Latest Permian Deep-Water Ostracod (Crustacea) Fauna from South China

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Thèse de Doctorat

Faune d'Ostracodes (Crustacea) d'eau profonde du Permien Terminal de Chine du Sud

par

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博士学位论文

华南晚二叠世末期深水相
介形虫动物群研究

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China University of Geosciences (Wuhan)

Latest Permian Deep-Water Ostracod (Crustacea) Fauna from South China

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研究生学位论文原创性声明

Declaration of Originality

我以诚信声明：

本人所呈交的博士学位论文是在导师指导和相关项目资助下开展研究工作所取得的成果，文中所研究的华南晚二叠世深水相地层介形虫化石均系本人与课题组成员共同采集得到的原始资料，涉及介形虫的属种鉴定、古环境分析和灭绝方面的讨论均系本人独立完成；所引用他人思路、方法、观点、成果均在参考文献或脚注中进行了明确标示，所引用他人数据、图件等原始资料均已征得所有者同意，并在文中相应引用处做了详细标注，在引用前人资料基础上进行相应修改的部分也进行了说明；对本论文的顺利完成提供过帮助的相关人员也已在文中进行了说明并致以谢意。

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Faune d'Ostracodes (Crustacea) d'eau profonde du Permien Terminal de Chine du Sud

Résumé

Comme tous les organismes marins, les ostracodes subissent un changement drastique au cours de l'extinction en masse de la fin du Permien. En Chine du Sud, le Permien supérieur affleure largement. Des études précédentes ont été conduites sur la taxonomie, la biostratigraphie et le paléoenvironnement des ostracodes néritiques du Permien supérieur. C'est ici la première étude sur les ostracodes profonds du Permien supérieur de Chine et la première dans le monde sur le Permien terminal. A ce jour, les seules données disponibles sur les ostracodes profonds du Permien proviennent du Permien inférieur d'Indonésie et du Permien moyen – Wuchiapingien d'Italie.

Dans cette thèse, quatre coupes de séries profondes de Chine du Sud (Bassin du Hunan-Guizhou-Guangxi et Bassin du Yangste inférieur) sont étudiées en détail pour la taxonomie, le paléoenvironnement (paléobathymétrie et niveau de paléo-oxygénation) et les processus "d'extinction".

La taxonomie des ostracodes est le travail de base. Une faune diversifiée est représentée par 43 genres et 128 espèces. Deux nouvelles espèces *Bairdia dongpanensis* et *Spinomicrocheilinella anterocompressa* ont été décrites. Un nouveau genre *Denticupachydomella* n.gen. et deux nouvelles espèces *Pseudobythocypris guiqianensis* n.sp. et *Denticupachydomella spinosa* n.sp. sont proposés. Beaucoup de spécimens ont une conservation médiocre et ne présentent pas suffisamment de caractères pour une identification précise. Les spécimens déterminés appartiennent aux Palaeocopida, Podocopida et Myodocopida. Les espèces typiquement Paléozoïque dominent la faune et sont accompagnées de quelques formes à affinité mésozoïque (i.e. *Abrobairdia*, *Lobobairdia*). 19 espèces ont été rattachées à du matériel précédemment décrit du Dévonien supérieur au Permien supérieur d'Amérique du Nord, d'Europe et d'Asie du Sud-Est. La faune étudiée a un taux d'endémisme de 85.2%.

La paléobathymétrie est analysée à partir du modèle de Lethiers & Raymond (1991) qui utilise les proportions d'ostracodes psychrosphériques/Bairdiidea/autres espèces néritiques. 38 espèces sont considérées comme psychrosphériques. Elles appartiennent aux Bairdiidae épineux, Bythocytheridae, Tricorninidae, Berounellinidae, Rectonariidae, Pachydomellidae, Healdiidae, Quasillitidae, Polycopidae, *Discoidella* et deux espèces indetminées de podocopid. La coupe de Dongpan est la plus profonde et présente des variations de bathymétrie depuis la plate-forme externe jusqu'au milieu bathyal. Ces interprétations sont bien en adéquation avec les résultats d'autres analyses (radiolaires, sédimentologie, minéralogie et géochimie). Quelques événements locaux (courants de turbidité) peuvent perturber le signal.

Pour l'évaluation de la teneur en oxygène, le modèle FF% (pourcentage d'ostracodes filtreurs) de Lethiers & Whatley (1994) est appliqué pour la première fois à des faunes profondes. Un seul horizon dans la coupe de Dongpan présente un niveau d'oxygénation proche de la dysoxie.

En milieu néritique, un intervalle de transition, avec des faunes typiquement paléozoïques et des nouveaux venus mésozoïques a récemment été mis en évidence. Il semble que ce phénomène soit observable également en milieu profond. Il ne semble pas y avoir de phénomène de miniaturisation chez les ostracodes profonds à l'approche de la limite Permien-Trias. Dans la coupe groupée Liuqiao-Dongpan, deux horizons d'extinction sont mis en évidence. Le premier horizon correspond à la crise majeure chez les radiolaires, à la régression, à une activité volcanique intense et peut-être un niveau disoxique. Ces niveau d'extinction sont corrélés avec le GSSP de la limite Permien-Trias à Meishan. Il semblerait que les événements d'extinction soient plus précoces en milieu profond qu'en milieu néritique.

Mots clé: ostracodes, Permien supérieur, eau profonde, Chine du Sud, paléoécologie, paléobathymétrie, extinction

华南晚二叠世末期深水相介形虫动物群研究

摘　要

晚二叠世末期，发生了显生宙以来最大规模的生物灭绝事件，介形虫也同其他海洋生物一样遭受了重创。在晚二叠世地层广泛连续出露的华南，前人已对浅海相介形虫动物群在该时期的分类学、生物地层学和古环境分析等方面进行了详细的研究，积累了丰富的资料，也极大地增加了对华南晚二叠世介形虫的认识。但是，同时期深水相介形虫动物群的研究目前还未见有专门的研究报道，对于介形虫这一对其生存环境响应敏感的微体生物而言，其个体特征和生态组合都因环境不同而各异，因此深水相介形虫资料的缺乏，必将影响对介形虫动物群在晚二叠世末期这一重大地史转折期的特点的全面认识。

本论文即着眼于华南晚二叠世末期深水相介形虫动物群，选取位于湘黔桂盆地（广西东攀剖面、广西柳桥剖面和贵州晒瓦剖面）和下扬子盆地（安徽巢湖剖面）的四个深水相剖面进行系统分类学、古生态学和灭绝模式的探讨，旨在通过本研究，丰富对晚二叠世介形虫的整体认知。这是对我国晚二叠世深水相介形虫的首次研究；同时，目前在全球范围内，二叠纪深水相介形虫的研究也仅见于印度尼西亚（帝汶岛）早二叠世和意大利（西西里岛）中二叠世－吴家坪阶地层，因此本研究也是世界上首次对长兴阶深水相介形虫动物群开展的研究，将填补该时段内深水相介形虫研究的空白。

经系统分类学研究，共鉴定43属128种，其中包括2个新种（已发表）*Bairdia dongpanensis* 和 *Spinomicrocheilinella anterocompressa*，1个提名（未发表）新属 *Denticupachydomella* n.gen. 以及2个提名新种 *Pseudobythocypris guiqianensis* n.sp.和 *Denticupachydomella spinosa* n.sp.。总体上，所研究动物群以薄壳、小个体的介形虫为主，兼有壳体较厚、壳饰发育的分子（如部分土菱介科分子）；壳体多为单瓣壳，且总体保存情况不好，相当一部分壳体因保存太差而无法鉴定。从分类单元来看，动物群由古足目介、速足目介和丽足目介分子共同组成，其中速足目介所占比例最高，呈现出以古生代分子为主同时含有少量中生代分子（如：*Abrobairdia*, *Lobobairdia*）的混合动物群面貌。动物群表现出明显的地方化，地方种所占比例达85.2%，仅有19个种曾见报道于欧洲、北美和东南亚的晚泥盆世－晚二叠世地层。

通过介形虫科及超科所指示的生态意义，对介形虫动物群进行了初步的环境分析；进而，采用 Lethiers 和 Raymond（1991）提出的三角比例模型对各剖面内部及剖面之间进行了古水深变化的推测、追踪和对比。该模型基于动物群中古冷水圈型介形虫和浅海介形虫分异度的相对比例来反映古水深。古冷水圈型介形虫，即之前所认为的图林根型分子（本论文对采用“古冷水圈”而不使用“图林根”一词的理由进行了阐述，并建议介形虫工作者为避免和地质年代阶名的混淆而不再使用“图林根”一词），以薄壳、光滑或带有精美壳饰和具1－4个刺的古代分子为典型代表，一般认为可指示稳定、低能的较深水环境，古冷水圈型分子所占比例越大，一般即认为水体深度越大。根据定义，本研究中38个种可以看作古冷水圈型介形虫，它们分别属于刺状 Bairdiidae、Bythocytheridae、Tricorninidae、Berounellinidae、Rectonariidae、Pachydomellidae、

Healdiidae、Quasillitidae、Polycopidae、*Discoidella* 和两个速足目未定种。对广西东攀剖面 14 个介形虫产出相对丰富的亚层在三角比例模型图中的投点显示，东攀剖面在研究区段内发生了频繁的水深变化。贵州晒瓦、广西柳桥和安徽巢湖剖面因丰富层位太少而不足以对单个剖面进行古水深变化的追踪。但是剖面之间的对比清晰地显示出各剖面所反映的古环境之间的关系。在所研究剖面中，广西东攀剖面指示最深的水体环境，变化于外陆棚到半深海环境；晒瓦剖面次之，可能沉积于内陆棚到斜坡上部环境；巢湖剖面以光滑、薄壳、壳体狭长的土菱介分子占绝对优势，因此指示的可能是正常的开放海环境；从介形虫动物群组成来看，柳桥剖面应该是最浅水体环境下的沉积，该剖面产出部分厚壳和壳饰复杂的土菱介分子（部分为中生代先驱分子）和其他典型滨浅海型介形虫。通过介形虫动物群分析得出的上述结论得到了来自其他学科研究（放射虫研究、沉积学、矿物学和地球化学等）的证实。但是在与其他研究成果对比中，也对三角比例模型的应用提出了限定条件，该模型自身不能去除某些地区性的事件影响，比如在广西东攀剖面，浊流的注入有极大的可能带入浅海区的分子，导致浅海介形虫比例突然增加，深水动物群结构发生重组，从而影响对动物群原始面貌的真实反映。这也同时说明，在进行古环境恢复研究时，开展多学科研究的重要性。

本研究首次在深水介形虫动物群中利用介形虫的给养方式进行了海水古含氧量水平的分析。该模式之前均应用于浅海底栖介形虫动物群，基本原理是含氧量水平和滤食类分子在动物群中所占比例相关。本研究选取介形虫产出较为丰富的层位进行分析，结果显示，总体上，所研究动物群产于常氧－富氧环境。对广西东攀剖面的 19 个（亚）层进行分析表明，其中仅有 03DP4 这一层位，含有 62.5％的滤食类分子，指示贫/缺氧环境。该结论与由微量元素和有孔虫分析得出的结论相一致，从而初步证明利用该模式进行深水介形虫动物群重建含氧量水平的可行性。但是，应该指出的是，在广西东攀剖面，稀土元素 Ce 异常和遗迹化石所指示的贫/缺氧层位和上述三者并不吻合，因此，深水环境含氧量水平的重建目前仍相对困难，需要更多工作的验证。

在介形虫灭绝部分，对混生、分异度和丰度变化、小型化等几个和灭绝相关的问题进行了讨论。本研究动物群以古生代常见分子占优势，同时含有一些中生代先驱分子，呈现出混生的特点，在这一方面与同时代浅海相介形虫动物群具有可比性。但是，深水相动物群的组成仍在很大程度上有别于浅海相，表现在其古生代分子中含有部分具有很长延限带的古冷水圈型分子，这些分子多报道于晚泥盆世－早石炭世地层。这种组成上的区别必然会导致不同水体条件下介形虫动物群灭绝模式的差异。动物群的分异度和丰度在各剖面没有明显的沿剖面从下向上逐步降低的趋势，但是在二叠系－三叠系界线层未发现介形虫个体，在二叠系－三叠系界线之下分异度和丰度发生突然降低（为零）。在所研究动物群中，未观察到个体大小随层位变化而变小即“小型化”现象，对 19 个常见种（曾报道于欧洲、北美和东南亚的晚泥盆世－晚二叠世）进行个体大小的统计，结果亦未显示小型化特征，甚至本研究中部分介形虫壳体要大于其更早的同类分子。有些壳体比其更早的部分同类分子个体偏小，本研究倾向于将之视为幼年个体，原因是部分种在不同时代和产地的更早同类分子个体大小各异，比如 *Bairdia* ? sp. 6 *sensu* Bless, 1987 在本研究中个体比更早同类分子偏小，但是报道于意大利中二叠世的个体大小介于印度尼西亚早二叠世和本研究所得个体大小之间；又如 *Bairdia altiarcus* Chen 1958 在本研究中比产自华南晚二叠世浅海相地层和意大利中二叠世地层中产出的个体小，但是晚二叠世浅海相地层的个体要大于中二叠世同类分子。这种相同种在不同时代不同产地出现的个体大小相异的现象，

可能有助于认识该种的系统发育特征。另外，成年个体和幼年个体的共生进一步证明本研究动物群为原地埋藏。

对介形虫灭绝模式的具体讨论主要在广西东攀和柳桥剖面展开。由于东攀剖面上覆于柳桥剖面，因此在本部分讨论中将两个剖面连接为一个剖面（东攀&柳桥剖面）（注：中间有地层缺失）进行讨论。通过对介形虫在东攀&柳桥剖面的属级（37 个属）和种级（82 个种）地层分布图的分析，提出该动物群存在两次表象灭绝（apparent extinction）。第一次表象灭绝发生在东攀&柳桥剖面 03DP5 顶到 03DP6 底，该层之上，仅有 6 个种存活。第二次表象灭绝发生在 03DP10，该层为介形虫在东攀&柳桥剖面出现的最后层位，该层之上未发现介形虫。第一次（主要）表象灭绝面和放射虫的主灭绝幕相对应，同时沉积学、矿物学和地球化学等分析显示该层发生明显的海平面下降、强烈的火山活动和可能的贫/缺氧等地质事件，TOC 曲线亦在该层出现一个最大幅度的正偏，所有分析都突出了该层是“事件层”的特征。

