdia? *ambigua* Ishizaki, 1964																												23										
Bairdia sp. 29																												2										
Sulcella sp. 1																												1										
Sulcella mesopermiana? Kozur, 1985																												1										
Kirkbya sp. 5																												1										
Bairdia sp. 30																												8	–	–	2	2	–	–	–	–	5	
Microcheilinella sp. 14																												8	1	–	–	–	–	–	–	–	1	
Microcheilinella sp. 15																												1	–	1	–	–	–	–	–	–	4	
Microcheilinella sp. 16																													1	–	–	2	–	1	–	–	1	
Basslerella sp.12																														1	–	4	–	–	–	2		
Microcheilinella sp. 17																														1	–	–	–	–	–	–	1	
Bairdia sp. 31																														1	1	–	–	2	–	–	2	
Silenites? sp. 5																														2	–	–	–	–	–	4	2	
Bairdia sp. 32																															1							
Silenites? sp. 6																															1	3	–	1	2	5	3	
Bairdia sp. 33																																5						
Bairdia sp. 34																																2						
Bairdiacypris? sp. 9																																4						
Fabalicypris sp. 5																																4						
Acratia sp. 5																																3						
Mirabairdia sp. 2																																2	–	1				
Acratinella? sp. 5																																1	–	1				
Kirkbya sp. 6																																2	–	3				
Bairdia sp. 35																																3	–	–	–	1		
Bairdia sp. 36																																2	–	–	–	1		
Bairdiacypris sp. 10																																2	–	1	–	2	2	
Bairdiacypris? sp. 11																																1	1	1	–	2	2	
Bairdiacypris? sp. 12																																3	–	1	–	4	1	
Cetollina sp. 1																																2	–	–	–	–	1	
Bairdia sp. 37																																		1	–	2		
Bairdia sp. 38																																		1	–	2	1	
Bairdia sp. 39																																				2		
Bairdia sp. 40																																				3		
Bairdia sp. 41																																				1		
Bairdia sp. 42																																				3		
Bairdia sp. 43																																				2	4	
Bairdia sp. 44																																				2	1	
Bairdia sp. 45																																					4	
Bairdia sp. 46																																					3	
Bairdia sp. 47																																					2	
Bairdia sp. 48																																					8	

ABBREVIATIONS

AB	anterior border;
ADB	antero-dorsal border;
AVB	antero-ventral border;
DB	dorsal border;
H	height;
L	length;
LV	left valve;
PB	posterior border;
PDB	postero-dorsal border;
PVB	postero-ventral border;
RV	right valve;
VB	ventral border;
W	width.

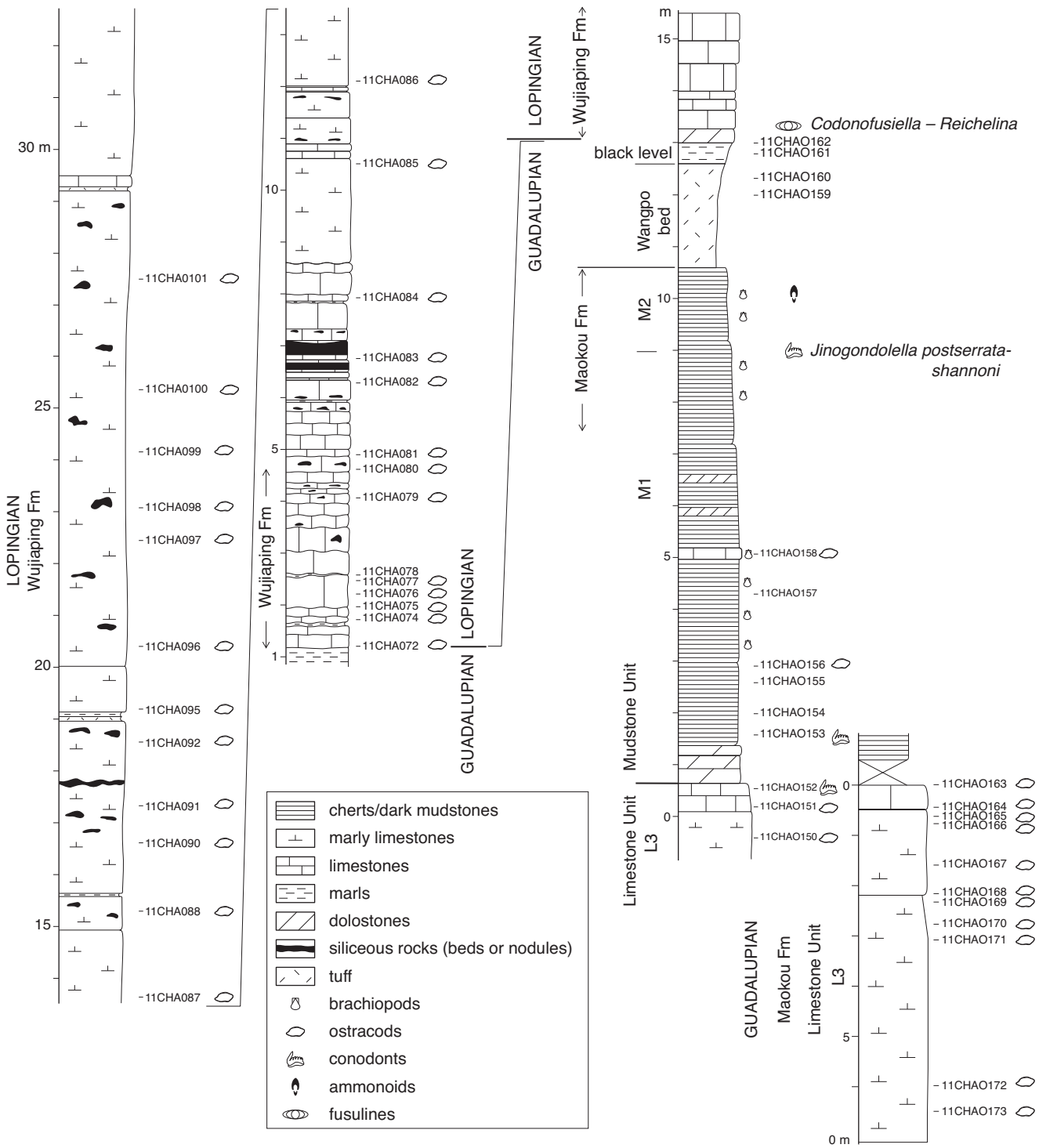

FIG. 4. — Stratigraphic column of the Chaotian section, South China, with location of studied samples. Ammonoid occurrences from Zhao *et al.* (1978), conodont and fusuline occurrences from Isozaki *et al.* (2008) and Lai *et al.* (2008).

SYSTEMATIC PALEONTOLOGY

The classification adopted here follows Moore (1961) and Horne *et al.* (2002).

Class OSTRACODA Latreille, 1806
Subclass PODOCOPA Müller, 1894
Order PODOCOPIDA Müller, 1894
Suborder PODOCOPINA Sars, 1866
Superfamily BAIRDIOIDEA Sars, 1887
Family ACRATIIDAE Gründel, 1962

Genus *Acratia* Delo, 1930

TYPE SPECIES. — *Acratia typica* Delo, 1930 by original designation.

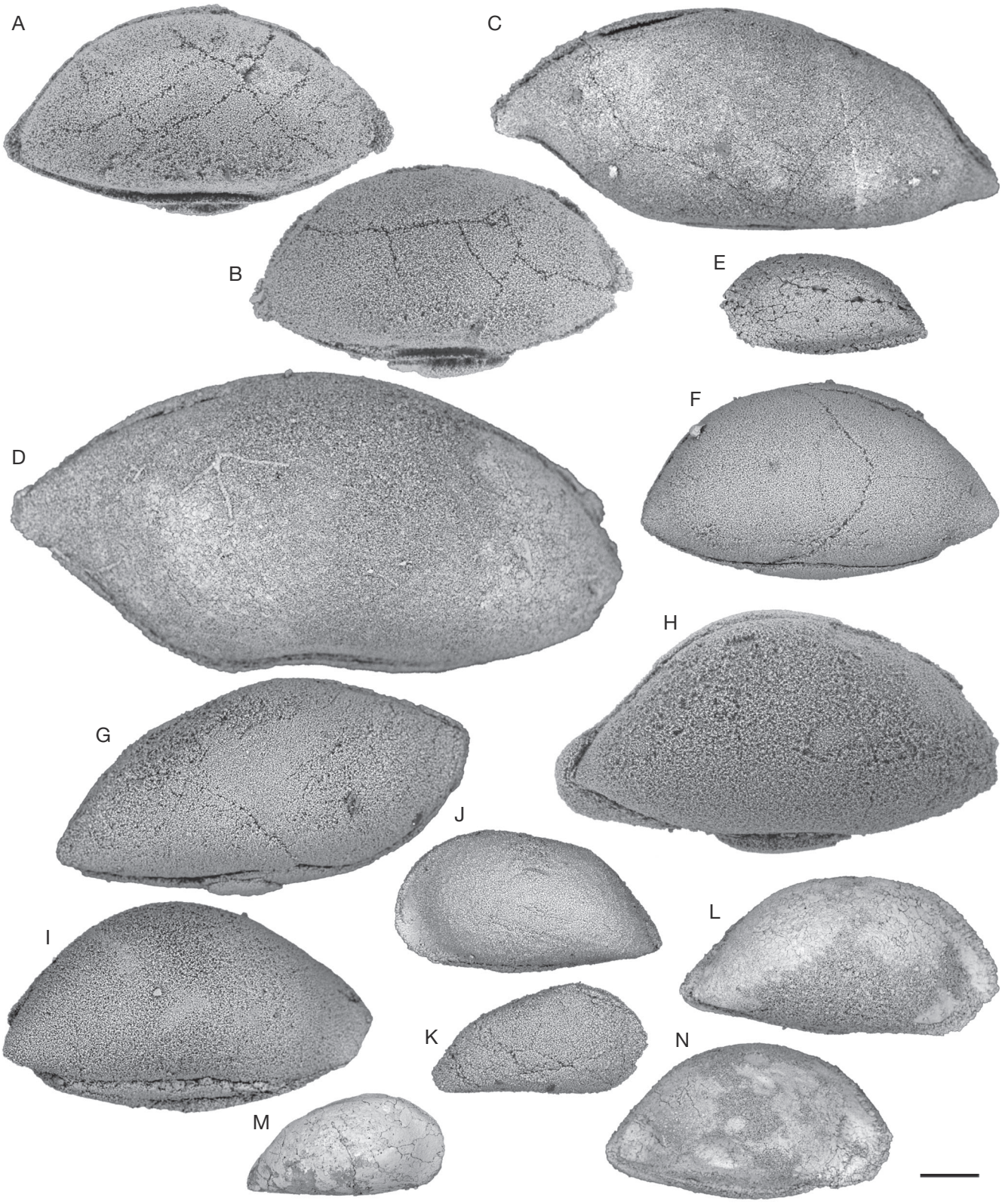

Fig. 5. — Ostracods from Guadalupian-Lopingian boundary interval in South China: **A**, **B**, *Acratia nagyvisnyoensis*? Forel, 2013; **A**, right lateral view, P6M3596, 11CHAO84; **B**, right lateral view, P6M3597, 11CHAO81; **C**, **D**, *Acratia recurvata*? Cordell, 1952; **C**, left lateral view, P6M3598, 11CHAO81; **D**, left lateral view, P6M3599, 11CHAO99; **E**, *Acratia* sp. 1, right lateral view, P6M3600, sample 11CHAO171; **F**, *Acratia* sp. 2, right lateral view, P6M3601, sample 11CHAO167; **G**, *Acratia* sp. 3, right lateral view, P6M3602, sample 11CHAO95; **H**, *Acratia* sp. 4, left lateral view, P6M3603, sample 11CHAO80; **I**, *Acratia* sp. 5, right lateral view, P6M3604, sample 11CHAO95; **J**, *Acratinella* sp. 1, left lateral view, P6M3605, sample 11CHAO173; **K**, *Acratinella*? sp. 2, right lateral view, P6M3606, sample 11CHAO173; **L**, *Acratinella* sp. 3, right lateral view, P6M3607, sample 11CHAO99; **M**, *Acratinella* sp. 4, right lateral view, P6M3608, sample 11CHAO99; **N**, *Acratinella*? sp. 5, right lateral view, P6M3609, sample 11CHAO97. All photographs represent complete carapaces. Scale bar: 100 µm.

Acratia nagyvisnyoensis? Forel, 2013 (Fig. 5A, B)

Acratia nagyvisnyoensis Forel *in* Forel *et al.*, 2013: 204, fig. 10K-O.

Material examined. — Four complete carapaces and two broken carapaces.

Dimensions. — L=629-682 µm; H=308-373 µm.