最后本文对广西东攀&柳桥、浙江煤山（GSSP）和巢湖剖面的灭绝规律进行了对比讨论。煤山剖面介形虫动物群的灭绝主幕发生在 25 层底，明显滞后于东攀&柳桥剖面（据 Feng et al.（2007a）和 Zhang et al.（2007a, b），东攀剖面 03DP6 底对应于煤山剖面 24e 底）。这种滞后可能反映了介形虫动物群在不同水深条件下灭绝过程的差异。动物群在深水条件下首先灭绝，可能指示深水环境首先受到灾变事件的影响，比如一些学者提出的深海中二叠世即开始的缺氧事件到晚二叠世才影响到表层海水。另外值得注意的是，东攀&柳桥和煤山剖面的主要灭绝层都位于火山成因粘土岩之下，这可能暗示不同水体介形虫动物群灭绝都和强烈的火山活动相关。安徽巢湖剖面介形虫动物群在从第 5 层底往上分异度和丰度急剧下降，仅见个别介形虫壳体或碎片。按照剖面对比，巢湖剖面第 5 层底对应于煤山剖面第 25 层底。如果将巢湖第 5 层底视为介形虫在该剖面的主灭绝层，则同处于下扬子板块的巢湖和煤山剖面的介形虫动物群灭绝具有同步性。从而说明，古环境（水深）并非决定灭绝过程的唯一要素，古地理位置也不容忽视。

总之，本论文首次对华南晚二叠世深水相介形虫动物群进行了研究，迈出了该时段深水相介形虫研究的第一步，通过分类学、古环境分析和灭绝模式的讨论，初步系统化地勾勒出了华南晚二叠世深水相介形虫动物群的整体面貌。当然，这只是晚二叠世深水相介形虫研究的起步，要全面认识晚二叠世深水相介形虫，进而联系浅海相介形虫动物群，诠释整个介形虫动物群在晚二叠世的面貌和对事件的响应，还需要未来更多更系统化的工作。

关键词：介形虫，晚二叠世，深水相，华南，古生态，古水深，灭绝

Latest Permian Deep-Water Ostracod (Crustacea) Fauna from South China

ABSTRACT

As the other marine organisms, ostracods suffered drastic change during the end-Permian mass extinction, the largest event among the “Big Five” in the Phanerozoic history. In South China, Late Permian strata are well and widely exposed, which provides the great availability for related studies. Previous studies on Late Permian shallow water ostracod faunas in South China have been evolved in the taxonomy, biostratigraphy and palaeoenvironment. These studies have greatly increased our knowledge on Late Permian shallow water ostracods. However, the absence of studies on contemporary deep water ostracods makes it difficult to comprehensively understanding the Late Permian ostracods during that significant geological time.

This dissertation will focus on the latest Permian deep water ostracod faunas in South China and aims to enrich our understanding on Late Permian ostracods. This is the first study on the Late Permian deep water ostracods in China and on the latest Permian deep water ostracods worldwide. For the time being, the only available data on Permian deep water ostracods were from the Early Permian of Indonesia and Middle Permian-Wuchiapingian of Italy. Thus this work will fill the gap in the history of lastest Permian deep water ostracod study.

In this dissertation, four sections from the deep water strata in South China (Hunan-Guizhou-Guangxi basin and Lower Yangtze basin) are studied in detail on ostracod taxonomy, paleoecology (paleobathymetry and oxygen level) and “extinction” process.

The ostracod taxonomy was carried out as the preliminary work. The diverse faunas are represented by 43 genera and 128 species. Two new species *Bairdia dongpanensis* and *Spinomicrocheilinella anterocompressa* were described. One new genus *Denticupachydomella* n.gen. and two new species *Pseudobythocypris guiqianensis* n.sp. and *Denticupachydomella spinosa* n.sp. are proposed. In general, the ostracod faunas are dominated by small and thin-shelled individuals, although there are also some heavily shelled and strongly ornamented representatives. Many specimens are in very poor preservation and did not provide information for identifying. The recognized ostracods belong to Palaeocopida, Podocopida and Myodocopida. The typical Paleozoic species dominated the faunas accompanying with several Mesozoic forms (e.g. *Abrobairdia*, *Lobobairdia*). Compared with previous studies, 19 common species were reported from the Late Devonian-Late Permian strata of Europe, North America and Southeast Asia. Thus the studied faunas have a rather high endemic rate (85.2%).

The paleobathymetry is generally interpreted according to the families/superfamilies with the paleoecological significance. The triangular model, proposed by Lethiers & Raymond (1991), is

adopted for precisely tracing the paleobathymetric variation along each studied section and between studied sections. In this model, the paleobathymetry is suggested by virtue of the relative proportion of paleopsychrospheric and neritic species. The paleopsychrospheric species mean the ostracods with the following characters: archaic, smooth/delicately ornamented, thin-shelled and/or having one to four spines. According to the definition, in the studied faunas, 38 species are regarded to be paleopsychrospheric. They belong to the spinose Bairdiidae, Bythocytheridae, Tricorninidae, Berounellinidae, Rectonariidae, Pachydomellidae, Healdiidae, Quasillitidae, Polycopidae, *Discoidella* and the two undetermined podocopid species. The beds/sub-beds yielding relatively abundant and diverse ostracods are analysed. The analyses based on 14 sub-beds in the Dongpan Section indicated the frequent variations of the paleobathymetry. The few/barren beds in the Shaiwa, Liuqiao and Chaohu Sections were insufficient to trace the paleobathymetric variations along the section. But the comparison between sections displays, among the studied faunas, the Dongpan fauna was yielded in the deepest habitats from the outer shelf to bathyal environments, the Shaiwa fauna was in the next place and indicated a inner shelf to upper slope environment, then the Chaohu fauna dominated by thin-shelled and elongated bairdiids may represent the open-marine environments, and the last, the Liuqiao fauna indicated the shallowest normal marine environments by the presence of heavily shelled and strongly ornamented bairdiids and other typical neritic species. The paleobathymetric interpretation based on ostracods was well supported by other evidences (radiolarians, sedimentology, mineralogy and geochemistry). The comparison also implied the necessity of integration with other evidence when the triangular model is applied. Some local geoevents (e.g. turbid current) may influence the original fauna and thus distort the meaning of the assemblage.

For the oxygen level reconstruction, the FF% (percentage of the filter-feeders) model is attempted here for the first time in the deep-water fauna. This model is based on the alimentation mode of the benthic ostracods. According to this model, the oxygen level is associated with the percentage of the filter-feeders. In this study, the analyses are carried out for beds/sub-beds with relatively abundant and diverse individuals. The general oxic conditions can be inferred from the analyses. In the Dongpan Section, 19 bed/sub-beds were analysed the proportion of filter-feeders. The bed 03DP4, yielding 62.5% filter-feeders, was the unique dysoxic horizon according to the relationship between FF% and oxygen level proposed by Lethiers & Whatley (1994). This interpretation appeared accordant with the results by trace elements and foraminifera. Thus the application of FF% model seems reliable. But it should be mentioned that the oxygen level reconstruction in deep water environments seems still very difficult, because not all evidence from different methods support the same horizons. More work is needed in oxygen level reconstructing.

Before discussing the concrete “extinction” process, some hotspots related to the extinction event were evolved in this dissertation. As the contemporary shallow water ostracod faunas, the “mixed” phenomenon was also reflected by the latest Permian deep water ostracod faunas, which were dominated by typical Paleozoic species accompanying with Mesozoic forms. But the deep water faunas differed from their shallow contemporary by including the long-ranging paleopsychrospheric species, reported from the Late Devonian-Early Carboniferous strata. The difference in composition may result in various "extinction" process. The change of diversity and abundance in studied sections did not show continuous decline along the studied interval from the bottom up. But below the Permian-Triassic boundary, the diversity and abundance showed sudden decline because no ostracod was found from the topmost of Upper Permian and lowermost Triassic. The discussion on miniaturization was also carried out. In the studied faunas, the change in individual size was not observed along the section. The comparison of the 19 common species between the studied faunas and previous occurrences also did not display the miniaturization. Some individuals found in this study were even larger than their ancestors. Thus no general miniaturization occurred in the latest Permian deep water ostracods. The presence of different sizes of intraspecies individuals reflects the ontogenic lineage among different occurrences. The smaller individuals than the ancient ones are considered as the instars. The coexistence of instars and adults supports the preservation *in situ* of the studied faunas.

The concrete discussion on ostracod "extinction" was involved in the Dongpan and Liuqiao joint section due to the clear stratigraphical relationship between the two sections. According to the specific and generic distribution, two apparent extinction horizons were proposed for the Dongpan and Liuqiao faunas. The First/Major apparent extinction horizon was located at the top of 03DP5 to the bottom of 03DP6. Above this horizon only 6 ostracod species survived. The Second apparent extinction horizon was in 03DP10, above which all ostracod taxa disappeared in the Dongpan Section. The First apparent extinction horizon is corresponding to the first crisis of radiolarians, the regression, the strong volcanic activities and possible anoxia/dysoxia. And the TOC curve showed the largest positive excursion in this horizon. All studies highlighted this "event horizon".

The "extinction" process was compared between the Dongpan and Meishan Sections. The delay of the "extinction" in the Meishan Section was revealed. In the Dongpan Section, the First/Major apparent extinction took place at the bottom of 03DP6, which is corresponding to the boundary of 24d and 24e in the Meishan Section. In the Meishan Section, the major ostracod "extinction" occurred at the bottom of the bed 25. The delay of "extinction" in the Meishan Section may indicate that the deep water area was earlier affected by the catastrophic events, such as the anoxia. Both the major "extinction" horizon in the Dongpan and Meishan Section was underlied the volcanic ash bed. This may indicate that the ostracod "extinction" in both sections were associated with the volcanic activities. The comparison between Dongpan, Meishan and Chaohu faunas displays the role of paleogeography in the "extinction". In the Chaohu Section, the bed CH5 is corresponding to the bed 25 of the Meishan Section (stratigraphical correlation based on the "sandwich" PTBST) and ostracods rapidly declined in diversity and abundance at the bottom of bed CH5. This synchronism between the Chaohu and Meishan indicated that the paleoenvironment was not the only definitive factor for the "extinction" process. The paleogeography also played an important role. The reason resulting in the similarities and differences by the paleogeography is still pendent. However, without doubt, the variety of "extinction" between the different paleoenvironments and paleogeographical localities, indicates the necessity of the research on

deep water ostracods, comparing the shallow water contemporaries with relatively abundant data (although systematic collation and revision are necessary).

Key words: ostracoda, Late Permian, deep-water, South China, paleoecology, paleobathymetry, extinction

Contents

Preface

Ostracod, a small bi-valved animal, is one of the most widespread and diverse crustaceans with 33,000 living and fossil species (Holmes & Chivas, 2002, p.5). These small crustacean have a long temporal repartition since the Ordovician and a vast spatial distribution in all aquatic and some semi-terrestrial environments. Both the ostracod individual and assemblage has a sensitive relationship with all (paleo)physiochemical conditions of their habitats. Thus ostracoda play an important role in (paleo) environmental reconstructions, especially during the great transitional interval of the geological history.

Brief review on Late Permian ostracod study in South China

The end-Permian mass extinction was the largest event among the “Big Five” during the Phanerozoic history (Sepkoski, 1981; Erwin, 1994). As the other marine organisms, ostracods suffered drastic change (Wang, 1978; Hao, 1994, 1996; Wang & Wang, 1997; Crasquin-Soleau *et al.*, 2004, 2007; Yi, 2004).

In South China, Late Permian strata are well and widely exposed. Many previous studies on Late Permian shallow water ostracod faunas in South China have been evolved in the taxonomy, biostratigraphy and palaeoenvironment (Wang, 1978; Chen & Shi, 1982; Shi & Chen, 1987, 2002; Becker & Wang, 1992; Hao, 1992a, 1993, 1994, 1996; Yi, 1992, 1993, 2004). These studies have greatly increased our knowledge on Late Permian shallow water ostracods of South China. Ostracoda are very sensitive to their habitats and greatly vary in different environments. For drawing a general conclusion, the thorough investigations in deep water ostracod faunas are indispensable.

The other problem, which restricts our comprehensive understanding on Late Permian ostracods, is the very poor knowledge on ostracods during the Permian-Triassic events in South China. This problem obviously emerges when we discuss the ostracod extinction. For example, Jin *et al.* (2000) proposed the “sudden extinction” in ostracod fauna of the Meishan Section (GSSP) during the Permian-Triassic events. Note that the Changhsingian ostracods in the Meishan Section were systematically studied even though the revision is necessary (Shi & Chen, 1987). In contrast, ostracods from the Permian-Triassic boundary and Lower Triassic were poorly investigated. Thus the results were probably influenced by the low research extent on ostracods from the Permian-Triassic boundary interval and did not mean real extinction at all. At present, in South China, the available data are focused on either the Late Permian (e.g. Shi & Chen, 1987, 2002) or the Early-Middle Triassic (e.g. Zheng, 1976, 1988) ostracods. In the few reported ostracod faunas spaning the Permian-Triassic boundary (Wang, 1978; Yi, 1992, 2004; Hao, 1994, 1996; Wang & Wang, 1997), only the lowermost Triassic was involved. Thus it is difficult to trace the ostracod evolution during the Permian-Triassic events.

In a word, the expansion in two aspects is important for Late Permain ostracod study in South China. The first is to expand studies on faunas from different paleoenvironments. The other expansion is to choose the ostracod faunas completely spaning the Permian-Triassic events as the study objective. This thesis will focus on latest Permian deep water ostracod faunas in South China. The second expansion has been evolved in the author's new project and will be carried out in the future work.

This dissertation: significance, study area, method and acquired results

With a view to the first expansion, this dissertation will focus on the latest Permian deep water ostracod faunas in South China for the first time and aims to enrich our understanding on Late Permian ostracods. In addition, it should be noticeable that the only world-wide data available on Permian deep-water ostracods were from the Early Permian of Timor, Indonesia (Gründel & Kozur, 1975; Bless, 1987) and Middle Permian-Wuchiapingian of Sicily, Italy (Kozur, 1991a, b; Crasquin-Soleau *et al.*, 2008). Thus this study will also fill the gap on the latest Permian deep water ostracod faunas worldwide.