Occurrences. — Bükk Mountains, Hungary, Late Permian (Forel *et al.* 2013); ?Chaotian section, Sichuan Province, China. Wujiaping Formation, basal Wuchiapingian, Late Permian (this study, samples: 11CHAO81, 11CHAO84, see Table 1).

Remarks

Our specimens are very similar to *A. nagyvisnyoensis* Forel, 2013 from the Late Permian of Hungary (Forel *et al.* 2013) but differ in having longer carapaces and a less arched DB.

Acratia recurvata? Cordell, 1952 (Fig. 5C, D)

Acratia recurvata Cordell, 1952: 81, 82, pl. 20, fig. 65. — Shi & Chen 2002: 81, 82, pl. 20, figs 19-24.

Material examined. — Three complete carapaces and 13 broken carapaces.

Dimensions. — L=499-1197 µm; H=244-500 µm.

Occurrences. — Oread Formation, Missouri, USA, Late Carboniferous (Cordell 1952); Guangxi, China, Late Permian (Shi & Chen 2002); ?Chaotian section, Sichuan Province, China, Wujiaping Formation, basal Wuchiapingian, Late Permian (this study, samples: 11CHAO81, 11CHAO85, 11CHAO90, 11CHAO95, 11CHAO97, 11CHAO98, 11CHAO99, 11CHAO100, see Table 1).

Remarks

Our specimens are very similar to *A. recurvata* Cordell, 1952 from the Late Pennsylvanian (Late Carboniferous) of Missouri (USA; Cordell 1952) and Late Permian of South China (Shi & Chen 2002) but differ in having a more concave AVB, a VB slightly concave at mid-L and the PDB connection with DB forming a more or less marked angle.

Family Bairdiidae Sars, 1887

Genus *Bairdia* McCoy, 1844

Type species. — *Bairdia curta* McCoy, 1844 subsequently designated by Ulrich & Bassler (1923: 320).

Bairdia chaotianensis Zazzali, n. sp. (Fig. 6D, E; 18)

Type material. — Holotype: one complete carapace (P6M3613; Fig. 6D); paratype: one complete carapace (P6M3614; Fig. 6E).

Etymology. — From the Chaotian section, Type locality.

Material examined. —24 complete carapaces and 35 isolated valves.

Dimensions. — L=694-1160 µm; H=322-631 µm. Holotype: L=1050 µm; H=557 µm. Paratype: L=914 µm; H=459 µm (Fig. 18).

Type horizon. — Sample 11CHAO172, "Limestone Unit" (L3), Maokou Formation, Middle Capitanian, Middle Permian.

Type locality. — Chaotian section (30°23.713N-106°49.615E), Sichuan Province, P. R. China.

Occurrences. — Chaotian section, Sichuan Province, China, Maokou and Wujiaping Formations, Middle Capitanian-basal Wuchiapingian, Middle-Late Permian (samples: 11CHAO173, 11CHAO172, 11CHAO170, 11CHAO169, 11CHAO168, 11CHAO167, 11CHAO166, 11CHAO165, 11CHAO164, 11CHAO151, 11CHAO87, 11CHAO88, 11CHAO92, see Table 1).

Diagnosis. — A species of *Bairdia* with elongated carapace, AB and BP with small radius of curvature, hinge line located below DB; both valves present a more or less expressed shoulder with a crest at the top, parallel to the hinge line.

Description

Overlap: absent at DB, narrow to absent at AB, PB and PVB, narrow at AVB and distinct at ADB, PDB and VB.

DB broadly convex at right lateral view. Hinge line located below DB; presence of more or less expressed shoulder at DB of both valves with a crest at the top, parallel to the hinge line; shoulder and crest extend from DB to PDB at RV and from ADB to PDB at LV.

RV: ADB significantly concave at its median part. AB with small radius of curvature. AB maximum convexity slightly above mid-H. AVB gently convex to nearly straight. VB faintly curved (convex) to nearly straight. PVB in the lengthening of VB. PB with a smaller radius of curvature than anterior one. PB pointed near or slightly below mid-H. PDB more slightly concave than anterior one.

LV: ADB more slightly concave the RV one. AB with small radius of curvature. AB maximum convexity at mid-H. AVB gently convex to nearly straight. VB faintly curved (convex) to nearly straight. PVB gently curved. PB with a smaller radius of curvature than anterior one. PB pointed near or slightly below mid-H. PDB more slightly concave than RV one.

Greatest L slightly above mid-H. Greatest H slightly anterior to mid-L.

In dorsal view, lateral outlines asymmetrically convex, with a maximum of W at mid-L and mid-H. RV slightly to significantly wider than LV.

L/H=0.5.

Remarks

Within Wuchiapingian specimens some intraspecific variations are observed. Some specimens present slightly higher valves, wider carapaces and, at LV more prominent DB shoulder and crest than at RV. More or less faint angles could be observed at RV between DB and upper half of PDB and ADB. Some differences could also be noticed between Capitanian and Wuchiapingian specimens. Capitanian ones show more rounded valves, with a RV significantly wider than LV, and a more marked mid-dorsal crest on shoulder's top. Wuchiapingian specimens are, proportionally, slightly longer, DB is also longer. DB of Wuchiapingian

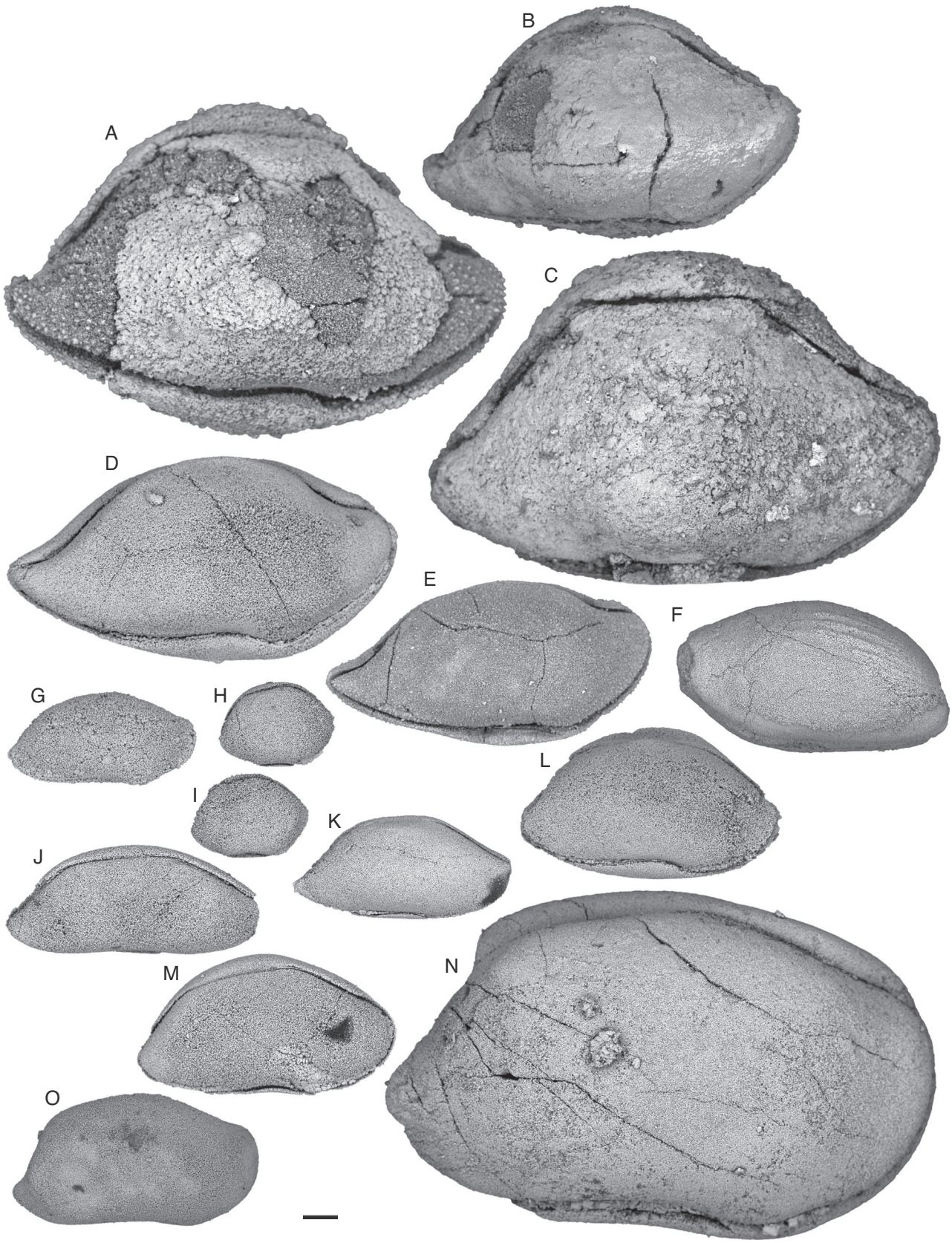

Fig. 6. — Ostracods from Guadalupian-Lopingian boundary interval in South China: **A**-**C**, *Ceratobairdia*? *ambigua* Ishizaki, 1964; **A**, P6M3610, 11CHAO88; **B**, P6M3611, 11CHAO88; **C**, P6M3612, 11CHAO88; **D**, **E**, *Bairdia chaotianensis* Zazzali, n. sp.; **D**, holotype, P6M3613, 11CHAO172; **E**, paratype, P6M3614, 11CHAO88; **F**, *Bairdia* sp. 1, P6M3615, sample 11CHAO173; **G**, *Bairdia* sp. 2, P6M3616, sample 11CHAO173; **H**, **I**, *Bairdia* sp. 3; **H**, P6M3617, sample 11CHAO171; **I**, P6M3618, sample 11CHAO171; **J**, *Bairdia* sp. 4, P6M3619, sample 11CHAO172; **K**, *Bairdia* sp. 5, P6M3620, sample 11CHAO171; **L**, *Bairdia* sp. 6, P6M3621, sample 11CHAO171; **M**, *Bairdia* sp. 7, P6M3622, sample 11CHAO171; **N**, **O**, *Bairdia* sp. 8; **N**, P6M3623, sample 11CHAO170; **O**, P6M3624, sample 11CHAO165. All photographs represent complete carapaces in right lateral view, except **F** in left lateral view. Scale bar: 100 µm.

specimens is about the half of L and about the third of L for Capitanian ones.

The presence of DB shoulder and crest on each valve distinguishes *B. chaotianensis* Zazzali, n. sp. from all the other close species. *Bairdia chaotianensis* Zazzali, n. sp. could be compared to *B.* sp. 9 *sensu* Cordell (1952) from the Late Pennsylvanian (Late Carboniferous) of Missouri (USA; Cordell 1952) by its general lateral RV shape. It differs here by the absence of overlap at DB, more concave ADB and PDB and by more rounded sides in dorsal view. *Bairdia chaotianensis* Zazzali, n. sp. is also close to *Orthobairdia oklahomensis* (Harlton, 1927) (*in* Melnyk & Maddocks 1988b) from the Late Pennsylvanian (Late Carboniferous) of Texas (USA) by RV general lateral outline. It differs here by a PDB more concave at RV, the absence of DB overlap, and a longer posterior end. *B. chaotianensis* Zazzali, n. sp. differs here from *B. urodeloformis* Chen, 1987 (*in* Crasquin *et al.* 2010) from latest Permian of Meishan section, Zhejiang province, China, by its PB and AB smaller radius of curvature. It differs also here by an arched DB, an ADB deeply concave in right lateral view and a maximum of overlapping located at VB.

Internal characters could not be observed due to the infilling and preservation.

Genus *Ceratobairdia* Sohn, 1954

Type species. — *Ceratobairdia dorsospina* Sohn, 1954 by original designation.

Ceratobairdia*? *ambigua Ishizaki, 1964 (Fig. 6A-C)

Ceratobairdia? *ambigua* Ishizaki, 1964: 155, pl.19, fig. 6a, b (non figs 7, 8).

Bairdia guangxiensis Guan *in* Guan *et al.*, 1978: 154, pl. 38, figs 3, 4. — Wang 1978: 291 pl. 3, fig. 5. — Chen & Shi 1982: 122, pl. 5, fig. 17. — Wei *et al.* 1983: 56, pl. 15, fig. 6. — Chen & Bao 1986: 114, pl. 3, figs 7, 8. — Shi & Chen 1987: 31, pl. 3, figs 1-9; 2002: 67, pl. 5, figs 1-9; pl. 28, figs 1, 2.

Bairdia fujisan Tanaka & Maeda *in* Tanaka *et al.*, 2012: 96, fig. 6.3.

Bairdia nishiwakii Tanaka & Nishimura *in* Tanaka *et al.*, 2013: 297, fig. 8.1 (non fig. 2).

Material examined. — Five complete carapaces, ten broken carapaces, five isolated valves and three broken valves.

Dimensions. — L=1020-1570 µm; H=666-974 µm.

Occurrences. — Kitakami Massif, North-East Japan, Middle Permian (Ishizaki 1964); Guangxi Province, China, Late Permian (Guan *et al.* 1978); Guizhou province, China, Late Permian (Wang 1978); Jiangsu Province, China, latest Permian (Chen & Shi 1982); Guizhou Province, China, Late Permian (Wei *et al.* 1983); Jiangsu Province, China, Early Permian (Chen & Bao 1986); Zhejiang Province, China, latest Permian (Shi & Chen 1987); Guangxi, China, Late Permian (Shi & Chen 2002); Gifu Prefecture, Japan, Early Permian (Tanaka *et al.* 2012); Gifu Prefecture, Japan, Middle Permian (Tanaka *et al.* 2013); Chaotian section, Sichuan Province, China, basal Wuchiapingian, Late Permian (this study; sample: 11CHAO88, see Table 1).

Remarks

Ceratobairdia? *ambigua* Ishizaki, 1964 shows a strong dorsal and ventral overlap. L of DB is about the third of carapace L. DB and VB are nearly straight at RV and slightly convex to nearly straight at LV. The maximum thickness is located at mid-L, slightly below midventral part of valves. In anterior and posterior views, VB is quite flat and bounded by a ventral ridge or alae. This structure, added to the flat ventral area, leads to a specific subtriangular shape that could be observed in anterior/posterior view. A sinuous midventral contact margin is also observed. We suggest then that *Bairdia guangxiensis* Guan, 1978, *Bairdia fujisan* Tanaka & Maeda, 2012 and *Bairdia nishiwakii* Tanaka & Nishimura, 2013 are junior synonyms of *C.*? *ambigua* Ishizaki, 1964.

Suborder SIGILLIOCOPINA Martens, 1992
Superfamily Sigilloidea Mandelstam, 1960
Family Microcheilinellidae Gramm, 1975

Genus Microcheilinella Geis, 1933

Type species. — *Microcheilus distortus* Geis, 1932 by original designation.

Microcheilinella wujiapingensis Zazzali, n. sp. (Fig. 11G, H)

Type material. — Holotype: one complete carapace (P6M3690; Fig. 11G); paratype: one complete carapace (P6M3691; Fig. 11H).

Etymology. — From the Type horizon, Wujiaping Formation.

Material examined. — Four complete carapaces and three broken carapaces.

Dimensions. — LV: L=524-567 µm; H=353-386 µm. Holotype: L=535 µm; H=370 µm. Paratype: L=531 µm; H=386 µm.

Type horizon. — Sample 11CHAO88, Wujiaping Formation, basal Wuchiapingian, Late Permian.

Type locality. — Chaotian section (30°23.713N, 106°49.615E), Sichuan Province, P. R. China.

Occurrences. — Chaotian section, Sichuan Province, China, Wujiaping Formation, basal Wuchiapingian, Late Permian (sample: 11CHAO88, see Table 1).

Diagnosis. — A species of *Microcheilinella* with medium sized carapace. Both valves present prominent mid-dorsal shoulder. Maximum W located behind mid-L at RV and in front of mid-L at LV.

Description

LV overlaps RV all around the carapace: very slightly at DB, narrowly at PDB, PVB and AVB, distinctly at ADB, AB, PB and VB. Overlap maximum at VB.

Hinge line straight, equalling about two third of RV length and about half the LV length, located well below DB of both valves which present prominent mid-dorsal shoulder.

RV: DB nearly straight and mid-dorsal shoulder broadly convex in lateral view. PDB and PB slightly flattened laterally.

Fig. 7. — Ostracods from Guadalupian-Lopingian boundary interval in South China: **A**, *Bairdia* sp. 9, P6M3625, sample 11CHAO168; **B**, *Bairdia* sp. 10, P6M3626, sample 11CHAO165; **C**, *Bairdia* sp. 11, P6M3627, sample 11CHAO166; **D**, *Bairdia* sp. 12, P6M3628, sample 11CHAO163; **E**, *Bairdia* sp. 13, P6M3629, sample 11CHAO81; **F**, *Bairdia* sp. 14, P6M3630, sample 11CHAO82; **G**, **H**, *Bairdia* sp. 15; **G**, P6M3631, sample 11CHAO95; **H**, P6M3632, sample 11CHAO99; **I**, *Bairdia* sp. 16, P6M3633, sample 11CHAO85; **J**, *Bairdia* sp. 17, P6M3634, sample 11CHAO82; **K**, *Bairdia* sp. 18, P6M3635, sample 11CHAO83; **L**, *Bairdia* sp. 19, P6M3636, sample 11CHAO87; **M**, **N**, *Bairdia* sp. 20; **M**, P6M3637, sample 11CHAO88; **N**, P6M3638, sample 11CHAO88; **O**, *Bairdia* sp. 21, P6M3639, sample 11CHAO95. All photographs represent complete carapaces in right lateral view. Scale bar: 100 µm.

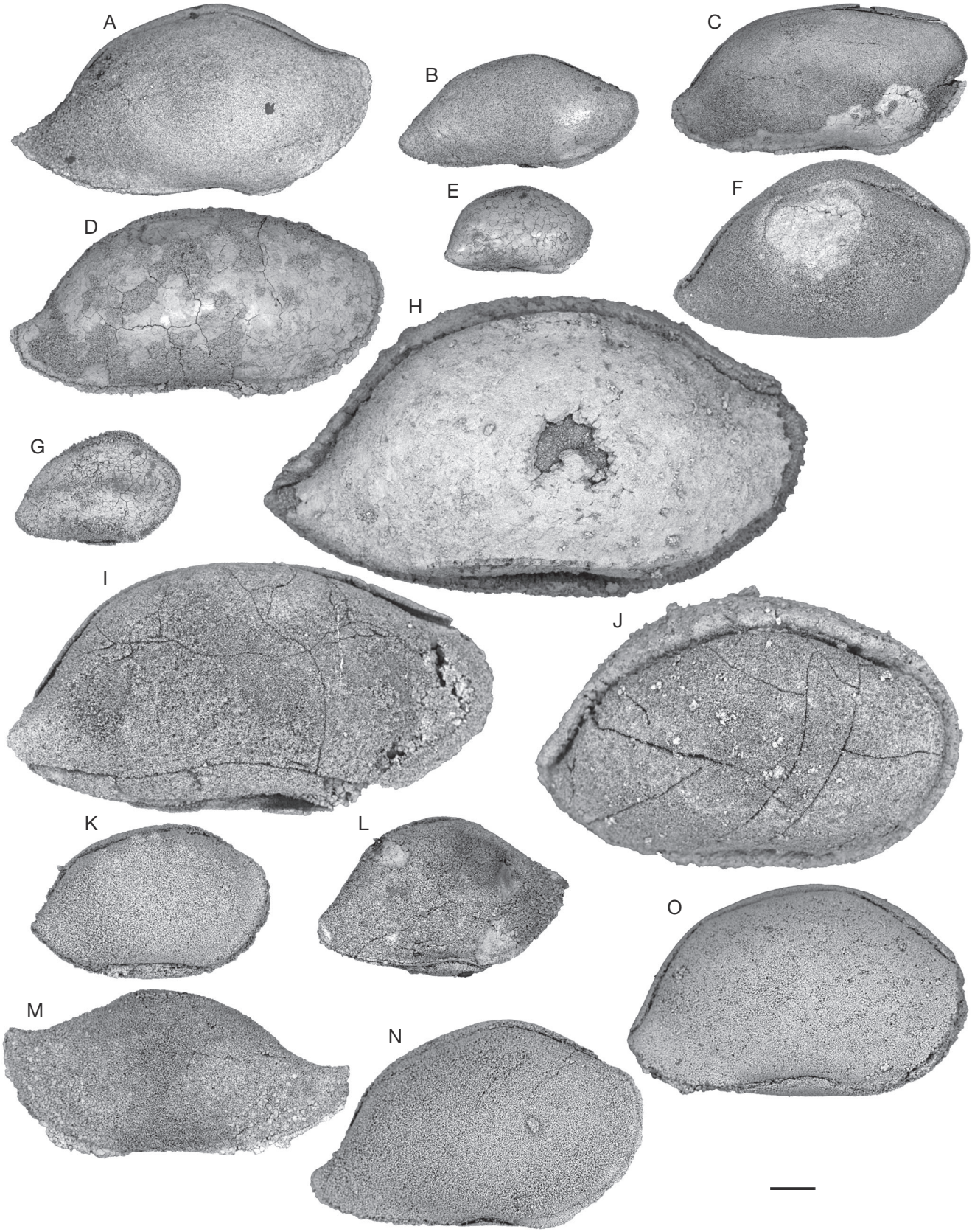

Fig. 8. — Ostracods from Lopingian in South China: **A**, *Bairdia* sp. 22, P6M3640, sample 11CHAO96; **B**, *Bairdia* sp. 23, P6M3641, sample 11CHAO99; **C**, **D**, *Bairdia* sp. 24; **C**, P6M3642, sample 11CHAO87; **D**, P6M3643, sample 11CHAO100; **E**, *Bairdia* sp. 25, P6M3644, sample 11CHAO95; **F**, *Bairdia* sp. 26, P6M3645, sample 11CHAO100; **G**, *Bairdia* sp. 27, P6M3646, sample 11CHAO100; **H**, *Bairdia* sp. 28, P6M3647, sample 11CHAO88; **I**, *Bairdia* sp. 29, P6M3648, sample 11CHAO88; **J**, **K**, *Bairdia* sp. 30; **J**, P6M3649, sample 11CHAO88; **K**, P6M3650, sample 11CHAO95; **L**, *Bairdia* sp.31, P6M3651, sample 11CHAO100; **M**, *Bairdia* sp. 32, P6M3652, sample 11CHAO92; **N**, *Bairdia* sp. 33, P6M3653, sample 11CHAO95; **O**, *Bairdia* sp. 34, P6M3654, sample 11CHAO95. All photographs represent complete carapaces in right lateral view, except **M** which is a left valve in left lateral view. Scale bar: 100 µm.

Fig. 9. — Ostracods from Lopingian in South China: **A**, *Bairdia* sp. 35, P6M3655, sample 11CHAO99; **B**, *Bairdia* sp. 36, P6M3656, sample 11CHAO99; **C**, *Bairdia* sp. 37, P6M3657, sample 11CHAO97; **D**, *Bairdia* sp. 38, P6M3658, sample 11CHAO100; **E**, *Bairdia* sp.39, P6M3659, sample 11CHAO99; **F**, *Bairdia* sp. 40, P6M3660, sample 11CHAO99; **G**, *Bairdia* sp. 41, P6M3661, sample 11CHAO99; **H**, *Bairdia* sp. 42, P6M3662, sample 11CHAO99; **I**, *Bairdia* sp. 43, P6M3663, sample 11CHAO99; **J**, *Bairdia* sp. 44, P6M3664, sample 11CHAO99; **K**, *Bairdia* sp. 45, P6M3665, sample 11CHAO100; **L**, *Bairdia* sp. 46, P6M3666, sample 11CHAO100; **M**, *Bairdia* sp. 47, P6M3667, sample 11CHAO100; **N**, *Bairdia* sp. 48, P6M3668, sample 11CHAO100; **O**, *Cetollina* sp. 1, PM3775, sample 11CHAO95. All photographs represent complete carapaces, except **O** which is a broken one, all in right lateral view. Scale bar: 100 µm.