In this dissertation, four sections from the deep water strata in South China are studied in detail for latest Permian deep water ostracods, i.e. the Dongpan Section and the Liuqiao Section from Guangxi, the Shaiwa Section from Guizhou and the Chaohu Section of Anhui deposited in the lower Yangtze basin. The following table shows the preparative work in the earlier stage of this dissertation.

WHAT	HOW MANY	WHO
Field work	4 times, 30 days	Group work
Investigated sections	5	Group work
Collected microfossil samples	254	Group work
Collected macrofossil samples	Several hundreds	
Collected samples for geochemical analysis	80	
Processed samples	255	Group work
	154	My own work
Picked samples	470	My own work
Attained ostracod individuals	4839	My own work
Scanned photos	1383	My own work

In method, this dissertation is characterized by the combination of ostracod study and integrated analyses. For ostracod study, the systematic taxonomy is carried out as the preliminary work and then the paleoenvironments (paleobathymetry and oxygen-level) are reconstructed based on the ostracod taxa and assemblages. The paleoenvironmetal results are then compared and integrated with different data (other fossils, sedimentology, mineralogy, geochemistry) of intra-section. Afterwards, the comparison is evolved between studied faunas. At last, the similarity and difference are discussed to the contemporary shallow water ostracod faunas and the deep water ostracod faunas in other geological time.

Through the above mentioned studies, four main achievements are obtained in this dissertation.

(1) Systematic taxonomy is carried out for the four studied ostracod faunas. The diverse fauna (43 genera, 128 species) greatly substantiates our understanding on the latest Permian deep water ostracods for the first time.

(2) Ostracods are successfully applied in the paleobathymetric and oxygen-level reconstruction in the latest Permian deep water strata. The paleobathymetric results are accordant to those from radiolarians, sedimentology and mineralogy. The oxygen-level reconstruction, based on the FF% model (see §4.3), is firstly applied in the deep water ostracod fauna. Although its usability needs further validation, the corresponding with foraminifer and trace element analyses still aroses our confidence to this model.

(3) The ostracod "extinction" in the deep water faunas is discussed herein. Two apparent extinction horizons are proposed for the Dongpan fauna. The First (major) apparent extinction was accordant to the regression event, strong volcanic activities and possible anoxia/dysoxia in the Dongpan Section. This proposition steps the primary foot on understanding the deep water extinction in the Permian-Triassic boundary interval.

(4) The studied deep water ostracod faunas are compared to the contemporary shallow water ostracod faunas in composition, paleoecological assemblage, diversity, abundance and "extinction" process. Both the similarities and differences, revealed through the comparison, demonstrate the necessity of deep water ostracod research for comprehensive understanding the ostracod faunas.

Chapter 1 Regional Geology and Stratigraphic Correlation

The geographical domain of South China spans over Guangdong, Guangxi, Guizhou, Sichuan, Hunan, Hubei, Jiangxi, Zhejiang, Fujian and some parts of Yunnan, Anhui and Jiangsu (Fig.1-A). Geologically, the South China Block, is bordered to the North China Block by the Qinling-Dabie orogenic belt on the north, bounded by the Songpan-Ganzi orogenic belt on the northwest, bordered to the Siamo Block by the Ailaoshan suture zone on the southwest and the Indochina Block by the Songma suture zone on the south (Ren, 1980; Metcalfe, 1996, 2002; Yin *et al.*, 1999； Ingersoll *et al.*, 2002; Wang, 2004; Lehrmann *et al.,* 2005).

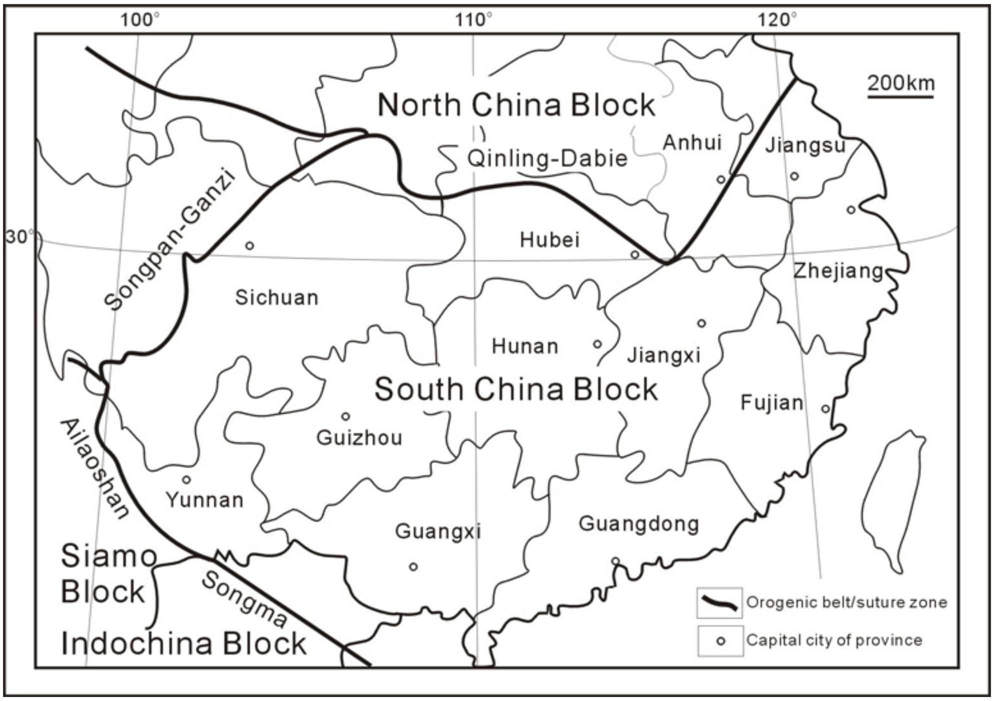

Fig. 1-A Geographical and geological sketch map of South China

(after Wang, 2004, Fig. 1.1; Lehrmann *et al.*, 2005, Fig.1)

The continuous Changhsingian strata are well and widely developed in South China. A variety of facies have been recognized, including the terrestrial, the littoral, the carbonate platform, the slope and the basin (trough) facies. The basin facies were distributed mainly in three basins, southern Qinling basin, lower Yangtze basin and the Hunan-Guizhou-Guangxi basin (Feng *et al.*, 1994; Feng & Gu, 2002; Wang, 2004; Wang & Cao, 2004). Deep water sediments* are well exposed in these regions especially in Guizhou and Guangxi. In this work, four sections in two of these basins were chosen for latest Permian deep water ostracod study, i.e. the Dongpan Section and the Liuqiao Section from Guangxi, the Shaiwa Section from Guizhou and the Chaohu Section of Anhui deposited in the lower Yangtze basin (Fig.1-B).

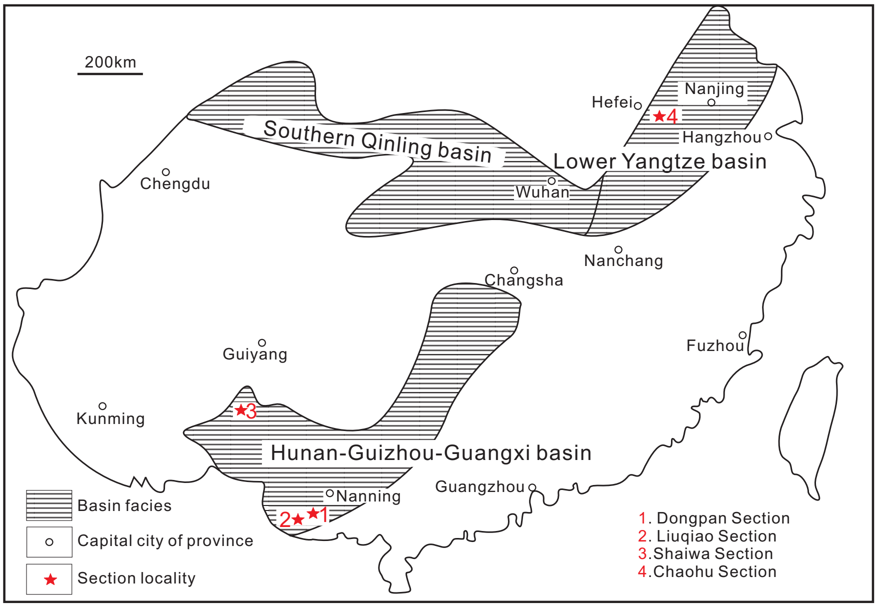

Fig.1-B: Sketch map showing the Changhsingian basins of South China and studied sections in this work (after Wang *et al.*, 1994; Wang, 2004)

§ 1.1 Description of sections

1. 1. 1 Dongpan Section (DP) & Liuqiao Section (LQ)

During the Late Paleozoic, western Guangxi was in the open marine to pelagic environment. The present shallow-water platforms were islands interspersed among the open marine (Kuang & Wu, 2002). Wu *et al.* (1994) and Wu (1999) interpreted the western Guangxi as archipelago through the studies on sedimentary rocks and volcanics. In addition, regional geological survey investigated that the patch reef on the margin of the platform was surrounded by the deep-water siliceous rocks and calcareous

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[*] Deep water facies here implies the sedimentary environment with siliceous rocks and siliceous mudstones widely distributed and radiolarians abundantly yielded. It is not strictly equal to the basin facies. In Chapter 3, the interpretation through ostracods yielded in the deep water sediments provides more new information for understanding the deep water facies in South China.

turbidites. In Bunong, 20 km west away from the studied area, the basalt with thickness of 100m was recognized. The presence of *Palaeofusulina* sp. yielded in the limestone interlayered with the basalt, suggests the rift tectonic background during the Changhsingian. Eastwardly, the basalt becomes thinner and turned to be tuff in the studied area. Then, in the studied area, the archipelagic palaeogeography constituted of deep-water basin and shallow platform is widely confirmed and adopted.

In southwestern Guangxi, the Late Palaeozoic strata are well exposed. The lowermost strata are the open carbonate platform sediments deposited in the Carboniferous to the Middle Permian. The Dongwu Tectonic Movement gave rise to multi-facies sedimentary. The reef facies in some areas lasted until latest Permian. During the Late Permian, the carbonate platform was broken and dropped. Along with the areal tectonic uplift, the reef on the margin of the platform not submerged was interspersed in the deep water basin. In Dongluo, north to the studied sections, coal-bearing nearshore to marsh sediments retained all the time. Most strata of the studied sections were dominated by siliceous organic limestones in the confined platform facies during the Wuchiapingian and deep water siliceous rocks, siliceous mudstone and organic limestone in the Changhsingian. The Early Triassic sediments consist of mudstones, muddy limestones and nodule limestones and graduate to brecciated limestones. The Middle Triassic is mainly composed of terrigenous clastic turbidites (Kuang & Wu, 2002).

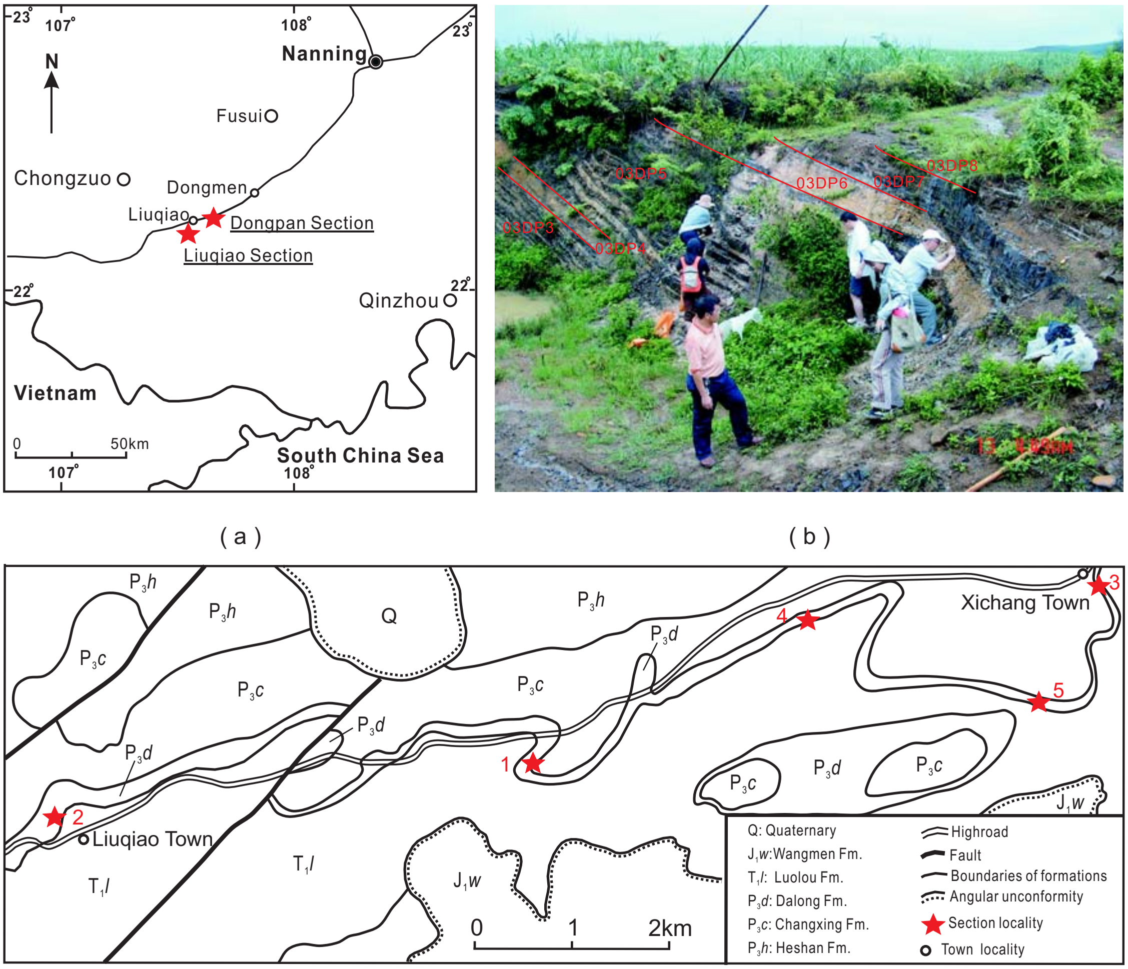
The Dongpan Section (22°16.196′ N, 107°41.505′ E) is located approximately 5km southwest of Dongpan Village, Liuqiao Town, Fusui County, southwestern Guangxi (Fig. 1-1-A (a)). It is adjacent to the milepost of 884.5km on the 322 national highway between Hengyang, Hunan and Youyiguan, Guangxi. The Liuqiao Section is situated along the highway in Liuqiao Town and near the Dongpan Section (Fig. 1-1-A (a)). It is very convenient for working in the two sections.