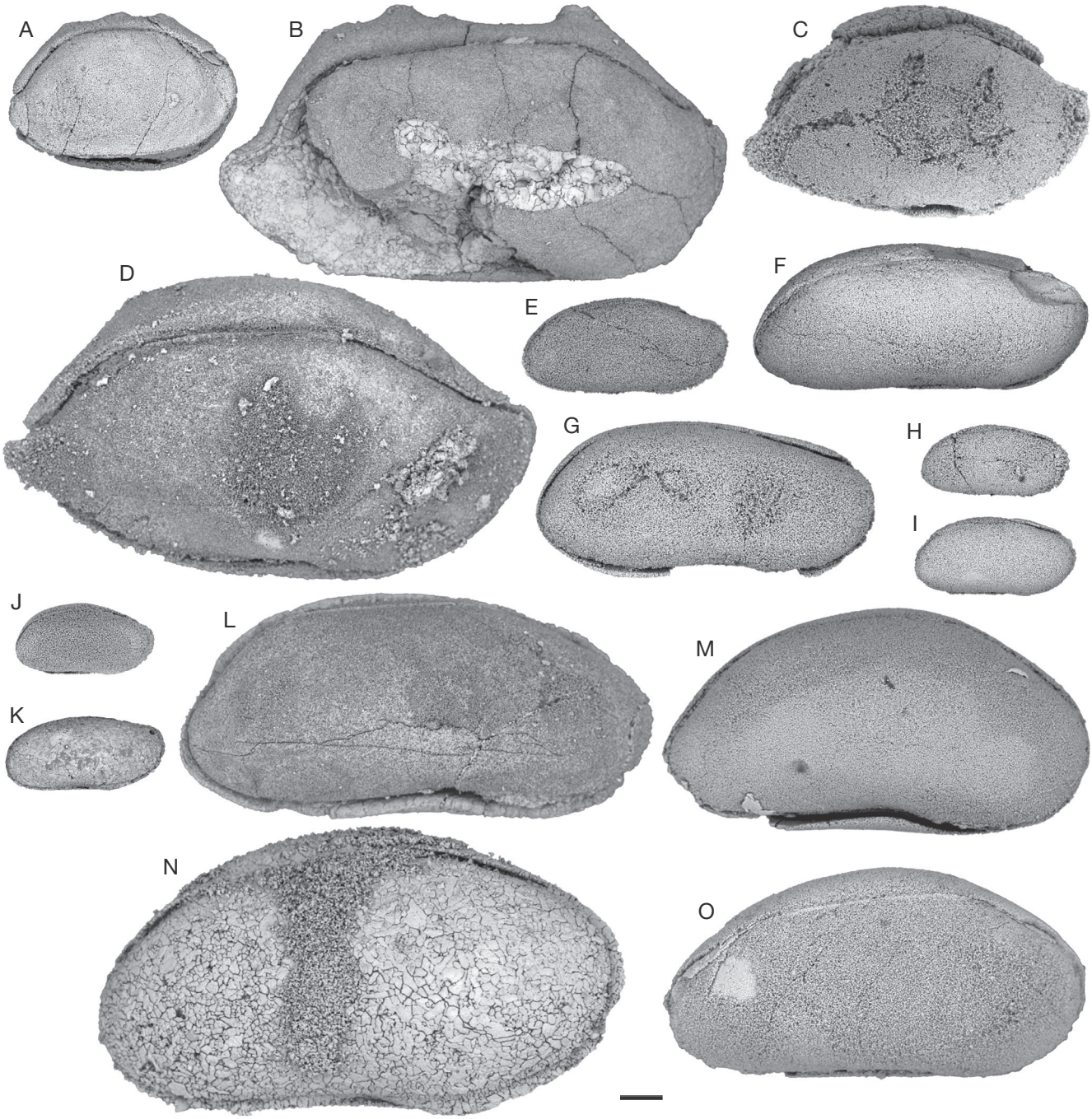

Fig. 10. — Ostracods from Guadalupian-Lopingian boundary interval in South China: **A**, *Mirabairdia* sp. 1, P6M3669, sample 11CHAO173; **B**, *Mirabairdia* sp. 2, P6M3670, sample 11CHAO97; **C**, *Petasobairdia* sp. 1, P6M3671, sample 11CHAO82; **D**, *Petasobairdia* sp. 2, P6M3672, sample 11CHAO88; **E**, *Bairdiacypris* sp. 1, P6M3673, sample 11CHAO171; **F**, *Bairdiacypris* sp. 2, P6M3674, sample 11CHAO173; **G**, *Bairdiacypris* sp. 3, P6M3675, sample 11CHAO172; **H**, *Bairdiacypris*? sp. 4, P6M3676, sample 11CHAO169; **I**, *Bairdiacypris* sp. 5, P6M3677, sample 11CHAO166; **J**, *Bairdiacypris* sp. 6, P6M3678, sample 11CHAO80; **K**, *Bairdiacypris* sp. 7, P6M3679, sample 11CHAO87; **L**, *Bairdiacypris* sp. 8, P6M3680, sample 11CHAO88; **M**, *Bairdiacypris*? sp. 9, P6M3681, sample 11CHAO95; **N**, *Bairdiacypris* sp. 10, P6M3682, sample 11CHAO99; **O**, *Bairdiacypris* sp. 11, P6M3683, sample 11CHAO100. All photographs represent complete carapaces in right lateral view. Scale bar: 100 µm.

PB with small radius of curvature. PB maximum convexity located at mid-H. Ventral margin broadly convex. AB broadly rounded with maximum convexity at mid-H. Greatest L located at mid-H. Greatest H located slightly anterior to mid-L.

LV: DB nearly straight. Mid-dorsal shoulder more prominent than at RV. Anterior part of the shoulder nearly straight. ADB and AB broadly rounded with maximum convexity located slightly below mid-H. Posterior part of the shoulder slightly concave at median part. PDB nearly straight. PB with small radius of curvature, smaller than RV one. PB maximum convexity located slightly above mid-H. Ventral margin more convex at LV than at RV. Greatest L located slightly above mid-H at LV. Greatest H located slightly anterior to mid-L.

Fig. 11. — Ostracods from Guadalupian-Lopingian boundary interval in South China: **A**, *Bairdiacypris*? sp. 12, P6M3684, sample 11CHAO95; **B**, *Fabalicypris* sp. 1, P6M3685, sample 11CHAO172; **C**, *Fabalicypris* sp. 2, P6M3686, sample 11CHAO82; **D**, *Fabalicypris* sp. 3, P6M3687, sample 11CHAO83; **E**, *Fabalicypris* sp. 4, P6M3688, sample 11CHAO95; **F**, *Fabalicypris* sp. 5, P6M3689, sample 11CHAO95; **G**, **H**, *Microcheilinella wujiapingensis* Zazzali, n. sp.; **G**, holotype, P6M3690, 11CHAO88; **H**, paratype, P6M3691, 11CHAO88; **I**, **J**, *Microcheilinella pagodaensis* Zazzali, n. sp.; **I**, holotype, P6M3692, 11CHAO99; **J**, paratype, P6M3693, 11CHAO166; **K**, **L**, *Microcheilinella rectodorsata*? Forel, 2010; **K**, P6M3694, 11CHAO81; **L**, P6M3695, 11CHAO80; **M**, *Microcheilinella* sp. 1, P6M3696, sample 11CHAO172; **N**, *Microcheilinella* sp. 2, P6M3697, sample 11CHAO167; **O**, *Microcheilinella*? sp. 3, P6M3698, sample 11CHAO156. All photographs represent complete carapaces, except **O** which is a broken one, all in right lateral view. Scale bar: 100 µm.

Carapace asymmetric in dorsal view with W max located behind mid-L at RV and posterior to mid-L at LV. RV thicker than LV.

Remarks

Microcheilinella wujiapingensis Zazzali, n. sp. is close to *M. venusta* Chen, 1958 from the Early Permian of South China (Chen 1958). It differs here by its DB which is nearly straight unlike the convex one of *M. venusta* Chen, 1958, and by its mid-dorsal shoulder present on both valves. VB, at RV, is here broadly convex but seems nearly straight for *M. venusta.* VB, at LV, is here more convex than *M. venusta* one. *Microcheilinella venusta* maximum W is located near mid-L at both valves, whereas *M. wujiapingensis* Zazzali, n. sp. maximum W is located behind mid-L at RV and posterior to mid-L at LV. RV thicker than LV.

Microcheilinella wujiapingensis Zazzali, n. sp. is close to *M. venusta* Chen, 1958 (*sensu* Chen & Shi 1982. In this paper, the species is different from the original one) from latest Permian of South China, by its LV and RV general outline in lateral view, its mid-dorsal shoulder on each valves, the LV ends radius of curvature and maximum on convexity position and the general overlap. It differs by the maximum W, located in the anterior quarter of both valves for *M. venusta* (*sensu* Chen & Shi 1982) in dorsal view.

Microcheilinella pagodaensis Zazzali, n. sp. (Figs 11I, J; 19)

Type material. — Holotype: one complete carapace (P6M3692; Fig. 11I); paratype: one complete carapace (P6M3693; Fig. 11J).

Etymology. — Reference to the pagoda at the top of the Chaotian section.

Material examined. — 22 complete carapaces and four broken carapaces.

Dimensions. — L=209-350 µm; H=110-187 µm. Holotype: L=263 µm; H=138 µm. Paratype: L=306 µm; H=169 µm (Fig. 19).

Type horizon. — Sample 11CHAO99, Wujiaping Formation, basal Wuchiapingian, Late Permian.

Type locality. — Chaotian section (30°23.713N-106°49.615E), Sichuan Province, P. R. China.

Occurrences. — Chaotian section, Sichuan Province, China, Maokou and Wujiaping Formations, Middle Capitanian-basal Wuchiapingian, Middle-Late Permian (samples: 11CHAO 173, 11CHAO172, 11CHAO171, 11CHAO166, 11CHAO84, 11CHAO90, 11CHAO92, 11CHAO97, 11CHAO99, 11CHAO100, see Table 1).

Diagnosis. — A species of *Microcheilinella* with small sized carapace. RV anterior half significantly higher than posterior one in lateral view. Maximum W located behind mid-L at RV and in front of mid-L at LV.

Description

LV overlaps RV all around the carapace: very slightly at AVB and VB, narrowly at AB, ADB, PDB and PB, distinctly at DB.

Hinge line straight, equalling about half L.

In right lateral view: DB slightly arched to nearly straight at RV and broadly convex at LV. PDB arched. PB with small radius of curvature. PB maximum convexity located below mid-H. PVB convex. VB slightly concave to nearly straight. AVB broadly convex. AB broadly rounded with maximum convexity located at mid-H. Greatest L located near mid-H. Greatest H anterior to mid-L at RV and near mid-L at LV. RV anterior half significantly higher than posterior one.

In dorsal view: posterior extremities rounded, anterior extremities slender. Maximum W located behind mid-L at RV and in front of mid-L at LV.

Remarks

The new species is quite different from all the previously described species. The closest species is an unpublished species, *M.* sp. 10 (Chitnarin 2010, unpublished PhD thesis; pl. 16, fig. 7), from the Middle Permian of Thailand. This last species has the same general outline. Here PB radius of curvature at RV is smaller, the overlap less marked at PDB and ADB and the RV anterior half significantly higher than posterior one.

Microcheilinella rectodorsata? Forel, 2010 (Fig. 11K, L)

Microcheilinella rectodorsata Forel *in* Crasquin *et al.,* 2010: 359, fig. 22A-G.

Material examined. — Six complete carapaces and two broken carapaces.

Dimensions. — L=292-416 µm; H=163-235 µm.

Occurrences. — Meishan section, Changxing Formation, Meishan Member, Changhsingian, Late Permian (Crasquin *et al.* 2010); ?Chaotian section, Sichuan Province, China, Wujiaping Formation, basal Wuchiapingian, Late Permian (this study, samples: 11CHAO80, 11CHAO81, 11CHAO85, 11CHAO95, 11CHAO99, 11CHAO100, see Table 1).

Remarks

Our specimens are very similar to *M. rectodorsata* Forel, 2010 from the Late Permian of China (Crasquin *et al.* 2010) but differ in having longer carapace, less marked overlapping and more acute PB.

Order PALAEOCOPIDA Henningsmoen, 1953
Suborder BEYRICHICOPINA Scott, 1961
Superfamily Aparchitoidea Jones, 1901
Family Aparchitidae Jones, 1901

Genus *Cyathus* Roth & Skinner, 1930

Type species. — *Cyathus ulrichi* Roth & Skinner, 1930 by original designation.

Cyathus caperata? (Guan, 1978) (Fig. 14E, F)

Sinocoelonella caperata Guan *in* Guan *et al.,* 1978: 149, pl. 37, fig. 17, pl. 38, fig. 1.

Cyathus caperata – Chen & Bao 1986: 111, pl. 4, fig. 3. — Shi & Chen 1987: 32, pl. 10, figs 10-18. — Yuan *et al.* 2009: 388, 392, pl. 1, fig. 15. — Crasquin *et al.* 2010: 332-334, fig. 3A-D. —Chitnarin *et al.* 2012: 806, fig. 4A, B, D, E. — Burrett *et al.* 2014: 15-16, fig. 12s, t.

Material examined. — Eight complete carapaces and two broken carapaces.

Dimensions. — L=276-453 µm; H=174-255 µm.

Occurrences. — Wugang, Hunan Province, China, Early Permian (Guan *et al.* 1978); Chisia Formation, Jiangsu Province, China, Early Permian (Chen & Bao 1986); Meishan section, Baoqing and Meishan Members, Changxing Formation, Zhejiang Province, China, Late Permian (Shi & Chen 1987; Crasquin *et al.* 2010); Saiwa section, Guizhou Province, China, latest Permian (Yuan *et al.* 2009); Chaiyaphum Province, North-eastern Thailand, Early Permian, Phetchabun Province, central Thailand, Early Permian and Nakhon Sawan Province, central Thailand, Middle Permian (Chitnarin *et al.* 2012); E-Lert Formation, Thailand, Early Permian (Burrett *et al.* 2014); ?Chaotian section, Sichuan Province, China, Maokou Formation, Middle Capitanian, Middle Permian (this study, samples: 11CHAO 173, 11CHAO171, 11CHAO170, 11CHAO167, see Table 1).