Dongpan Section displays a continuous uppermost Permian (upper Dalong Formation) to lowermost Triassic (Luolou Formation) sedimentary sequence (Fig. 1-2) (BGMRGZAR, 2001). The Dalong Formation, as exposed, is 11.2m thick and divided into 12 beds. The Dalong Formation is mainly composed of thin-bedded siliceous rocks, muddy siliceous rocks and siliceous mudstones with claystones interlayered. The age of the Dalong Formation, determined by the associated radiolarians (*Neoalbaillella optima* zone in the beds from 03DP2 to 03DP6 (Yao *et al.* 2001)) and ammonoids (*Huananoceras* cf. *perornatum* Chao and Liang, *Laibinoceras* cf. *compressum* Yang (Yang *et al.*, 1987), *Qianjiangoceras* sp. at the top of the bed 03DP12), is Late Changhsingian (Feng *et al.*, 2004, 2006, 2007a; He *et al.*, 2005; Meng, 2005; Jin *et al.*, 2007; Zhang *et al.*, 2007a, 2007b). The Triassic Luolou Formation overlies the Dalong Formation in conformity. The lithology of the Luolou Formation is represented by interbedded yellow mudstones, grey claystones, grey thin-bedded calcareous mudstones and muddy limestones. The Early Triassic age was proved by the Triassic ammonoids *Ophiceras* sp., *Ophiceras tingi* Tien and the bivalve *Claraia dieneri* Nakazawa yielded from the base of the bed 03DP13 (He *et al.*, 2005).

In Liuqiao Section, only uppermost Permian (upper Dalong Formation) is exposed (Fig. 1-2). The upper Dalong Formation is mainly composed of muddy siliceous rocks and siliceous mudstones interlayered with mudstones in the upper part and intercalated by claystones in the lower part. The

Changhsingian age of the Dalong Formation in Liuqiao Section is also determined by the radiolarian *Neoalbaillella optima* zone.

The detailed stratigraphic descriptions for each bed of the Dongpan Section and Liuqiao Section are displayed as follows (Fig. 1-1-A (b), Fig. 1-2) (further information about the lithology for each sub-bed see Meng *et al.*, 2005a). In each section, the descriptions are from top to bottom.



(a) (b)

(c)

Fig.1-1-A: (a) Location of the Dongpan Section and the Liuqiao Section (after Yuan *et al.*, 2007); (b) The photo of the Dongpan Section; (c) Geological map showing the investigated sections: 1. Dongpan Section; 2. Liuqiao Section; 3. Xichang Section; 4. Paibi Section; 5. Balong Section.

Dongpan Section

Luolou Formation (T_1l) **total measured thickness 525.5cm**

03DP16 - brown calcareous mudstones in the lower part and grey mudstones with darkish grey thin-bedded muddy limestones interlayered in the upper part, yielding fossils: a few bivalves *Claraia guizhouensis* Chen, *C.* cf. *wangi* and *C. griesbachi* and ammonoid *Ophiceras* sp. 100cm

03DP15 - grey mudstones interlayered by darkish grey thin-bedded muddy limestones, composed of two cycles, the limestone layer increasing from the bottom up 140cm

03DP14 - grey thin-bedded calcareous mudstones intercalated by silty calcareous mudstones, a few ammonoids and bivalves yielded 110cm

03DP13 - yellow calcareous mudstones and grayish, white claystones interlayered, yielding fossils: ammonoids *Ophiceras tingi* Tien at the bottom and bivalves *Bakevellia* sp., *Claraia dieneri* Nakazawa, *Eumorphotis* sp., *Palaeoneilo* sp. and *Posidonia* sp. 175.5cm

——————— **Conformity contact** ———————

Dalong Formation (P_3d) **total measured thickness 1120cm**

03DP12-3 - celadon thin-bedded mudstones, single layer thinner than 6 cm, some silt (3%) contained, yielding fossils: a few radiolarians *Copicyntra, Palaeolithocyclia*, ammonoids *Huanannoceras* cf. *perornatum* Chao &Liang, *Laibinoceras* cf. *compressum* Yang and *Qianjiangoceras* sp. and bivalves *Claraia* sp., *Euchondria jingxianensis* Gu & Liu, *Posidonia* sp., *Nuculopsis* sp., and *Nuculopsis* cf. *yangtzensis* (Frech) 55cm

03DP12-2 - caesious and grey claystones 1.5cm

03DP12-1 - celadon thin-bedded mudstones containing some silt, with a layer of caesious sphenoid claystone at the bottom, yielding fossils: a few radiolarians *Copicyntra* and *Palaeolithocyclia* and bivalves 10cm

03DP11 - yellow thin-bedded silty mudstones, ammonoids and radiolarians *Entactinosphaera, Copicyntra* and *Palaeolithocyclia* yielded 10cm

03DP10 - celadon to darkish green thin-bedded siliceous mudstones interlayered with grey claystones, yielding fossils: a few ammonoids, gastropods, radiolarians *Copicyntra, Hegleria, Palaeolithocyclia* and *Entactinia*, brachiopods *Costatumulus* sp., *Dongpanoproductus* sp., *Martinia* sp., *Paracrurithyris pigmaea* (Liao), *Permophricodothyris* sp., *Pygmochonetes* sp., *Schuchertella* sp. and *Spinomarginifera* sp. and ostracods *Bairdia* sp.4, *Discoidella xingyangensis* Zhang, *Fabalicypris* cf.*minuta* Cooper, *Pseudobythocypris guiqianensis* n.sp., *Spinomicrocheilinella anterocompressa* Yuan & Crasquin-Soleau, etc. 53cm

03DP9 – celadon thin-bedded siliceous mudstones, silty mudstone and grey claystones interlayered, yielding fossils: radiolarians *Copicyntra* and *Entactinosphaera*, brachiopods *Anidanthus* sp., *Cathaysia* sp., *Costatumulus* sp., *Dongpanoproductus* sp., *Martinia* sp., *Paracrurithyris pigmaea* (Liao), *Permophricodothyris* sp., *Pygmochonetes* sp., *Schuchertella* sp., *Spinomarginifera* sp., bivalves and bryozoans 34cm

03DP8 – green thin-bedded siliceous mudstones and yellow calcareous mudstones interlayered, with a layer of claystones in the lower part, yielding fossils: radiolarians *Copiconica*, *Foremanhelena circula, Hegleria mammilla*, *Ishigaum* sp., *Palaeolithocyclia*, *Paroertlispongus fontainei* and *Triplanospongos musashiensis*, brachiopods *Anidanthus* sp., *Cathaysia* sp., *Costatumulus* sp., *Dongpanoproductus* sp., *Martinia* sp., *Orthotichia* sp., *Paracrurithyris pigmaea* (Liao), *Schuchertella* sp. and *Spinomarginifera* sp. and bivalves *Euchondria dalongensis* Yin and *Leptochondria intermidia* Yin 18.5cm

03DP7 - darkish-grey and -celadon thin-bedded siliceous mudstones, higher siliceous content in the upper part, a great number of well-preserved brachiopods *Anidanthus* sp., *Cathaysia* sp., *Costatumulus* sp., *Dongpanoproductus* sp., *Martinia* sp., *Orthotichia* sp., *Paracrurithyris pigmaea*, *Permophricodothyris* sp., *Pygmochonetes* sp., *Schuchertella* sp. and *Spinomarginifera* sp. and trace fossils yielded, a few radiolarians *Copicyntra, Copicyntroides* sp., *Entactinia, Entactinosphaera, Hegleria mammilla*, *Ormistonella rubusta, Palaeolithocyclia* sp. and *Uberinterna virgisphinosum* yielded 60cm

03DP6 –interlayered darkish yellow thin-bedded muddy siltstones, yellow mudstones and grey lentoid claystones 46.5cm

03DP5 –interlayered grey to celadon thin-bedded siliceous mudstones, muddy siliceous rocks and grey claystones, a layer of turbidite limestone near the top, yielding fossils: radiolarians *Albaillella triangularis, Albaillella levis, Albaillella yaoi yaoi*, *Neoalbaillella optima* and *Neoalbaillella* sp., brachiopods *Costatumulus* sp., *Fanichonetes* sp., *Martinia* sp., *Paracrurithyris pigmaea*, *Pygmochonetes* sp. and *Spinomarginifera* sp. and abundant ostracods Bairdiidae, *Pseudobythocypris guiqianensis* n.sp., *Spinomicrocheilinella* spp., etc. 144cm

03DP4 - yellow calcareous mudstones and silty mudstones, radiolarian *Albaillella triangularis* and ostracods *Healdia* sp.1, *Permoyoungiella* ? sp.1 and *Spinomicrocheilinella* sp.1 yielded 27cm

03DP3 – black muddy siliceous rocks and grey claystones interlayered in the upper part, black siliceous rocks and mudstones interlayered in the lower part, with a layer of turbidite limestones at the bottom, radiolarians *Albaillella triangularis, Albaillella levis*, *Albaillella* sp.and *Neoalbaillella optima* and abundant ostracods yielded 146.5cm

03DP2 –intercalated mudstones and muddy siliceous rocks, yielding fossils: radiolarians *Albaillella triangularis, Albaillella yaoi yaoi, Neoalbaillella optima, Neoalbaillella miniscuta* and and brachiopods *Costatumulus* sp., *Martinia* sp., *Paracrurithyris pigmaea*, abundant ostracods Bairdiidae, Kirkbidae, *Spinomicrocheilinella* spp., *Pseudobythocypris* spp., etc. 437cm

03DP1 - yellow silty mudstones, siliceous mudstones and grey claystones, with a layer of turbidite limestones near the top >77cm

Base unknown

Liuqiao Section

Dalong Formation (P_3d) total measured thickness 903cm

Top unknown

LQ53 – grey siliceous mudtones intercalated with mudstones	> 200cm
LQ52 – grey mudstones	10cm
LQ51 – grey siliceous mudtones	6cm
LQ50 – darkish yellow mudstones and tuff	19cm
LQ49 – grey siliceous mudstones intercalated with a layer of claystones	10cm
LQ48 – mudstones	8cm
LQ47 – muddy siliceous rocks in white weathering color	17cm
LQ46 - grey claystones	4cm
LQ45 – darkish grey siliceous mudstones	5cm
LQ44 – mudstones	3cm
LQ43 – celadon siliceous mudstones interlayered with mudstones	22cm
LQ42 – grey mudstones in the upper part and darkish yellow mudstones in the lower part	12cm
LQ41 – siliceous mudstones and mudstones interlayered	14cm
LQ40-LQ28 – darkish siliceous mudstones and mudstones interbedded	121cm
LQ27 – celadon muddy siliceous rocks	6cm
LQ26 – grey claystones	5cm
LQ25 – calcareous siliceous mudstones	7cm
LQ24 – grey siliceous mudstones	9cm
LQ23 – darkish yellow tuff interlayered by darkish grey siliceous mudstones	50cm
LQ22 – siliceous mudstones intercalated mudstones and a few lentoid claystones	60cm
LQ21 – grey claystones	4cm
LQ20 – darkish grey siliceous mudstones and grey claystones interlayered	31cm
LQ19 – mudstones intercalated by muddy siliceous rocks and lentoid limestones	28cm
LQ18-LQ12 – muddy siliceous rocks and claystones interbedded	88cm
LQ11 – celadon mudstones interlayered with claystones and a few lentoid limestones	60cm
LQ10 – grey claystones	2cm
LQ9 – celadon muddy siliceous rocks	15cm

LQ8 – claystones and muddy siliceous rocks interlayered, with a few lentoid limestones intercalated	20cm
LQ7-LQ2 – muddy siliceous rocks and claystones interbedded	51cm
LQ1 – yellow silty mudstones	10cm

Base unknown

1. 1. 2 Shaiwa Section (SW)

The Shaiwa Section is located in Shaiwa Village, 15km northwestern of Houchang Town, Ziyun County, southwestern Guizhou (Fig.1-1-B) (i.e. the Sidazhai Section in Gao *et al.* (1999), Yang *et al.* (2000) and Gu *et al.* (2002), due to its locality, the designation of Shaiwa Section is adopted here following Feng & Gu, 2002; Gao *et al.,* 2005; Chen *et al.*, 2006).

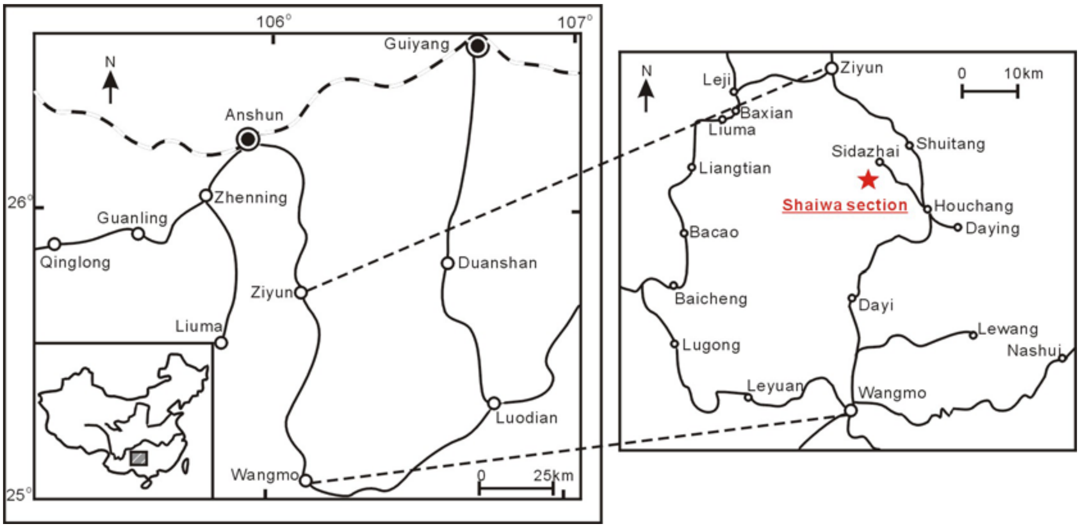


Fig.1-1-B: Location of the Shaiwa Section (modified after Gao *et al.*, 2005 and Chen *et al.*, 2006)

During the Late Permian, southwestern Guizhou was situated at the NW-trending Shuicheng-Ziyun aulacogen in the Nanpanjiang basin on the southern margin of the Yangtze platform (Fig.1-B). This aulacogen became a deep water trough during the Changhsingian.

Changhsingian deep water sediments are well exposed in Shaiwa Section along a road with a huge thickness of 762m (Yin *et al.*, 1999; Gao *et al.*, 2001; Wang *et al.*, 2006). Most of the Changhsingian deep water strata, composed of siliceous rocks and siliceous mustones, are named as Dalong Formation in South China (detailed discussion about the sedimentary facies of the Dalong Formation see Yin *et al.*, 1995, p.62-68). However, in southern Guizhou, the strata are recognized as Shaiwa Group (BGMRGP, 1987; Jin *et al.*, 2000; Feng & Gu, 2002) which is turbidity current deposit mainly consisting of siliciclastic and carbonate clastic sediments. The Shaiwa Group is divided into 95 beds belonging to four members as follows (Gao *et al.*, 2005; Chen *et al.*, 2006). The descriptions for the section below are from top to bottom.

Luolou Formation (T_1l)

——————— **Conformity contact** ———————

Shaiwa Group (P_3) **total thickness 762m**

Member IV (1-22) – interbedded siliceous mudstones, mudstones and limestones
Member III (23-48) – interbedded siltstones and mudstones with minor siliceous and argillaceous cherts
Member II (49-69) – siltstones and pebbly siltsonte with muddy siltstone and siliceous mudstone
Member I (70-95) – grey, thin-bedded siliceous mudstones interbedded with mudstones and siltstones

——————— **Conformity contact** ———————

Sidazhai Formation (P_2)

The Wuchiapingian age of the Member I is determined by the appearance of ammonoid genus *Tauroceras*. The conodont *Clarkina wangi* reported from the top of the Member II indicates the beginning of the Changhsingian. The presence of the zonal conodont species for the late Changhsingian *Clarkina changxingensis* (Wang & Wang) in the Member III and the typical brachiopod species and radiolarian zone *Neoalbaillella ornithoformis* confined to the late Changhsingian discovered in the Member IV furtherly determined the age of Changhsingian in the top of the Member III. The bivalve assemblage is also correlated to other Changhsingian bivalve assemblages (Hao *et al.*, 1999; Yang & Gao, 2000; Gao *et al.*, 2001, 2005; Wang & Shang, 2001; Feng & Gu, 2002; Gu *et al.*, 2002; Chen *et al.*, 2006). In this work, all samples were collected from the upper part (Bed 1 to Bed 5 in Chen *et al.*, 2006) of the Member IV (Linghao Formation). The strata are exposed 11.4m and subdivided into 13 beds and 87 sub-beds (Fig. 1-2). Lithology of each sub-bed has been described in Gu (2002).

1.1.3 Chaohu Section (CH)

The Chaohu Section (i.e.West Pingdingshan Section, the GSSP candidate of the Induan-Olenekian boundary) is situated 5km northwest of Chaohu City, Anhui Province. There are railway and highway to connect with other big cities, e.g. about 60km southeast to Hefei City, the capital of Anhui Province (Fig.1-1-C (a)) (Tong & Zhao, 2005; Gui *et al.*, submitted).

During the Late Permian, the Chaohu area was situated in the northern margin of the Lower Yangtze basin (Fig.1-B). The stratigraphical sequence is exposed from the Upper Precambrian (Sinian) to Middle Triassic except for the absence of the Lower-Middle Devonian. This area began to receive terrestrial instead of marine sediments or be eroded since the Middle Triassic. All strata were folded as the Mt.Majiashan-Mt.Pingdingshan Syncline during the Indosinian Movement in the Late Triassic (Tong & Zhao, 2005; Tong *et al.*, 2005; Li *et al.*, 2007; Zhao *et al.*, 2008).

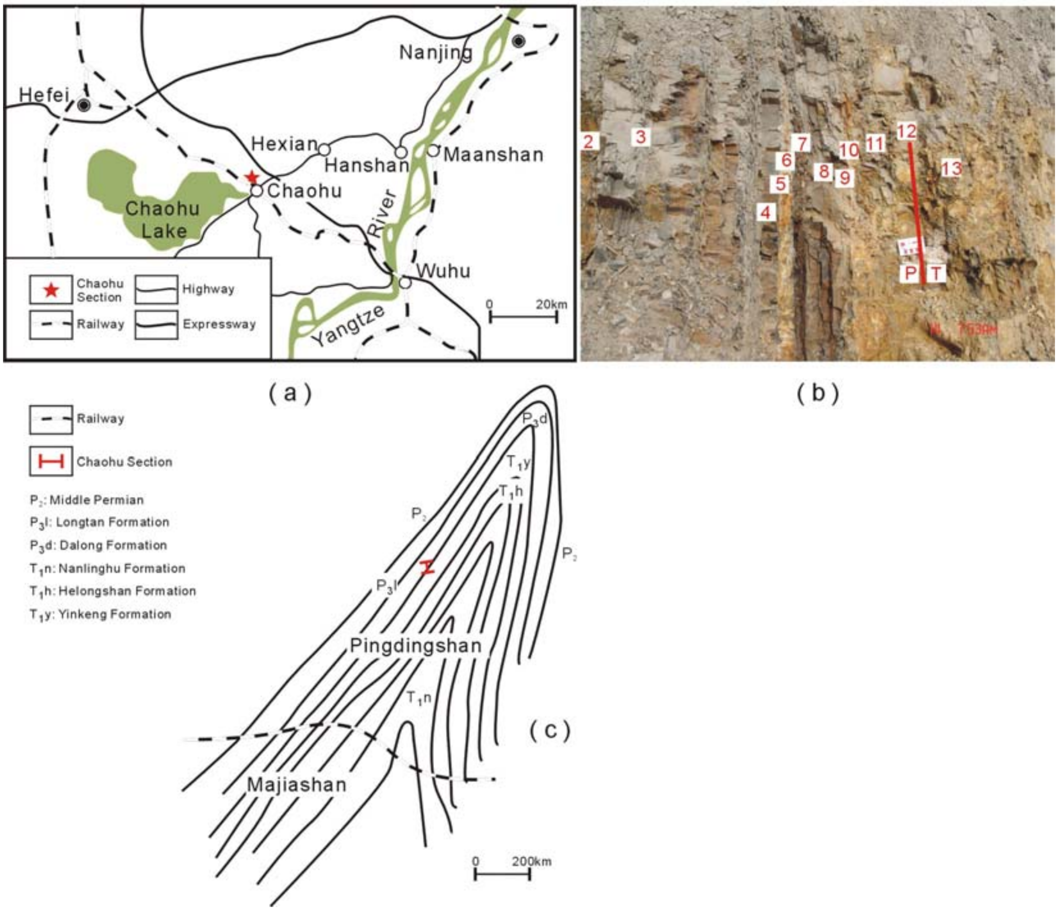


Fig.1-1-C: (a) Geographic location of the Chaohu Section (modified after Tong & Zhao, 2005); (b) The photo of the Chaohu Section; (3) Geologic location of the Chaohu Section (modified after Tong & Zhao, 2005).

The Chaohu Section is situated at the western slope of Mt. Pingdingshan. The strata from the Middle Permian (Gufeng Formation) through the Lower Triassic (Yinkeng Formation, Longshan Formation and lower Nanlinghu Formation) are well exposed (Fig.1-1-C (c), Fig.1-2). The Permian-Triassic boundary, at the middle the bed CH12 (i.e. Bed 5 in Zhao *et al.*, 2007), is determined by the lithostratigraphic correlation of “Permian-Triassic boundary stratigraphic set” (PTBST) (Peng *et al.*, 2001). The Late Permian Dalong Formation is mainly composed of the thin-bedded siliceous mudstones and mudstones. Radiolarians, foraminifera, ostracods, sponge spicules and small bivalves and brachiopods are yielded and abundant in some beds (Tong *et al.*, 2005; Zhao *et al.*, 2007; Gui *et al.*, submitted).

In this work, 24 samples of siliceous mudstones and 8 samples of mudstones were collected from the upper Dalong Formation. The descriptions of lithology for each bed are listed as follows from top to bottom (Fig.1-1-C (b)). (Remarks: The sample were not numbered by the bed number)

Yinkeng Formation (T_1y)

CH13 – yellow calcareous mudstones and marls	>10cm
CH12 (upper part) – mudstones and marl	7cm

——————— Conformity contact ———————

Dalong Formation (P_3d) **total measured thickness 114cm**

CH12 (lower part) – mudstones and marl	7cm
CH11 – celadon mudstones	14cm
CH10 – yellow mudstones	5cm
CH9 – greyly yellow mudstones	3cm
CH8 – greyly dark siliceous mudstones	12cm
CH7 – brown to dark mudstones	5cm
CH6 – yellow silty mudstones	4cm
CH5 – grey claystones	2cm
CH4 – interlayered dark siliceous mudstones and greyly yellow mudstones, the layer of siliceous mudstones much thicker than the mudstone layer	31cm
CH3 – greyly yellow mudstones in the upper part, dark siliceous mudstones in the lower part	17cm
CH2 – brown silty mudstones	4cm
CH1 – dark siliceous mudstones	>10cm

——————— Base unknown ———————

Remarks: The field work and sample processing have also been conducted in some other sections (see table below). However, they are not systematically included in this thesis except that some specimens from the Tieqiao Section and the Xichang Section are presented in the plate (Plate 2, figs 5-6, Plate 5, fig.8 and Plate 6, fig.15), the brief information about these sections are listed in the table below (Tab.1-1) and the detail descriptions are omitted here.

Tab.1-1 Geographic location and studied strata of the other investigated sections in this work

Studied section	Geographic location	Studied strata	Reference
Tieqiao Section	Laibin County, northern bank of Hongshui River, central Guangxi	Permian (Chihsia Fm., Maokou Fm., Wujiaping Fm. & Dalong Fm.)	Mei *et al.* 1998, 1999; Shen *et al*., 2007
Xichang Section	see Fig.1-1-A (c)	latest Permian (Dalong Fm.)	group work in process
Paibi Section		lastest Permian (Dalong Fm.)	
Balong Section		lastest Permian (Dalong Fm.)	
Xiakou Section	N31º06.874', E111º48.221', Yichang City, Hubei	latest Permian (Changxing Fm.) to Early Triassic (Daye Fm.)	Wang & Xia, 2004

§ 1.2 Stratigraphic correlation

1.2.1 Permian-Triassic Boundary

This study is focused on the latest Changhsingian strata. Thus the determination of Permian-Triassic boundary (PTB) is the first important problem.

In the Dongpan Section, the presence of the *Neoalbaillella optima* radiolarian zone in the beds from 03DP2 to 03DP 6 and ammonoids *Huananoceras* cf. *perornatum* Chao and Liang, *Laibinoceras* cf. *compressum* Yang, *Qianjiangoceras* sp. at the top of the bed 03DP12 indicates the Changhsingian age of the Dalong Formation. The first occurrence of the typical Triassic ammonoids *Ophiceras tingi* Tien and bivalve *Claraia dieneri* Nakazawa at the base of the bed 03DP13 gives the Luolou Formation Early Triassic age. Consequently, the PTB in DP Section is placed between the beds 03DP12 and 03DP13 (Feng *et al.*, 2004, 2006, 2007a; He *et al.*, 2005; Meng, 2005; Jin *et al.*, 2007; Zhang *et al*, 2007a, 2007b) (Fig. 1-2).

In the Liuqiao Section, the radiolarian *Neoalbaillella optima* zone assigns the strata to the Changhsingian.*Albaillellaria* is present from the bottom up along the whole section, which disappears above the bed 03DP6 of the DP Section. Furtherly, *Albaillellaria flabellata* was recognized in the top of the bed 03DP2 of the Dongpan Section but not found in the Liuqiao Section. Thus the Liuqiao Section should be underlying the top of the bed 03DP2 of the Dongpan Section. In addition, our investigation in the studied area (group work, unpublished data) indicates that there are still at least 5m strata between the bottom of Dongpan Section and the top of the Liuqiao Section. In another word, all the strata of the Liuqiao Section underlie the Dongpan Section and belong to the Changhsingian (Fig. 1-2).

The Member IV of the Shaiwa Section is constrained to the late to latest Changhsingian based on biostratigraphical studies. The presence of the ammonoids *Ophiceras* sp. and the bivalve *Claraia* sp. determines the PTB between the Shaiwa Group and the Luolou Formation (Yang *et al.*, 2000; Gao *et al.*, 2001, 2005; Feng & Gu, 2002; Chen *et al*., 2006).