Remarks

Our specimens are very similar to *C. caperata* (Guan, 1978) from the Permian of Thailand and China (see above) but differ in having longer and less arched carapaces in dorsal view and less prominent DB inflation.

Fig. 12. — Ostracods from Guadalupian-Lopingian boundary interval in South China: **A**, *Microcheilinella*? sp. 4, P6M3699, sample 11CHAO158; **B**, *Microcheilinella* sp. 5, P6M3700, sample 11CHAO97; **C**, *Microcheilinella* sp. 6, P6M3701, sample 11CHAO97; **D**, *Microcheilinella* sp. 7, P6M3702, sample 11CHAO81; **E**, *Microcheilinella* sp. 8, P6M3703, sample 11CHAO81; **F**, *Microcheilinella* sp. 9, P6M3704, sample 11CHAO87; **G**, *Microcheilinella* sp. 10, P6M3705, sample 11CHAO87; **H**, *Microcheilinella* sp. 11, P6M3706, sample 11CHAO95; **I**, *Microcheilinella* sp. 12, P6M3707, sample 11CHAO87; **J**, **K**, *Microcheilinella* sp. 13; **J**, P6M3708, sample 11CHAO95; **K**, P6M3709, sample 11CHAO88; **L**, *Microcheilinella* sp. 14, P6M3710, sample 11CHAO100; **M**, *Microcheilinella* sp. 15, P6M3711, sample 11CHAO100; **N**, *Microcheilinella* sp. 16, P6M3712, sample 11CHAO90; **O**, *Microcheilinella* sp. 17, P6M3713, sample 11CHAO100. All photographs represent complete carapaces in right lateral view, except **A** and **L** which are broken. Scale bar: 100 µm.

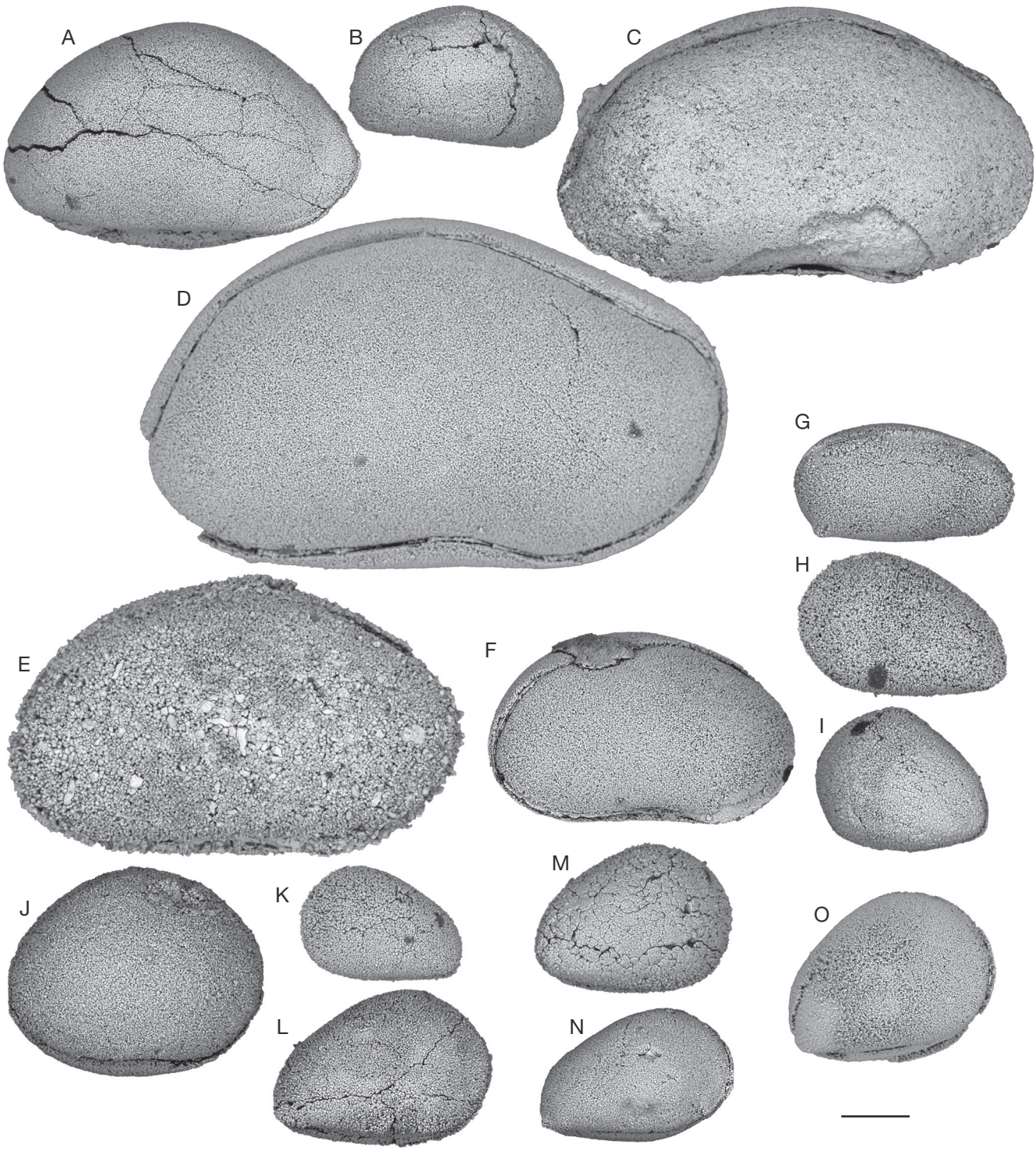

Fig. 13. — Ostracods from Guadalupian-Lopingian boundary interval in South China: **A**, *Silenites*? sp. 1, right lateral view, P6M3714, sample 11CHAO173; **B**, *Silenites*? sp. 2, right lateral view, P6M3715, sample 11CHAO172; **C**, *Silenites*? sp. 3, right lateral view, P6M3716, sample 11CHAO97; **D**, *Silenites*? sp. 4, right lateral view, P6M3717, sample 11CHAO87; **E**, *Silenites*? sp. 5, right lateral view, P6M3718, sample 11CHAO91; **F**, *Silenites*? sp. 6, right lateral view, P6M3719, sample 11CHAO95; **G**, *Waylandella* sp. 1, right lateral view, P6M3720, sample 11CHAO165; **H**, *Basslerella* sp. 1, left lateral view, P6M3721, sample 11CHAO173; **I**, *Basslerella* sp. 2, left lateral view, P6M3722, sample 11CHAO173; **J**, *Basslerella* sp. 3, right lateral view, P6M3723, sample 11CHAO173; **K**, *Basslerella*? sp. 4, left lateral view, P6M3724, sample 11CHAO171; **L**, *Basslerella* sp. 5, right lateral view, P6M3725, sample 11CHAO171; **M**, *Basslerella* sp. 6, right lateral view, P6M3726, sample 11CHAO171; **N**, *Basslerella* sp. 7, right lateral view, P6M3727, sample 11CHAO168; **O**, *Basslerella* sp. 8, right lateral view, P6M3728, sample 11CHAO87. All photographs represent complete carapaces. Scale bar: 100 µm.

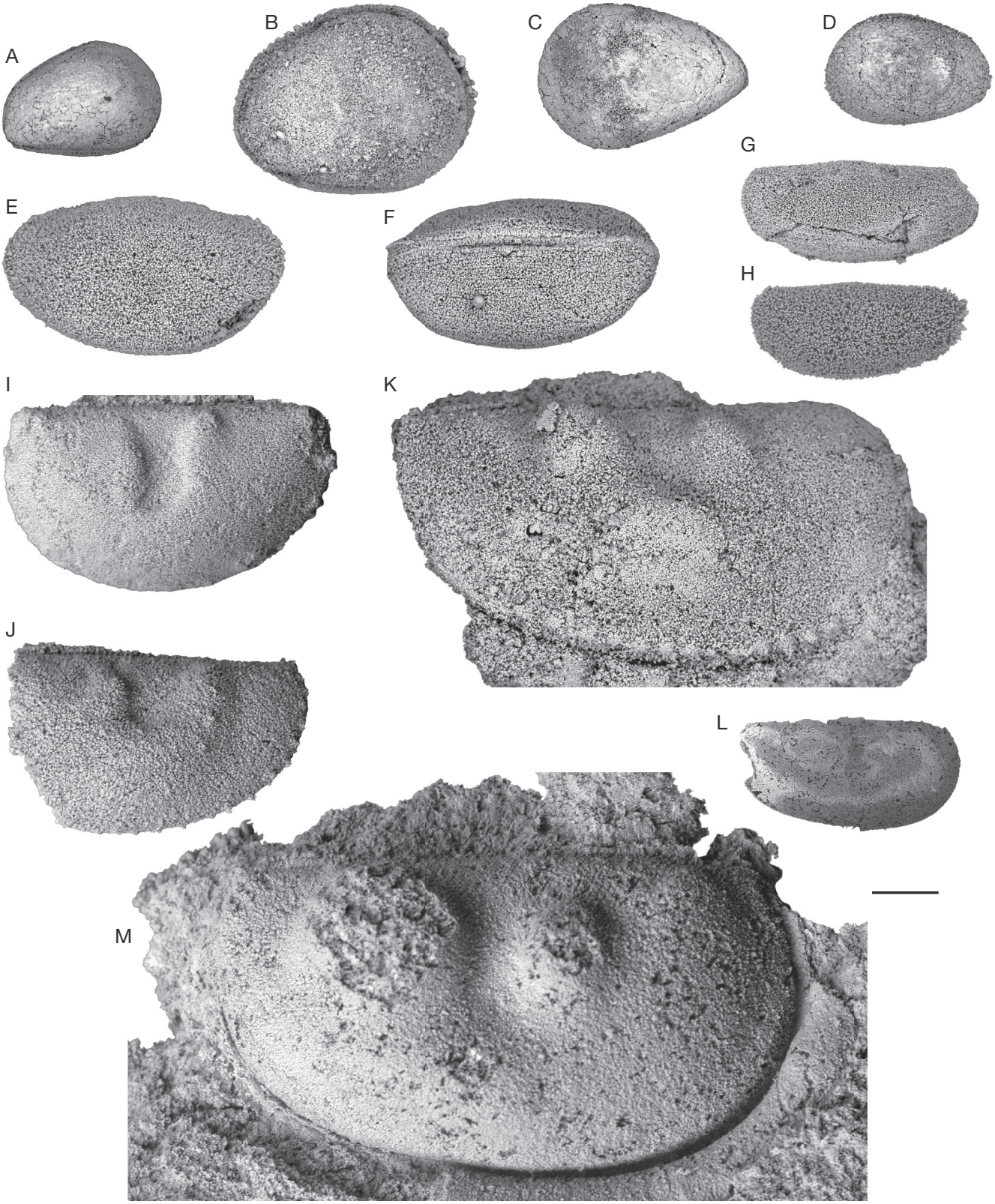

Fig. 14. — Ostracods from Guadalupian-Lopingian boundary interval in South China: **A**, *Basslerella* sp. 9, right lateral view of complete carapace, P6M3729, sample 11CHAO 99; **B**, *Basslerella* sp. 10, right lateral view of complete carapace, P6M3730, sample 11CHAO85; **C**, *Basslerella* sp. 11, left lateral view of complete carapace, P6M3731, sample 11CHAO100; **D**, *Basslerella* sp. 12, left lateral view of complete carapace, P6M3732, sample 11CHAO99; **E**, **F**, *Cyathus caperata*? (Guan, 1978); **E**, right lateral view of complete carapace, P6M3733, 11CHAO173; **F**, dorsal view of complete carapace, P6M3734, 11CHAO171; **G**, **H**, *Cyathus elliptica*? Shi, 1987; **G**, left lateral view of complete carapace, P6M3735, 11CHAO79; **H**, left lateral view of complete carapace, P6M3736, 11CHAO81; **I-K**, *Hollinella martensiformis* Crasquin, 2010; **I**, left lateral view of left valve, P6M3737, 11CHAO166; **J**, left lateral view of broken left valve, P6M3738, 11CHAO173; **K**, right lateral view of right valve, P6M3739, sample 11CHAO167; **L**, **M**, *Hollinella* sp. 1; **L**, right lateral view of broken right valve, P6M3740, sample 11CHAO72; **M**, right lateral view of broken right valve, P6M3741, sample 11CHAO72. Scale bar: 100 µm.

Cyathus elliptica? Shi, 1987
(Fig. 14G, H)

Cyathus elliptica Shi *in* Shi & Chen, 1987: 32, pl. 10, figs 20-23; pl. 17, figs 5, 6. — Crasquin *et al.* 2010: 334, fig. 3E-H. — Chitnarin *et al.* 2012: 810, fig. 4C, F, G, J. — Burrett *et al.* 2014: 16, fig. 12u-w.

Material examined. — One complete carapace and one broken carapace.

Dimensions. — L=334-374 µm; H=152-162 µm.

Occurrences. — Meishan section, Baoqing and Meishan Members, Changxing Formation, Zhejiang Province, China, Late Permian (Shi & Chen 1987; Crasquin *et al.* 2010); Chaiyaphum Province, Northeastern Thailand, Early Permian, Phetchabun Province, central Thailand, Early Permian and Nakhon Sawan Province, central Thailand, Middle Permian (Chitnarin *et al.* 2012); E-Lert Formation, Thailand, Early Permian (Burrett *et al.* 2014); ?Chaotian section, Sichuan Province, China, Wujiaping Formation, basal Wuchiapingian, Late Permian (this study, samples: 11CHAO79, 11CHAO81, see Table 1).

Remarks
Our specimens are attributed to *C. elliptica* Shi, 1987 from the Permian of China and Thailand (see above) with doubt because of the poor preservation state and the small number of specimens.

Suborder KLOEDENELLOCOPINA Scott, 1961
Superfamily Hollinoidea Swartz, 1936
Family Hollinellidae Bless & Jordan, 1971

Genus *Hollinella* Coryell, 1928

Type species. — *Hollinella dentata* Coryell, 1928 by original designation.

Hollinella martensiformis Crasquin, 2010
(Fig. 14I-K)

Hollinella martensiformis Crasquin *in* Crasquin *et al.,* 2010: 336, fig. 4D-F. — Chitnarin *et al.* 2012: 828, fig. 19A-D.

Material examined. — Two isolated valves and one broken valve.

Dimensions. — L=477-521 µm; H=286-298 µm.

Occurrences. — Meishan section, Baoqing and Meishan Member, Changxing Formation, Zhejiang Province, China, Late Permian (Crasquin *et al.* 2010); Phetchabun Province, Central Thailand, Early Permian and Nakhon Sawan Province, Central Thailand, late Early Permian and Middle Permian (Chitnarin *et al.* 2012); Chaotian section, Sichuan Province, China, Maokou Formation, Middle Capitanian, Middle Permian (this study, samples: 11CHAO 173, 11CHAO166, see Table 1).

Superfamily Kirkbyoidea Ulrich & Bassler, 1906
Family Kirkbyidae Ulrich & Bassler, 1906

Genus *Reviya* Sohn, 1961

Type species. — *Amphissites*? *obesus* Croneis & Gale, 1939 by original designation.

Reviya cf. *subsompongensis* Chitnarin, 2008
(Fig. 16F, G)

Reviya subsompongensis Chitnarin, 2008: 347, fig. 3.14-16.

Material examined. — Three isolated valves and one broken valve.

Dimensions. — L=469-617 µm; H=275-381 µm.

Occurrences. — Chaotian section, Sichuan Province, China, Maokou Formation, Middle Capitanian, Middle Permian (this study, samples: 11CHAO 167, 11CHAO166, 11CHAO151, see Table 1).

Remarks
General appearance of valves suggests *R. subsompongensis* Chitnarin, 2008 from the Middle Permian of Thailand (Chitnarin *et al.* 2008, 2012). However here, cardinal angles are more pronounced, PDB more convex, anterior and posterior flattened extremities more noticeably developed and ornamentation is also slightly different. Perhaps the present species could belong to a geographic subspecies of *R. subsompongensis*.

Superfamily Kloedenelloidea Ulrich & Bassler, 1908
Family Knoxitidae Egorov, 1950

Genus *Geffenina* Coryell & Sohn, 1938

Type species. — *Geffenina marmerae* Coryell & Sohn, 1938 by original designation.

Geffenina posterodorsospina? Chitnarin, 2012
(Fig. 15A, B)

Geffenina posterodorsospina Chitnarin *in* Chitnarin *et al.,* 2012: 814, fig. 8A-C.

Material examined. — Four complete carapaces and three broken carapaces.

Dimensions. — L=274-525 µm; H=130-305 µm.

Occurrences. — Phetchabun Province, Early Permian (Chitnarin *et al.* 2012); ?Chaotian section, Sichuan Province, China, Wujiaping Formation, basal Wuchiapingian, Late Permian (this study, sample: 11CHAO80, see Table 1).

Remarks
Our specimens are attributed to *G. posterodorsospina* Chitnarin, 2012 from the Early Permian of Thailand (Chitnarin *et al.* 2012) but differ in having less pronounced or absent posterior cardinal angle. Some specimens present a thickened ventromedian area which could be an expression of sexual dimorphism.

Superfamily Paraparchitoidea Scott, 1959
Family Paraparchitidae Scott, 1959

Genus *Samarella* Polenova, 1952

Type species. — *Samarella crassa* Polenova, 1952 by original designation.

Fig. 15. — Ostracods from Guadalupian in South China: **A**, **B**, *Geffenina posterodorsospina*? Chitnarin, 2012; **A**, left lateral view of complete carapace, P6M3742, 11CHAO80; **B**, right lateral view of complete carapace, P6M3743, 11CHAO80; **C**, Knoxitidae sp. 1, right lateral view of complete carapace, P6M3744, sample 11CHAO171; **D**, *Knoxiella* sp. 1, right lateral view of complete carapace, P6M3745, sample 11CHAO156; **E**, **F**, *Knoxiella* sp. 2; **E**, left lateral view of complete carapace, P6M3746, sample 11CHAO80; **F**, right sublateral view of complete carapace, P6M3747, sample 11CHAO80; **G**, *Permoyoungiella*? sp. 1, right lateral view of right valve, P6M3748, sample 11CHAO172; **H**, Kirkbyoidea sp. 1, left lateral view of left valve, P6M3749, sample 11CHAO166; **I**, Kirkbyoidea sp. 2, left lateral view of left valve, P6M3750, sample 11CHAO168; **J**, Kirkbyoidea sp. 3, right lateral view of right valve, P6M3751, sample 11CHAO167; **K**, **L**, *Roundyella*? sp. 1; **K**, left lateral view of left valve, P6M3752, sample 11CHAO168; **L**, left lateral view of complete carapace, P6M3753, sample 11CHAO168; **M**, *Roundyella* sp. 2, left lateral view, P6M3754, sample 11CHAO158; **N**, *Knightina* sp. 1, right lateral view of right valve, P6M3755, sample 11CHAO173; **O**, *Knightina*? sp. 2, right lateral view of right valve, P6M3756, sample 11CHAO167. Scale bar: 100 µm.

Samarella viscusforma Chitnarin, 2012 (Fig. 16M, N)

Samarella viscusforma Chitnarin *in* Chitnarin *et al.*, 2012: 818, 819, figs 13A-E, 15.

Material examined. — 34 complete carapaces and eight broken carapaces.

Dimensions. — L=281-592 µm; H=193-477 µm.

Occurrences. — Loei Province, Northeastern Thailand, Early Permian, Phetchabun Province, Central Thailand, Early Permian and Nakhon Sawan Province, Central Thailand, Late Early Permian and Middle Permian (Chitnarin *et al.* 2012); Chaotian section, Sichuan Province, China, Maokou and Wujiaping Formations, Middle Capitanian-basal Wuchiapingian, Middle-Late Permian (this study, samples: 11CHAO 173, 11CHAO172, 11CHAO171, 11CHAO169, 11CHAO163, 11CHAO151, 11CHAO80, 11CHAO81, 11CHAO82, 11CHAO83, 11CHAO84, 11CHAO88, 11CHAO92, 11CHAO100, 11CHAO101, see Table 1).

Remarks

Variations could be quite important in carapace size, DB shape or VB convexity. The question of the presence of different species could come up. But we observe all the transitional forms between the different extreme morphotypes. So we make the choice to gather all of them in *S. viscusforma*.

Order PLATYCOPIDA Sars, 1866
Suborder PLATYCOPINA Sars, 1866
Superfamily Cavellinoidea Egorov, 1950
Family Cavellinidae Egorov, 1950

Genus *Sulcella* Coryell & Sample, 1932

Type species. — *Sulcella sulcata* Coryell & Sample, 1932 by original designation.

Sulcella mesopermiana? Kozur, 1985 (Fig. 17A)

Sulcella mesopermiana Kozur, 1985: 22, pl. 5, figs 3, 4. — Crasquin-Soleau & Baud 1998: pl. 3, figs 3, 5, 6, 9.

Material examined. — One complete carapace.

Dimensions. — L=759 µm; H=434 µm.

Occurrences. — Bükk Mountains, Hungary, Middle and Late Permian (Kozur 1985); Hydra Island, Greece, Late Permian (Crasquin-Soleau & Baud 1998); ?Chaotian section, Sichuan Province, China, Wujiaping Formation, basal Wuchiapingian, Late Permian (this study, samples: 11CHAO88, see Table 1).

Remarks

Our specimen is very similar to *S. mesopermiana* Kozur, 1985 from Middle-Late Permian of Hungary and Greece (Kozur 1985) but differs in having longer and horizontal DB, shorter PDB and more arched PB.

Sulcella suprapermiana? Kozur, 1985 (Fig. 17B, C)

Sulcella suprapermiana Kozur, 1985: 22, pl. 5, figs 6, 8. — Crasquin-Soleau & Baud 1998: pl. 4, figs 1, 3.

Material examined. — Two complete carapaces.

Dimensions. — L=624-665 µm; H=285-313 µm.

Occurrences. — Bükk Mountains, Hungary, Late Permian (Kozur 1985); Hydra Island, Greece, Late Permian (Crasquin-Soleau & Baud 1998); ?Chaotian section, Sichuan Province, China, Maokou and Wuchiaping Formations, Middle Capitanian-basal Wuchiapingian, Middle-Late Permian (this study, samples: 11CHAO166, 11CHAO81, see Table 1).

Remarks

Our specimens are very similar to *S. suprapermiana* Kozur, 1985 from Late Permian of Hungary and Greece (Kozur 1985; Crasquin-Soleau & Baud 1998) but differ in having nearly vertical PB.

RESULTS

Species distribution

Study of the 40 fossiliferous samples from the Chaotian section allowed us to identify 154 ostracod species belonging to 29 genera, 16 families, 12 superfamilies and three orders. Assemblages present a relatively high diversity at high taxonomic levels. Thirty-seven of the analysed samples yield identifiable specimens. The species distribution is presented in Table 1.

Capitanian samples record 61 species. Most of them seem to disappear gradually by the top of the L3 subunit. The M1 subunit yields only five identified species. Transition from Capitanian to Wuchiapingian, at specific level, is marked by a near complete renewal of assemblages. Only four species, presenting a rather long stratigraphic range, passed the GLB. The transition is furthermore characterised by a significant increase of diversity after GLB with 96 species recorded in Wuchiapingian samples. Thus, specific extinction rate at the GLB is about 93% and turnover rate is about 97%.

However, variations at higher taxonomic levels are quite dissimilar. From the 25 genera recorded in Capitanian samples, only 16 pass the GLB. Four genera are here found only in the Wuchiapingian. It corresponds to a "disappearance" of about 36% of genera and a 20% turnover rate. From the 16 families found in Capitanian samples, 13 are also present in the Wuchiapingian. Kellettinidae, Scorbiculidae and Youngiellidae seem to "disappear". Nevertheless these three families are known in the Late Permian from other localities, even though they are clearly in decline. Scrobiculidae are for example found, mainly represented by the genus *Roundyella*, in the Wuchiapingian of Hungary (Kozur 1985) and Iran (Mette 2008) and the Changhsingian of Israel (Gerry *et al.* 1987). Kellettinidae are known in the Wuchiapingian (i.e. genus *Kindlella* in Hungary – Kozur 1985) and the Changhsingian (i.e. genus *Kellettina* in South China – Yuan *et al.* 2007). Youngiellidae occur in the Wuchiapingian (for example with