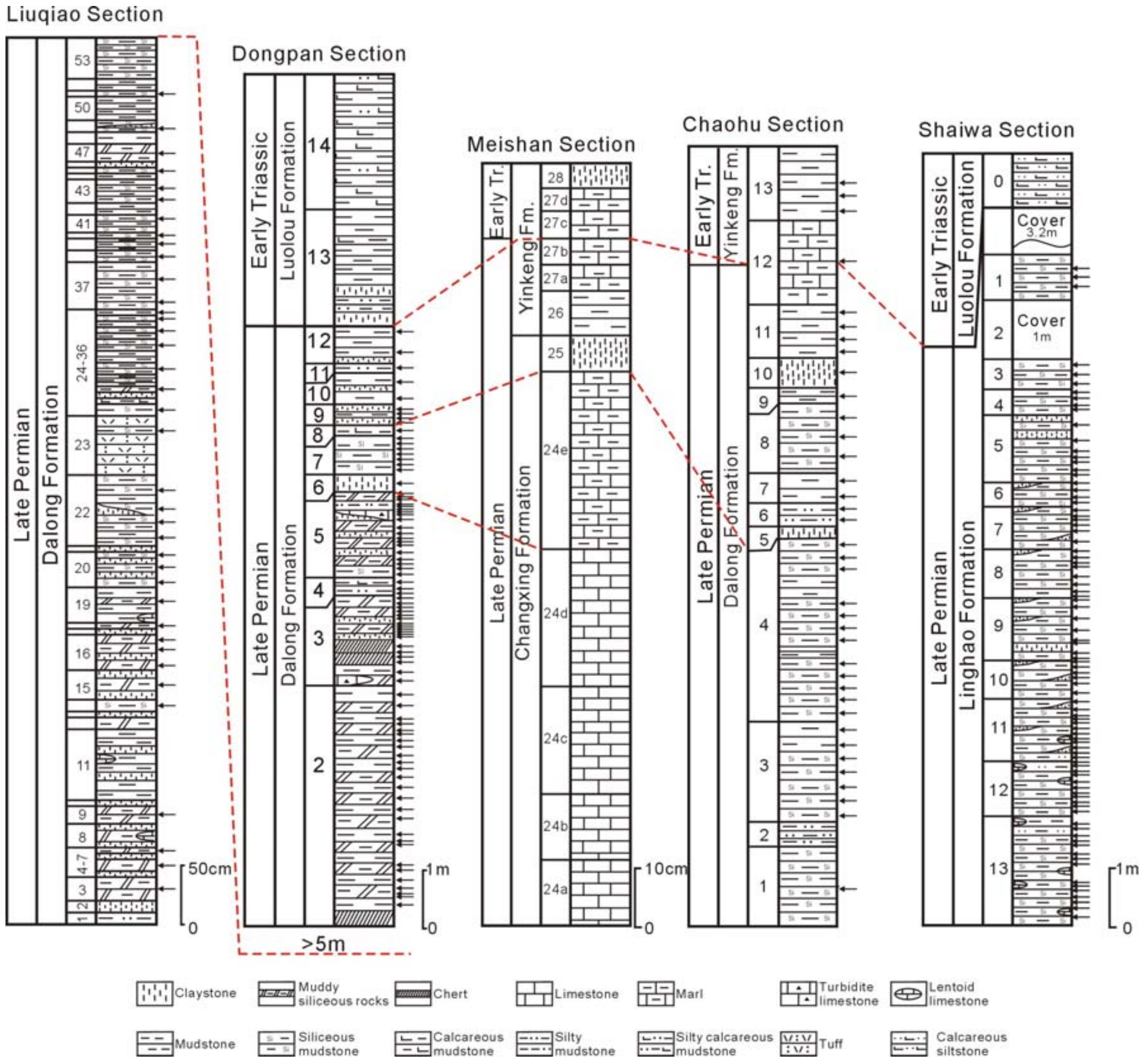


Fig. 1-2: Stratigraphic correlation between the Liuqiao Section, Dongpan Section, Meishan Section and Chaohu Section. The Meishan Section shares the common scale with the Chaohu Section (Meishan Section after Yin & Lu, 2006)

The PTB of the Chaohu Section is assigned according to the lithological "sandwich" PTBST which is characterized by the composition of the bottom clay (Bed 25 and 26 in the GSSP Meishan (MS) Section), the boundary rock and the top clay (Bed 28 in the Meishan Section) (Yin & Lu, 2006). The beds CH6 and CH7 can be considered as the bottom clay, which is constituted of "white claystone" and "black claystone", the bed CH12 is composed of the marls and hence considered as the boundary rock, the bed CH13 which is composed of the mudstones as the top clay. Thus the PTB is designated at the middle of the marl bed CH12 (the Bed 5 in Zhao *et al.*, 2007) (Fig. 1-1-C (b), Fig. 1-2).

1. 2. 2 Section Correlation

The correlation between the Dongpan Section, the Chaohu Section and the Meishan Section has been established based on the lithology, biostratigraphy, geochemistry and event-stratigraphy.

Dongpan Section & Meishan Section:

In the Dongpan Section, *Albaillella yao* zone in the beds from 03DP2 to 03DP5 can be correlated to the *Clarkina changxingensis – C. postwangi – C. postsubcarinata – C. deflecta* assemblage in Bed 23 to Bed 24d of the Meishan Section (Feng *et al*., 2007a; Zhang *et al*., 2007a, 2007b). The multi-layers of claystones in the Dongpan Section provide the research possibility of the event-stratigraphy. Studies on claystones in the bed 03DP9 indicate the volcanic origin and suggest the correlation with the lower claystones of the PTB in the Meishan section (Bed 25- Bed 26). The stratigraphic trend of the organic carbon isotope curve is accordant with that in the Meishan Section. The evident negative excursion of the organic carbon isotope also supports the correlation between the bed 03DP9 of the Dongpan Section and Bed 25 of the Meishan Section (Zhang *et al.*, 2007a, 2007b) (Fig. 1-2).

Chaohu Section & Meishan Section

As mentioned above, the correlation between the Chaohu Section and the Meishan Section is lithologic (see 1.2.1) (Fig. 1-2).

Chapter 2 Taxonomy of Ostracoda

This chapter is composed of three main parts. The object of the first and the second parts is to know what ostracods are and how to carry out the taxonomic research on fossil ostracods. With this understanding, in the third part, I systematically present all ostracods identified during this thesis (43 genera, 128 species).

Remarks:

(1) "Ostracoda" is the formal taxonomic name when referred to the class. From the beginning of ostracodology, there are two other different vernacular words "ostracode" and "ostracod". "Ostracode" is the usual spelling in North America and France. "Ostracod" is normally used elsewhere in Europe and in Australia (Holmes & Chivas, 2002, p.1). In this thesis, I uniformly use "**ostracod**".

(2) My thesis follows Bowman & Abele (1982) and Holmes & Chivas (2002, p.7) in considering the Ostracoda to be a Class.

(3) "Shell" is used here for an indefinite and general name either referring to the carapace or valve.

§ 2.1 Generality on ostracods

Ostracod is a small bi-valved Crustacea with a general size of **0.15-2mm**. There are some representatives with large size of 80 mm for Paleozoic species and 32 mm for recent swimming forms (Pokorný, 1978; Holmes & Chivas, 2002). The soft parts are protected in a bivalve carapace hinged dorsally and closed by adductor muscles. Chemical composition of the carapace is low-magnesium calcite.

Ostracoda is one of the most widespread and diverse crustaceans with **33,000** living and fossil species (Holmes & Chivas, 2002, p.5). This kind of small crustacean spans vastly both in spatial and temporal distribution.

The earliest fossil record of ostracods can be traced to the **Ordovician**. Ostracoda is divided into two subclasses, Myodocopa and Podocopa, which have been recorded from the Ordovician and are still very prosperous at present.

Ostracod can live in nearly all aquatic and some near/semi-terrestrial environments. Living ostracods can be found from damp leaf litter and fen soils, from small ponds to deep sea and from fresh to marine water. Fossil ostracods have been discovered in limestones, mudstones, siliceous and other rocks sedimented from the Ordovician onward. The ostracod soft parts, measurements, outline and ornamentation as well as its assemblage greatly vary in different regions and environments. Ostracods are effective (paleo) ecological markers and play an important role in paleoenvironmental and paleogeographical reconstructions.

The great majority of ostracods are benthic inhabitants and their larvae have the same ethology. The lack of planktonic mode means that marine ostracods can not get across the geographical barrier (vast ocean, temperature, etc.). The geographical isolation limits the biostratigraphical correlation between ostracods in different continents even regions. However, this disadvantage is largely outweighed by its powerful application in paleoecology and paleogeography (Moore, 1961, Q2; Pokorný, 1978; Holmes & Chivas, 2002, p.1, 5) (detailed introduction on paleoecological application see Chapter 4).

2. 1. 1 Soft parts of living ostracods (Moore, 1961; Kornicker, 1978; Cohen & Morin, 1993; Holmes & Chivas, 2002)

As all other crustacean, ostracods have a segmented body protected by a carapace. The ostracod body is divided into **cephalic** and **thoracic segment**s. The segmentation of the body is only observable on **appendage**s. All ostracod appendages are pair and typical biramous (Fig. 2-1-1) except the antennule which is uniramous.

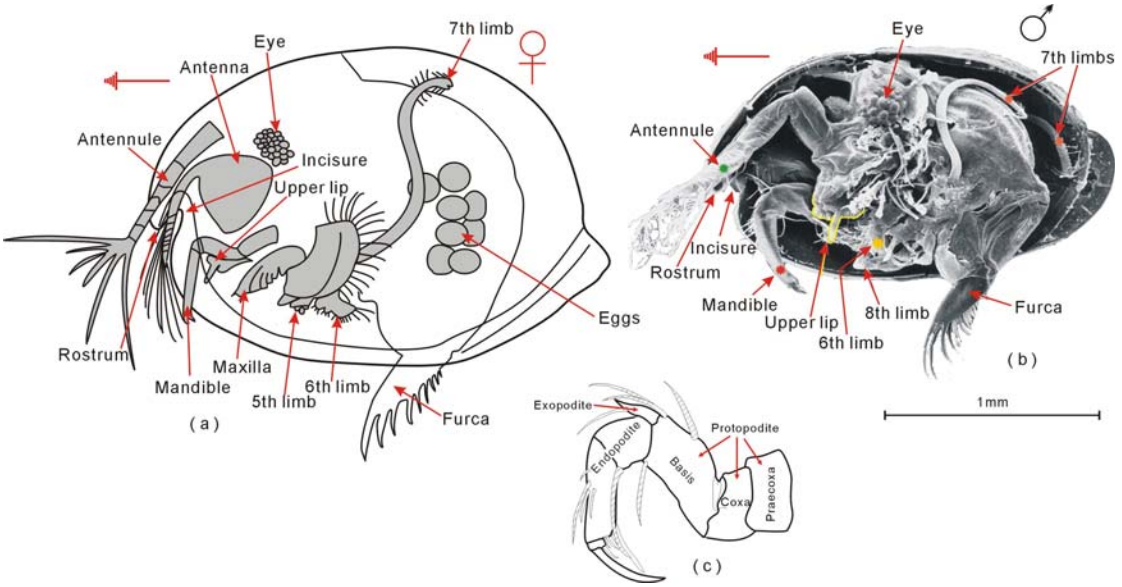


Fig. 2-1-1: Ostracod soft parts. (a) sketch of a Cypridinidae female; (b) SEM picture of a male (antenna, maxilla and fifth limb removed); (c) sketch of a biramous appendage (madibula of *Harbansus barnardi* Kornicker, 1978 (Myodocopida, Sarsielloidea), female), not to scale (after Cohen & Morin, 1993; Kornicker, 1978; Hinz-Schallreuter & Schallreuter, 1999)

The **cephalic segment** is composed of the forehead, upper lip, lower lip, hypostome and four pairs of appendages respectively termed as **antennule** (the first antenna, sensory and locomotory organ), **antenna** (the second antenna, locomotory or burrowing organ), **mandible** (locomotory, digging and feeding organ) and **maxilla** (feeding and respiratory organ) from front to back (Fig. 2-1-1).

The **thoracic segment** contains the digestive and reproductive systems and usually **one to four pairs** of **thoracic limbs** named as **fifth limb** (feeding, walking, respiratory and clasping organ), **sixth limb** (walking leg), **seventh limb** (walking leg) and **eighth limb** (male copulatory limb) (Fig. 2-1-1).

One pair of **furcae** (uropod) have unsegmented rami and functionate as locomotory organ when well developed (Fig. 2-1-1). The furca is mostly absent in some taxa.

2. 1. 2 Reproduction and ontogeny (Pokorný, 1978; Hao & Mao, 1993; Hinz-Schallreuter & Schallreuter, 1999; Ikeya & Kato, 2000; Holmes & Chivas, 2002)

Ostracods reproduce in three modes: **gamogenic**, **parthenogenetic** and **mixed**. Most of marine ostracods reproduce sexually. Few species are thought to be parthenogenetic by ostracodologists due to not finding male specimens in the investigations. In non-marine ostracods, all three modes exist but the main way of reproduction is parthenogenetic. Some fresh-water species reproduce in different modes according to the environments. In fitting conditions, they can reproduce sexually, whereas in not good conditions reproduce asexually. This phenomenon is known as "**geographical parthenogenesis**".

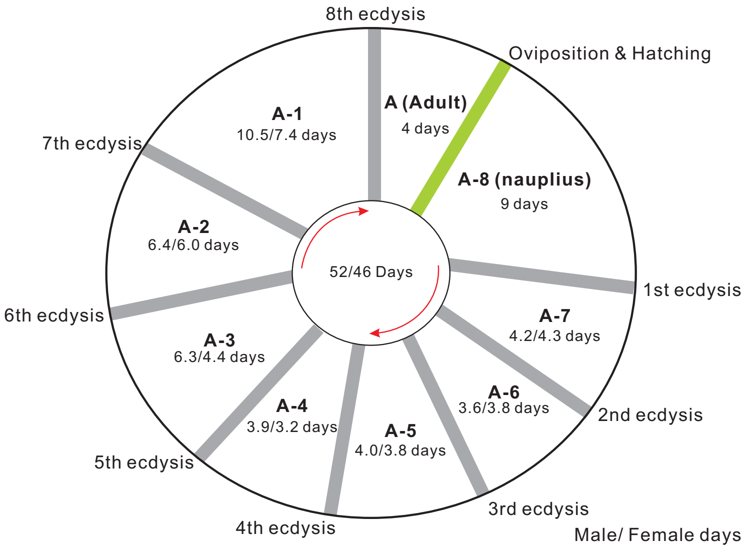


Fig. 2-1-2-A: chart showing ostracod ontogeny

(modified after Hinz-Schallreuter & Schallreuter, 1999 and Ikeya & Kato, 2000)

Ostracods usually have a life of several weeks to 4 years. They can oviposit at anytime of a year. The **egg**s hatch in the expanded posterior brood space of the adult female carapace or are laid directly into sea. The larva hatched from egg is called **nauplius** (**1st instar, A-8**) which is already enclosed by a bivalve carapace and has 3 pairs of appendages. Ostracod body grows until the nauplius carapace can not encase the body anymore. The nauplius will **molt** the old carapace and **secret** a new larger one. Then the larva gets into the **2nd instar (A-7)**. Before getting adult (**A**), the larva gives 8 instars as described above in Podocopida and 4 to 7 instars in Mydocopida (Fig. 2-1-2-A). At every instar transition, the old carapace is rejected and a new larger one is formed and calcified. Along with carapace molting and secreting, ostracod body grows larger and larger and inner organs and appendages get formed and matured.