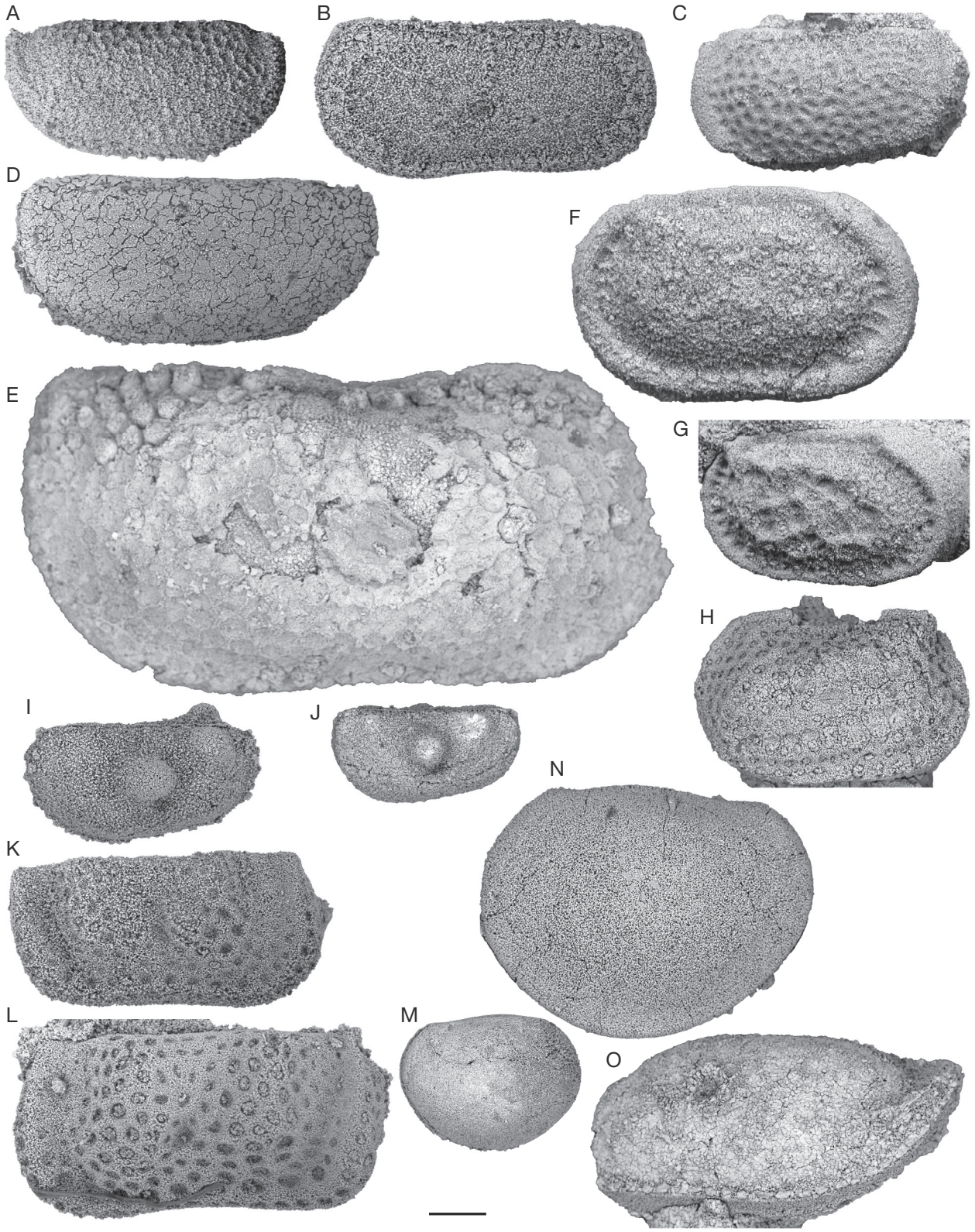

Fig. 16. — Ostracods from Guadalupian-Lopingian boundary interval in South China: **A**, *Kirkbya* sp. 1, right lateral view of complete carapace, P6M3757, sample 11CHAO172; **B**, *Kirkbya* sp. 2, left lateral view of left valve, P6M3758, sample 11CHAO164; **C**, *Kirkbya* sp. 3, left lateral view of left valve, P6M3759, sample 11CHAO166; **D**, *Kirkbya* sp. 4, left lateral view of left valve, P6M3760, sample 11CHAO158; **E**, *Kirkbya* sp. 5, left lateral view of left valve, P6M3776, sample 11CHAO88; **F**, **G**, *Reviya* cf. *subsompongensis* Chitnarin, 2008; **F**, right lateral view of right valve, P6M3762, sample 11CHAO167; **G**, right lateral view of right valve, P6M3763, sample 11CHAO166; **H**, *Neoamphissites* sp. 1, left lateral view of left valve, P6M3764, sample 11CHAO169; **I**, **J**, *Kegelites* sp. 1; **I**, left lateral view of complete carapace, P6M3765, sample 11CHAO81; **J**, left lateral view of complete carapace, P6M3766, sample 11CHAO99; **K**, **L**, *Kindlella* sp. 1; **K**, right lateral view of complete carapace, P6M3767, sample 11CHAO150; **L**, left lateral view of complete carapace, P6M3768, sample 11CHAO150; **M**, **N**, *Samarella viscusforma* Chitnarin, 2012; **M**, right lateral view of complete carapace, P6M3769, sample 11CHAO88; **N**, left lateral view of complete carapace, P6M3770, sample 11CHAO171; **O**, *Kirkbya* sp. 6, sublateral view of broken left valve, P6M3761, sample 11CHAO97. Scale bar: 100 µm.

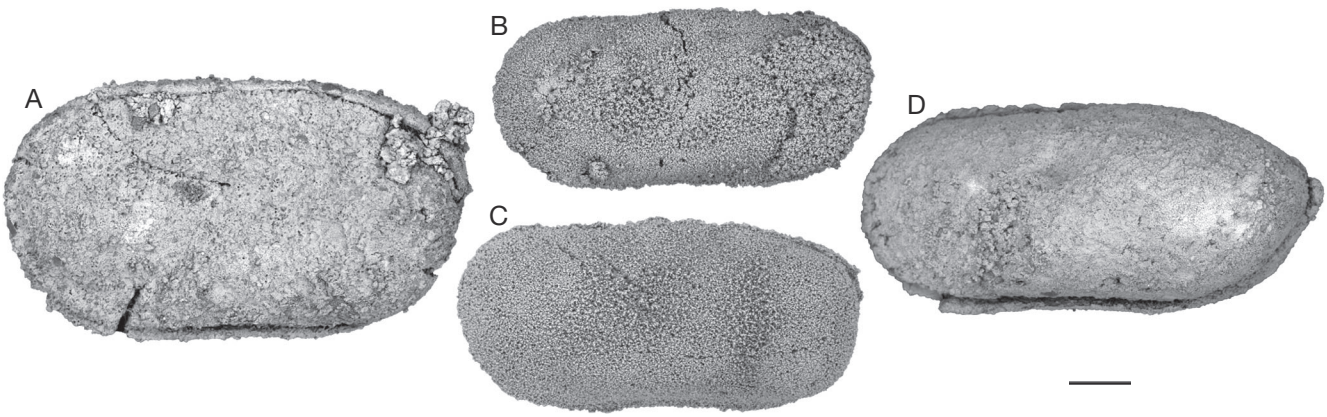

Fig. 17. — Ostracods from Guadalupian-Lopingian boundary interval in South China. **A**, *Sulcella mesopermiana*? Kozur,1985, P6M3771, 11CHAO88; **B**, **C**, *Sulcella suprapermiana*? Kozur,1985; **B**, P6M3772, 11CHAO166; **C**, P6M3773, 11CHAO81; **D**, *Sulcella* sp. 1, P6M3774, sample 11CHAO88. All photographs represent complete carapaces in left lateral view. Scale bar: 100 µm.

Permoyoungiella in Hungary – Kozur 1985 or *Youngiella* in Iran – Mette 2008) and in the Changhsingian (for example *Permoyoungiella* in China – Crasquin *et al.* 2010 or *Moorites* in Israel – Gerry *et al.* 1987).

Ostracod abundance and diversity

Ostracods are present from the upper part of the Maokou Fm "Limestone Unit" (L3 subunit, sample 11CHAO173, *Jinogondolella postserrata* conodont Zone) up to the first 27m of the Wujiiaping Formation (11CHAO101, *Codonofusiella-Reichelina* small fusuline assemblage), except in the middle part of the M1 subunit (see Material and methods).

In productive samples, abundance varies from one (11CHAO74) to 366 specimens (and 1895 undetermined fragments, 11CHAO88) and specific richness from one (11CHAO74) to 44 (11CHAO95) species. In most of assemblages the specific richness variations correlates with abundance (Fig. 20).

Ostracod faunas, from the L3 subunit of the Maokou Fm "Limestone Unit", show relatively high abundance and specific richness (11CHAO171, 361 specimens, 549 undetermined fragments; 11CHAO173, 32 species). Nevertheless, a two-step decrease of both abundance and specific richness is recorded through this interval until the "disappearance" of ostracods at the top of the "Limestone Unit" (11CHAO152).

The two productive samples of the M1 subunit (11CHAO 156 and 158, corresponding to the only two carbonate beds in the "Mudstone Unit") record relatively low abundance and diversity assemblages.

Basal six Wuchiapingian samples present the lowest abundance and specific richness recorded in the section. Indeed, except the very first Wuchiapingian sample (11CHAO72, 18 specimens belonging to one species, 11 undetermined fragments), the above samples yield only zero to six specimens (zero to 23 undetermined fragments) and no more than one identified species.

Finally, ostracod fauna recovery begins in the Wujiaping Fm around three meters above the GLB. It is marked by a two-step increase of abundance and diversity. Maximum Wuchiapingian abundance value (11CHAO88, 366 specimens, 1895 undetermined fragments) reaches the Capitanian one. The maximum of specific richness is substantially higher than Capitanian one, with the highest values recorded in the section (11CHAO95, 44 species).

Ostracods identified in Chaotian section samples belong to three orders: Podocopida, Palaeocopida and Platycopida. Palaeocopida are known to progressively disappear during the Late Permian, to become extinct after the PTB (Permian-Triassic Boundary, Crasquin-Soleau *et al.* 2004; Crasquin & Forel 2014). Thus, study of the distribution variations at order level at the GLB could bring relevant information about changes in ostracod assemblages during this poorly known period. The Figure 20 illustrates diversity and abundance variations of Podocopida and Palaeocopida along the section. Because of the too low number of Platycopida specimens found, their abundance and diversity variations are not figured here.

The Order Podocopida is the most abundant in Chaotian samples and represents 92.6% of identifiable specimens. It also presents the highest specific richness with 125 species identified corresponding to 80% of the total species recorded. These species belong to 13 genera, six families, five superfamilies and three suborders. Capitanian samples record 40 Podocopida species (Table 1). Only two of these are also found in Wuchiapingian samples, belonging to two distinct genera (*Bairdia* and *Microcheilinella*). The specific extinction rate is about 95%. Wuchiapingian samples record 86 species, twice more than Capitanian ones. Specific turnover rate is about 98%.

As they are largely dominant in samples, Podocopida abundance and specific richness variation curves follow the curves of complete assemblages (Fig. 20). Thus, high values recorded in basal samples from the upper L3 subunit (11CHAO171, 340 specimens, 26 species) also present a two-step decrease until ostracod "disappearance" at the top of L3 subunit.

The M1 subunit and the base of the Wujiaping Fm are characterised by a very low abundance and diversity phase (Table 1; Fig. 20).

The two-step "recovery", previously evoked, is also noticeable here. If maximum Wuchiapingian abundance values here reached (11CHAO88, 357 specimens) are similar to Capitanian maxima, highest Wuchiapingian specific richness values (11CHAO95, 42 species) are almost twice as great as Capitanian ones.

The Order Palaeocopida is significantly less abundant in samples with 7.2% of specimens and 18% of species (27 species). Nevertheless, it presents a relatively high generic and family level diversity with 15 genera (51.8%) and nine families (56.3%). Four Palaeocopida superfamilies belonging to two sub-orders are represented at Chaotian. Capitanian samples record 20 Palaeocopida species (Table 1). Only one of these is still present in Wuchiapingian samples, belonging to genus *Samarella*. The specific extinction rate is about 95%. Wuchiapingian samples record only eight species. Specific turnover rate is about 87.5%.

Much less abundant than Podocopida, Palaeocopida present moreover quite dissimilar distribution variations along the Chaotian section. If Capitanian abundance and specific richness are also maximum at the base of the upper L3 subunit (11CHAO173, 26 specimens, eight species), the extinction pattern differs from Podocopida. Indeed, relatively high values are also found in the middle part of this interval (11CHAO166, 18 specimens; 11CHAO167, eight species). Then abundance and specific richness decrease sharply until the "disappearance" of ostracods at the top of the L3 subunit (11CHAO163).

Unlike Podocopida, the two fossiliferous samples from the M1 subunit present here relatively high abundance values (11CHAO158, 14 specimens) but a low specific diversity (maximum two species, 11CHAO158).

The very first Wuchiapingian sample presents a relatively high abundance (18 specimens belonging to *Hollinella* genus, study in progress). Basal Wuchiapingian samples record extremely low abundance and specific richness.

Values rise rapidly to a Wuchiapingian maximum (11CHAO80) with a relatively high abundance (20 specimens) but specific richness stay really poor (three species). From that point, abundance and specific richness finally decrease and stabilise at relatively low values (zero to five specimens, zero to two species) to the top of the section.

Thus, the early Late Permian (Wuchiapingian) is here characterised by abundance and specific diversity significantly lower than those recorded in the late Middle Permian (Early/Middle Capitanian).

The Order Platycopida is the less abundant one in Chaotian samples with only seven specimens (0.2%), three species (2%) belonging to one genus (*Sulcella*). Due to the very occasional occurrences of specimens, we have not been able to distinguish any particular trend in Platycopida distribution along Chaotian section.

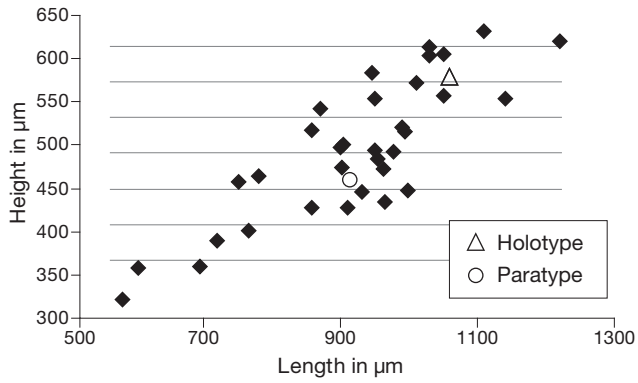

Fig. 18. — Height-length diagram of *Bairdia chaotianensis* Zazzali, n. sp.

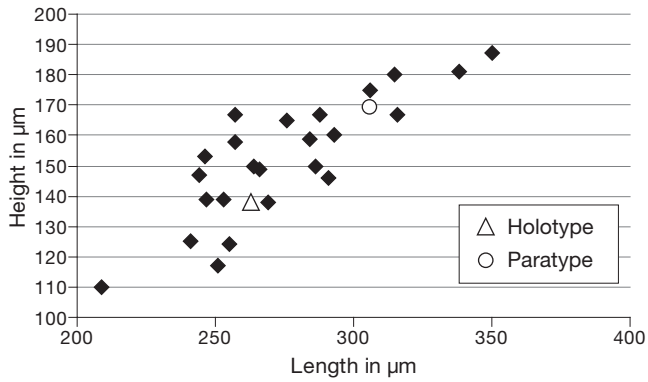

Fig. 19. — Height-length diagram of *Microcheilinella pagodaensis* Zazzali, n. sp.

DISCUSSIONS

Palaeoenvironmental changes at GLB

The L3 subunit from the "Limestone Unit" of the Maokou Fm is commonly associated with shallow-marine environment with sediments deposited on a continental shelf probably below storm wave base, within the euphotic zone (Isozaki *et al.* 2008; Lai *et al.* 2008; Saitoh *et al.* 2013a). While interpretations of these deposits seem to be a consensus, the top of the L3 subunit is the starting point of divergence between those suggesting a regression phase (Lai *et al.* 2008) and those proposing a transgression phase (Isozaki *et al.* 2008; Saitoh *et al.* 2013a). Lai *et al.* (2008) evoke an increasing degree of fragmentation of the bioclasts towards the L3 subunit, which could be in agreement with the gradual shallowing hypothesis. However, the fragment abundance does not seem to increase in our samples. In the top 5m of the L3 subunit, Isozaki *et al.* (2008) evoke a decrease of granulometry coincident with the beginning of a transgression phase. If our study could not allow, for now, to discuss about that last interpretation, we could nevertheless notice that this interval correspond to the decreasing trend of ostracod abundance and specific richness.

The "Mudstone Unit" is also a subject of controversy, presented as lagoonal deposit by Lai *et al.* (2008) and as deep sea deposit by Isozaki *et al.* (2008) and Saitoh *et al.* (2013a). Basal samples of the M1 subunit are barren of ostracods. Lai *et al.* (2008) characterised this interval by a disappearance of shallow marine taxa at the base of the "Mudstone Unit" (M1) due to a lagoonal hypersaline environment and by the presence of brachiopods at the top of the M2 subunit testifying more open-marine connections.

In our study, the ostracods of the M1 subunit are marine taxa. Furthermore, brachiopods were observed on the field

both in M1 and M2 subunits during our sampling (Fig. 4). This invalids the hypothesis of a lagoonal environment. Isozaki *et al.* (2008) and Saitoh *et al.* (2013a) evoke a basal subunit (M1) yielding abundant shallow marine taxa, such as conodonts, brachiopods, small foraminifera and ostracods and deposited in a first deepening phase. These taxa seem to have disappeared from the M2 subunit, replaced by deep marine taxa such as ammonoids and radiolarians, also with brachiopods in some beds. The ostracod associations in the two productive samples of the "Mudstone Unit" are poorly preserved but are clearly marine neritic taxa, with genera (*Kirkbya*, *Roundyella*, *Knoxiella*) characteristic of a shallow environment (Melnyk & Maddocks 1988a).

The hypothesis of a regression, during the missing Late Capitanian at Chaotian (Saitoh *et al.* 2013a), leading to an emergence phase at the top of the Wangpo Bed, is commonly accepted.

The basal part of the Wujiaping Fm is commonly presented as deposited during a rapid transgressive phase to a shallow marine environment. Samples from the base of the Wujiaping Fm yielded very few ostracods. Above the very first Wuchiapingian sample, this low abundance phase could be linked with rapid environmental changes, during a quick transgression, as proposed in the literature.

As the "Limestone Unit" of the Maokou Fm, the Wujiaping Fm is commonly associated with shallow-marine environment (Isozaki *et al.* 2008; Lai *et al.* 2008; Saitoh *et al.* 2013a). While further analyses of ostracods assemblages are needed in order to achieve precise palaeoenvironmental reconstructions, the prompt ostracod diversity recovery observed in the Wujiaping Fm suggests a rapid reinstatement of stable environmental conditions.

Faunal changes

Transition from Guadalupian to Lopingian, at Chaotian section seems coincident with important faunal changes. The passage from the "Limestone Unit" to the "Mudstone Unit", and then to the Wujiaping Fm, is marked by noticeable losses and appearances. Thus, high fusuline diversity, with presence of large forms (*Neoschwargerina*, *Lepidolina*, Isozaki *et al.* 2008) gives away to exclusively small form assemblages in the M2 subunit and in the Wujiaping Fm (Lai *et al.* 2008). Robust forms of calcareous algae, recorded in Capitanian, are replaced by more fragile forms at the base of Wuchiapingian (Lai *et al.* 2008). Crinoids, rugose corals and bivalves seem to disappear at the top of the L3 subunit (Isozaki *et al.* 2008; Saitoh *et al.* 2013a). Conodont last appearance is located in the "Mudstone Unit" (Isozaki *et al.* 2008), where taxa such as ammonoids and radiolarians are exclusively found. Then, diversity decreases radically in the first meters of the Wujiaping Fm.

Ostracod assemblages seem also clearly affected, from the Early-Middle Capitanian (L3) to the basal Wuchiapingian, by a significant decrease of abundance and diversity. If initial abundance seems to recover quickly after the GLB, it is important to notice that specific richness became even more important in Wuchiapingian records. Moreover, data present an important renewal in this interval (93% extinction rate and 96% turnover rate).

Transition from the Early-Middle Capitanian to the Late Permian seems to affect differently the Orders Podocopida and Palaeocopida.

Podocopida abundance and diversity decrease during Early Capitanian (L3 subunit), becoming extremely low in the Early-Middle Capitanian (M1 subunit) and the basal Wuchiapingian. However, recovery is recorded quite early in the Wuchiapingian sequence and specific richness reaches values twice as great as the highest ones recorded in the Capitanian. Thus, post-GLB assemblages seem more diversified.

Palaeocopida abundance also decreases at the top of the L3 subunit, but it remains relatively high in the M1 subunit fossiliferous samples and in the first Wuchiapingian sample. Specific richness decreases promptly from the middle to the top of the upper L3 subunit, not to rise significantly again. Coincidently with the Podocopida recovery, Palaeocopida abundance decreases a second time to remain low up to the top of the section. In any case, post-GLB Palaeocopida assemblages seem less diversified.

Palaeocopida are known to disappear progressively in the Late Permian, to become extinct at the basal Middle-Triassic (Crasquin-Soleau *et al.* 2004; Forel & Crasquin 2011; Crasquin & Forel 2014), while Podocopida became the predominant order during the Mesozoic-Recent period. Palaeocopida response to GLB events might here be interpreted as the first step of their early Middle-Triassic disappearance. Although this hypothesis seems in agreement with the GLB extinctions evoke in literature, additional investigations and more data from Late Capitanian (missing in this section) and from the Wujiaping Fm are needed. Data obtained in this study might, however, be interpreted as resulting from temporary and/or regional environmental changes, in agreement with the generic and family level "disappearances" recorded. Thus, these changes might have led to the establishment of environmental conditions more favourable to Podocopida than to Palaeocopida, as they present different patterns at the base of Wuchiapingian.

Further palaeoenvironnemental reconstitutions based on ostracod assemblage analysis, in addition to comparison with data from palaeogeographically distant sections, such as Penglaitan GSSP (South China) or Iran (both work in progress), will bring essential information to test these hypotheses.

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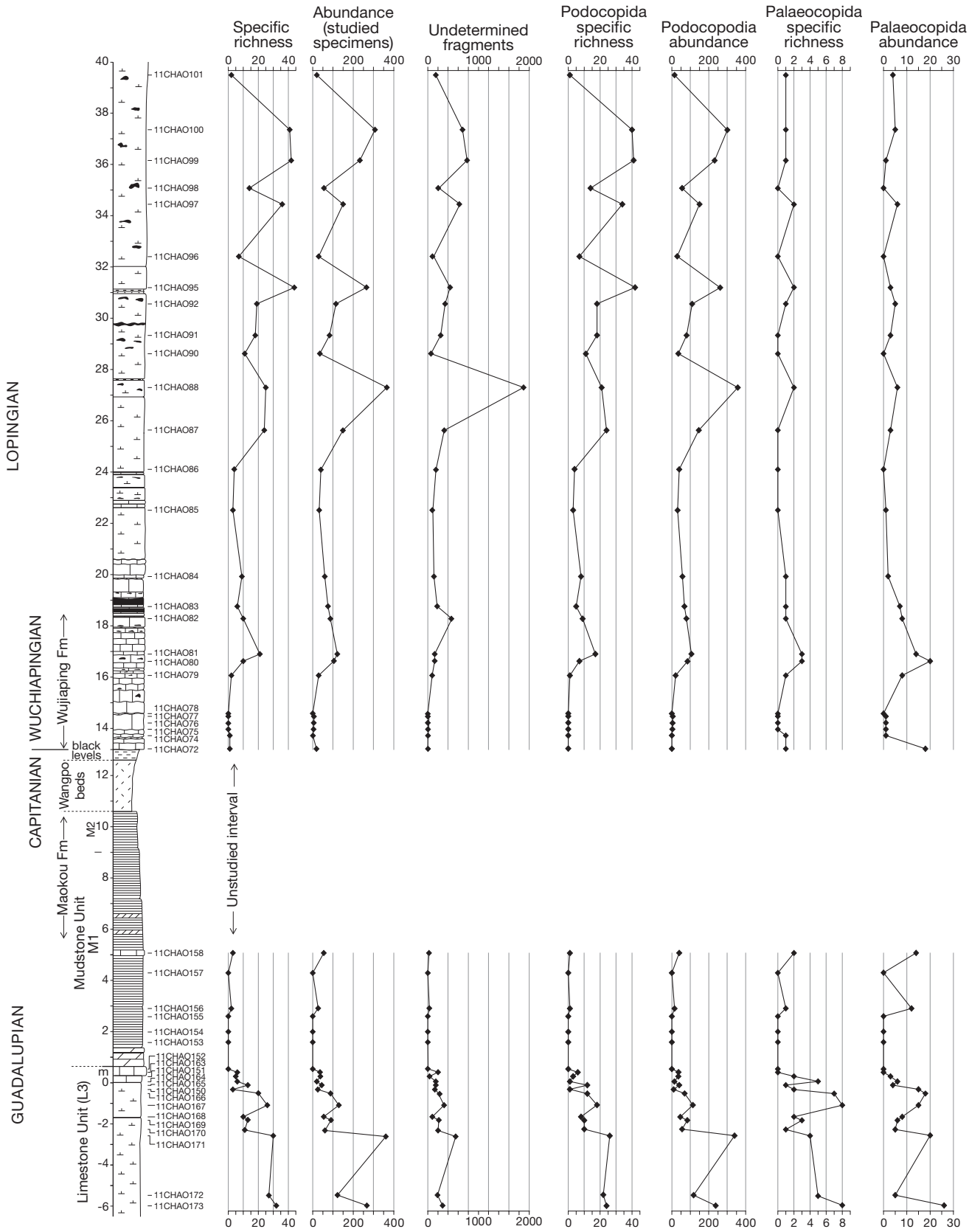

FIG. 20. — Specific richness (number of species), abundances (number of specimens) and number of unidentified fragments through Chaotian section. For lithology, same caption as Figure 4.

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