Ostracod shell has not the growth lines and is double layered. This shell structure gradually forms during the ontogeny. The double layers are respectively **outer lamella** and **inner lamella** composed of **calcite** and **chitinous cuticle** (Fig. 2-1-2-B). The soft body parts are just housed in the **body cavity** between the outer and inner lamellae. During the ontogeny, the **epidermis** invaginated from the join of cephalic and thoracic segments until envelope the whole body within the double layers. The outer lamella calcifies completely, while the inner lamella calcifies partially, with the rest remaining chitinous. The calcified inner lamella is called **duplicature** which appears only when the ostracod becomes adult.

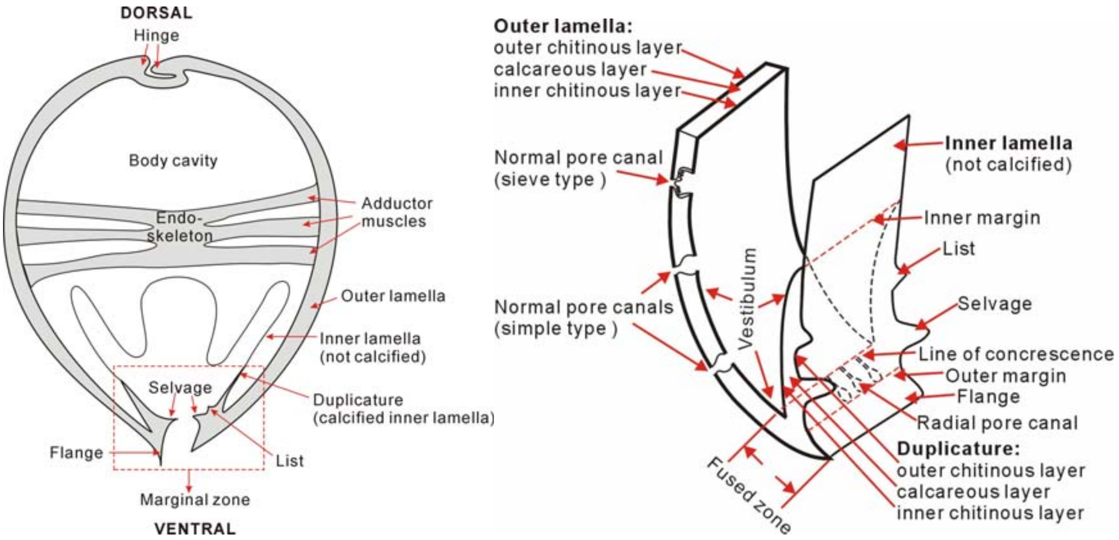


Fig. 2-1-2-B: transverse section and marginal structure of ostracod carapace

(modified from Scott, 1961; Harding, 1965; Pokorny, 1978)

Ostracods show sexual **dimorphism**. In total, there are two main dimorphism types, **domiciliar dimorphism** and **extradomiciliar dimorphism**. The male and female of the same species may distinguish in measurements, outline and inner structures for the former type and in ornamentation for the latter one. Males sometimes inflated posterior to accommodate the relatively large copulatory appendages. But in most taxa, female is larger and more inflated due to the brood care.

2. 1. 3 Shell morphology

In fossil record, the shell is generally the only preserved part. Consequently, shell morphology is the most useful tool (the only tool in most instances) to identify fossil ostracods. In this part, the shell morphological features involved in this thesis will be described. Some other features of hingement, adductor muscle scar and marginal zone are also very important taxonomic characters but not preserved in our specimens, whereas, the related descriptions will be omitted. This part is mainly referred to Moore (1961), Pokorný (1978), Crasquin (1984), Hao & Mao (1993) and Holmes & Chivas (2002). In all figures of this part, the arrow parallel to the length indicates the front of the carapace.

As described above, ostracod carapace is formed of two valves articulated dorsally. The two valves are respectively named as **right valve** (**RV**) and **left valve** (**LV**) (Figs 2-1-3-A, 2-1-3-C). The border bearing the hinge line is **dorsal border** (**DB**) / **dorsum**. The borders which are not concerned by the hinge are called **free margins**. Free margins are divided into **anterior border** (**AB**), **posterior border** (**PB**), and **ventral border** (**VB**). Accordingly, the lateral surface of the shell is divided into different portions (Fig. 2-1-3-B) which provide great convenience for ostracod describing.

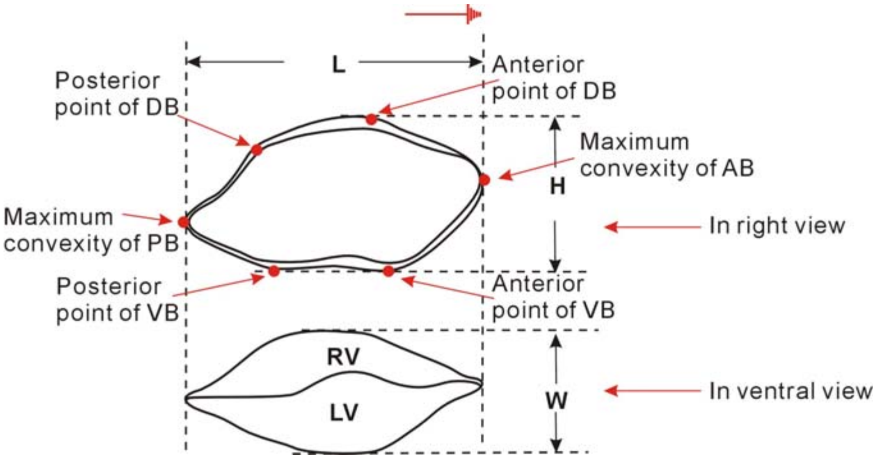


Fig. 2-1-3-A: measurements of a *Bairdia* carapace.

Generally, LV and RV are not simply mirror images of each other. They are sub-equal or unequal in size so that the larger valve **overlap**s the smaller one along part or all of its margins (Figs 2-1-3-C, 2-1-3-F (b), (f)).

Ostracod carapaces vary greatly in shape. The **shape/outline** of the shell is a rather important taxonomic character especially in fossil ostracods. **In lateral view**, the shell may be ovate, rectangular, triangular, rhombic, pentagonal, fusiform, bean-shaped or kidney-shaped. For some typical shapes the certain words are adopted as "**bairdian shape**" is used to indicate the rhombic outline with anterior and posterior beaks upwarded (Figs 2-1-3-A, 2-1-3-B (a), 2-1-3-C (a)). **Preplete**, **amplete** and **postplete** are also referred to the outline based on the position of the maximum height of the shell (Fig. 2-1-3-D). If the maximum height at the mid-length, it is considered as amplete, if anterior to the mid-length as preplete, if posterior to the mid-length as postplete. In **dorsal** or **ventral view** the carapace usually has symmetrically or asymmetrically biconvex lensoid shape. DB may be straight or convex/arched/bowed. When ostracod has a straight DB, **cardinal angle** (**CA**), the angle between hinge line and AB/PB, would be introduced to be an important classification index. There are **anterior cardinal angle** (**ACA**) and **posterior cardinal angle** (**PCA**) (Fig. 2-1-3-E). If DB is convex, two other “border” concepts would be defined as **anterior dorsal border** (**ADB**) and **posterior dorsal border** (**PDB**) (Fig. 2-1-3-B (a)). VB is straight, convex or slightly concave. There are also **anterior ventral border** (**AVB**) and **posterior ventral border** (**PVB**) accordingly (Fig. 2-1-3-B (a)). AB and PB appear usually rounded (broadly or acutely) or pointed. The variation of **curvature radius** is used to qualitatively describe the curving extent of AB and PB.

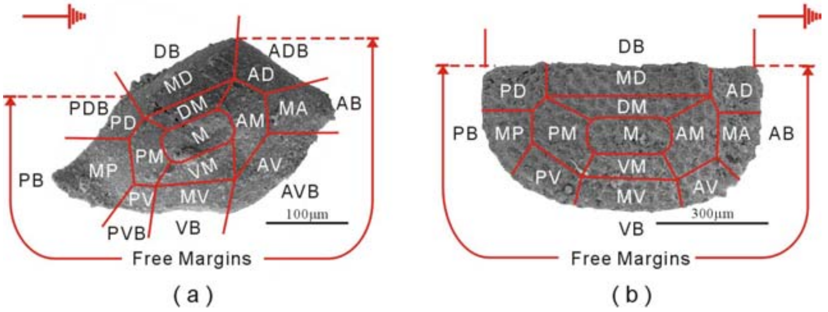


Fig. 2-1-3-B: morphological features of the lateral surface ((a) *Bairdia* sp.4 *sensu* Yuan & Crasquin-Soleau from Dongpan section, right lateral view of valve; (b) Kellettinidae indet. from Liuqiao section, in right lateral view of valve). Nomenclature referred to Scott (1961). MA: mid-anterior; MP: mid-posterior; M: median; MD: mid-dorsal; AD: anterodorsal; PD: posterodorsal; MV: mid-ventral; AV: anteroventral; PV: posteroventral; AM: anteromedian; PM: posteromedian; DM: dorsomedian; VM: ventromedian.

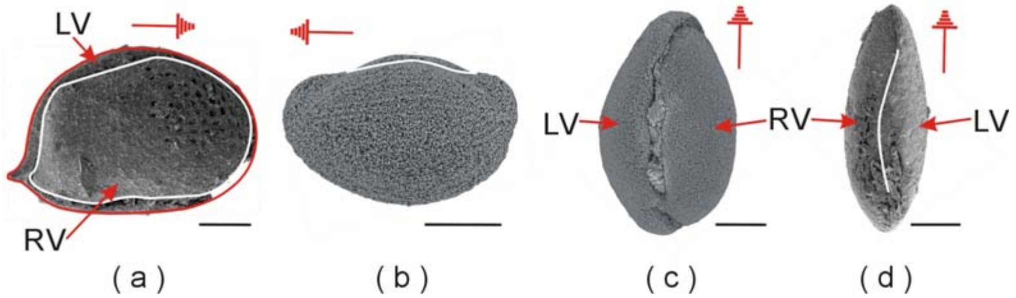


Fig. 2-1-3-C: examples of carapace overlap ((a) *Bairdia dongpanensis* Yuan & Crasquin-Soleau, 2007 from Dongpan section, LV>RV, right lateral view of carapace; (b) *Cyathus ceparata* (Guan 1978) from Tieqiao section. RV>LV, left lateral view of carapace; (c) from Tieqiao section. LV>RV, dorsal view of carapace; (d) *Fabalicypris* cf. *minuta* Cooper, 1946 *sensu* Yuan *et al.* (2007), LV>RV, ventral view of carapace). Scale bar is 100µm.

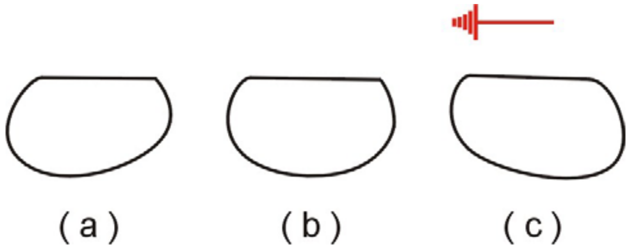


Fig. 2-1-3-D: sketch of preplete (a), amplete (b) and postplete (c) carapace.

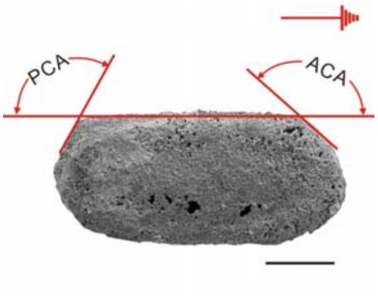


Fig. 2-1-3-E: cardinal angles of *Permoyoungiella* ?sp.1 *sensu* Yuan *et al.* (2007), right lateral view of valve. Scale bas is 100μm.

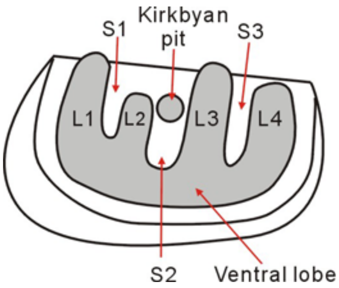


Fig. 2-1-3-H: sketch of lobes and sulci for palaeocopids.

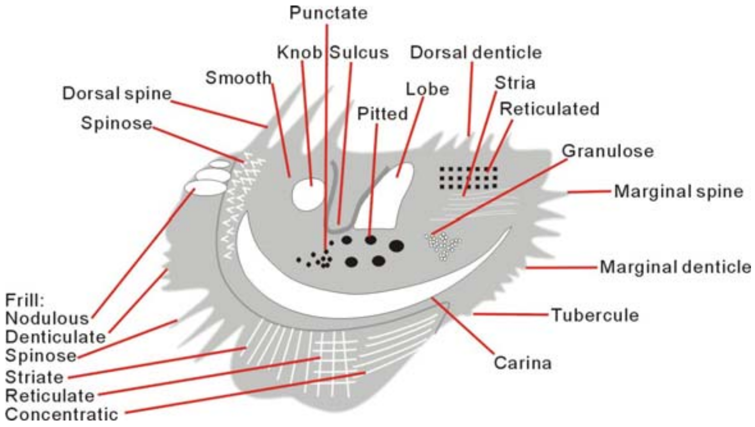


Fig. 2-1-3-F: sketch showing common ornamentation for ostracod shell. (modified after Scott, 1961)

The ostracod shell is smooth or ornamented (Fig. 2-1-3-F). Ornamentation may sometimes vary within a species due to the different environments, but the pattern of ornamentation is usually used as a specific character. In the view of whether or not reflected on the internal surface of the shell, the ornamentation can be divided into **primary ornamentation** (**valvular vaulting**) and **secondary ornamentation** (**sculpture**). In another view, if the ornamentation depresses below the surface, it is called **negative ornamentation**, by contrarily, if elevates, called **positive ornamentation**. In this thesis, both the two division systems are adopted for better describe the ornamentation (Tab.2-1-3-A).

Tab. 2-1-3-A Some common ornamentations of ostracods

	POSITIVE ORNAMENTATION	NEGATIVE ORNAMENTATION
PRIMARY ORNAMENTATION	lobe	sulcus, kirkbyan pit
SECONDARY ORNAMENTATION	spine, alae, ridge (rim, carine), tubercle, node, knob, granule, pustule, papillae, reticulation (muri)	puncate, fossa, reticulation (foveolation)

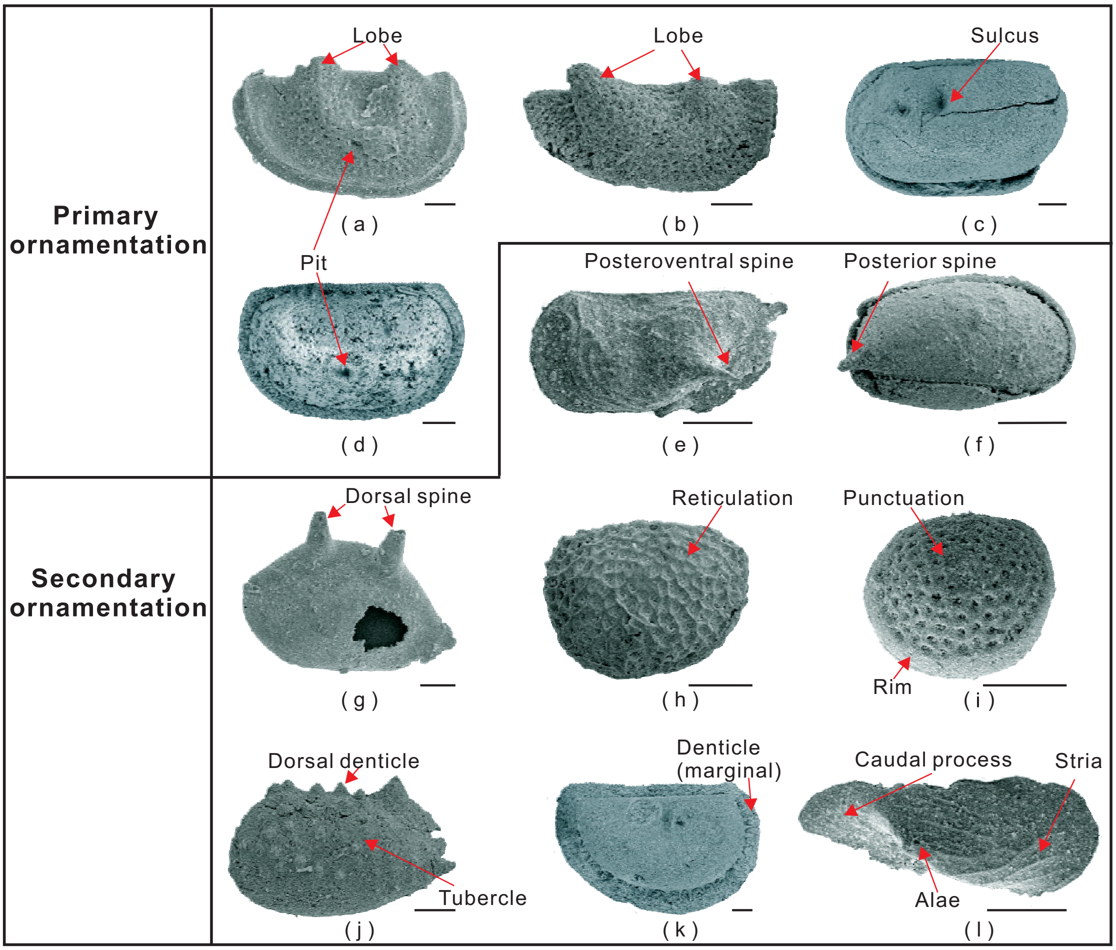


Fig. 2-1-3-G: some examples of ornamentations. All specimens from this work ((a) *Aurikirkbya* cf. *ultima* (Kozur, 1985), right lateral view of valve; (b) *Permokegelites* cf. *beichuanensis* Becker & Wang, 1992 *sensu* Yuan & Crasquin-Soleau 2007 , right lateral view of valve; (c) left lateral view of carapace; (d) right lateral view of carapace; (e) *Paraberounella* ?cf. *laterospina* Kozur, 1991 *sensu* Yuan *et al.* 2007, left lateral view of valve; (f) *Spinomicrocheilinella anterocompressa* Yuan & Crasquin-Soleau, 2007, right lateral view of carapace; (g) *Petasobairdia bicornuta* Chen, 1982, left lateral view of valve; (h) *Macronotella* ? sp.1 *sensu* Yuan *et al.* 2007, left lateral view of carapace; (i) ?*Libumella athabascensis* Green, 1963 *sensu* Yuan *et al*. 2007, right lateral view of valve; (j) *Denticupachydomella spinosa* n.gen.n.sp., left lateral view of valve; (k) *Hollinella* sp., right lateral view of valve; (l) *Monoceratina* sp.1 *sensu* Yuan *et al*. 2007, right lateral view of valve. Scale bas is 100µm.

Primary ornamentation (Figs 2-1-3-G (a)-(d)) is the elevation or depression reflected the inner anatomic structures. The **lobe** (bilobate / trilobite / quadrilobate valve, L1, L2, L3, L4) is positive ornamentation. And the **sulcus** (unisulcate / bisulcate / trisulcate valve, S1 usually found in very ancient species, S2 in center of which **kirkbyan pit/spot** is situated, S3) is the negative ornamentation (Fig. 2-1-3-H).

Secondary ornamentation (Figs 2-1-3-G (e)-(l)) is the sculpture in the external surface and has no corresponding trace on the internal surface, which includes the positive ornamentation of **ridge**, **carina**, **rim** (marginal ridge), **stria**, **frill** (ornamental border on a garment or certain gathered or pleated at one edge), **flange** (raised outside edge), **spine**, **tubercle** (hollow), **node** (solid), **knob, granule**, **pustule**, **papillae** and the negative ornamention as **puncate, pit** and so on. For the ornamentation of **reticulate** or **mesh**, the **muri** is of course the positive ornamentation, whereas, the **foveolation** between muris belongs to the negative ornamentation.

Remarks: some comparisons between the similar features:

(1) **tubercle, node** & **knob**: tubercle<node<knob;

(2) **ridge, rim, carina** and **velate structure**: ridge is a general nomenclature for all elongate or linear elevation of lateral surface. It is called rim (=marginal ridge/rim) if it is the linear elevation along free margins. When it is parallel to VB, it is equal to velate structure. When it is strong elevated (in Podocopida) or parallel to velate structure on its dorsal side, it is named as carina.

2.1.4 Principles for orientation and measurement (Moore, 1961; Hou & Chen, 1962; Pokorný, 1978; LSP, 1981; Hao & Mao, 1993)

Orientation and measurement are the premilinary work for the identification. For the living ostracods, depending on the features of the appendages and the other soft parts, the orientation is much easier recurring to the ontogeny and phylogeny. But it is not so easy for fossil ostracods without the soft parts preserved. As follows I summarize the common criteria adopted in peers and my own research. The two tables (Tab. 2-1-4-A, Tab. 2-1-4-B) present respectively the criteria for distinguishing anterior with posterior and dorsal with ventral. It should be noted that every criterion is not independent. In the practical identification, all available criteria that can be got from the material should be considered. In addition, there are some special but useful criteria for certain taxa, e.g. Palaeocopida has the greatest height anteriorly; in some bairdiids, the venter appears as a flat plane.

Tab. 2-1-4-A Common criteria for distinguishing the anterior and posterior parts of ostracods

	ANTERIOR	**POSTERIOR**
muscle scar	adductor muscle scar central to anterior	
	mandibular muscle scar in front	
brood care		present
outline (Figs 2-1-3-A, 2-1-3-C (a)(c), 2-1-3-D (a)(c))	higher, obtuse	thicker, relatively acute
hinge structure	more developed and complex	
ornamentation	carina and denticule developed better; single lobe/node anteriorly, anterior lobe/node smaller in bilobate shell	ventral ala or spine backward pointed
shoulder		present
marginal structure	more developed	
eye (Fig. 2-1-1)	present	
rostrum (Fig. 2-1-1)	present (incisure behind the rostrum)	

Tab. 2-1-4-B Common criteria for distinguishing the dorsal and ventral of ostracods

	DORSAL	**VENTRAL**
hingement	present	
cardinal angle (Fig.2-1-3-E)	present	
eye (Fig. 2-1-1)	present	
overlap (Figs 2-1-3-C, 2-1-3-G (f))		commonly stronger
ornamentation	sulcus opening towards dorsum	

After orienting, it is the step to measure the shell. A shell is characterized by **length** (**L**), **height** (**H**) and **width (W)** / **thickness** (**T**) (commonly written as **maximum length / height / width** in systematic descriptions) (Fig. 2-1-3-A).

I will describe the measurements here in a little detail since I feel important and not easy to carry out in practical work. As mentioned above, the outline of ostracod shell is various and the hingement is usually not preserved in fossil record. Furthermore, different literatures present varied measurement principles which would confuse the following study.

The reason, resulting in different measurement principles, is the definition of the three dimensions. No doubt the three dimensions are perpendicularly interrelated and **W** is the maximum distance between the lateral extremities of the carapace which is perpendicular to the sagittal plane. But for L and H, both have possibly two kinds of measurements. Take L for example.

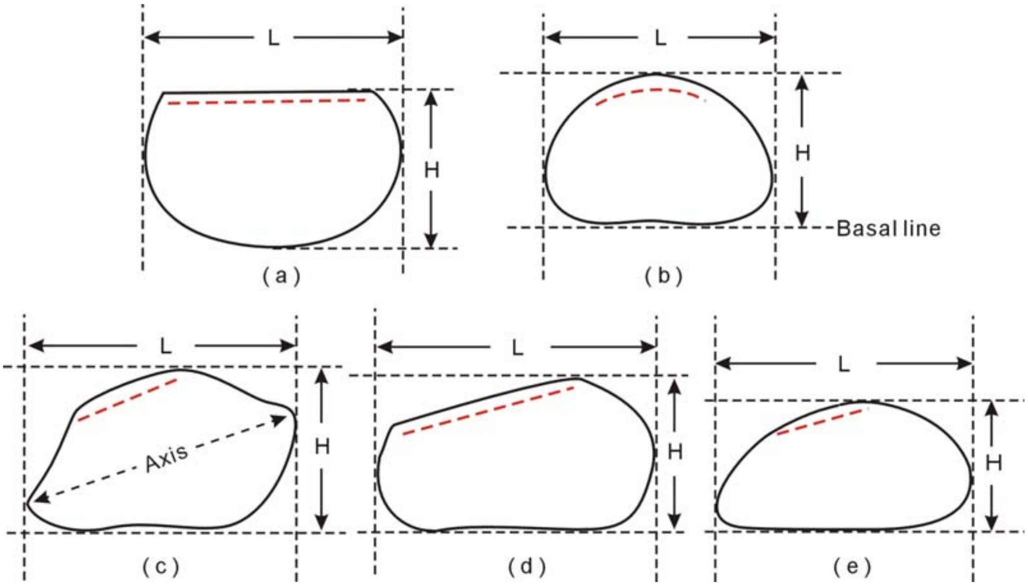


Fig. 2-1-4-A: measurements for ostracod with different outlines. The red dashed indicates the hinge line.

In the classical literature Treatise (Moore, 1961), L was respectively defined for the straight-backed and curve-backed ostracods. For the former, it is no problem. L is the maximum dimension in direction parallel to hinge line (Fig.2-1-4-A (a)). For the latter, L was defined as the maximum dimension parallel to the longitudinal axis of shell. In fact, for the curve-backed shell with straight hinge line as in Figs 2-1-4-A (c)-(e), if the shell axis is drawn, we can find out that the axis is parallel to the hinge line. In this way, the measurements for convex-backed (straight hinge line) ostracods have the same principle as the straight-backed ostracods. Then the division of measurement should be based on hinge line (whether or not straight) instead of "back". And if the measuring is conducted in this way, L would be **Ls** *sensu* Hinz-Schallreuter & Schallreuter (1999, p.16). However, in practical work, ostracodologists commonly measure **Lb** (Hinz-Schallreuter & Schallreuter, 1999, p.16), the "maximum distance of end points of the carapaces parallel to the **basal line**" (Pokorný, 1978) (Figs 2-1-4-A (b)-(e)). I calculated the relationship between the two measurements (Fig. 2-1-4-B). Lh and Lb can be transformed by the equation:

$$Lh=Lb \cos (\text{angle } h\&b) + (Ha-Hp) \sin (\text{angle } h\&b)$$

There are two special situations, if hinge line is horizontal, Lh and Lb will be equal; if maximum extremities of AB and PB are situated at the same height, Lh will be smaller than Lb. The most common status is Ha≠Hp, angle h&b≠0, when the relationship of Lh and Lb can not be evaluated generally. But it seems that they would be equal only in some instances. Commonly, different data are arisen by these two measurements.

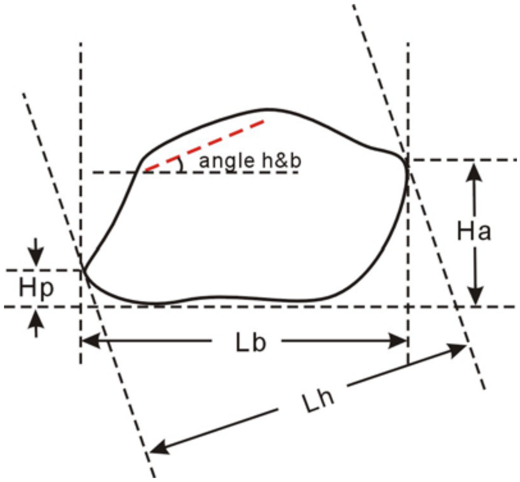


Fig. 2-1-4-B: comparison of measurements Lb and Lh.

Lb: maximum length parallel to hinge line; Lh: maximum length parallel to basal line; Ha: vertical distance between anterior extremity and basal line; Lp: vertical distance between posterior extremity and basal line; angle h&b: the angle between hinge line and basal line.

As many other ostracodologists, I also measured the Lb in my thesis. In my opinion, the basal line can be considered as the **balanced surface** for ostracod shell and also indicates the advancing direction of the ostracods. It would be more practical to consider L as the maximum measurement parallel to the advancing direction, especially for fossil ostracods without hinge line preserved. Consequently, in my thesis, L is unified as **the maximum dimension between maximum anterior and posterior curvatures parallel to the basal line.** This principle is applicable to all ostracods (for straight-backed ostracods, the hinge line is parallel to the basal line). Accordingly, H is defined as the maximum dimension between DB and VB perpendicular to L.

Remarks:

(1) If there are lobes, spines or other kinds of projections beyond the shell, the L, H and W should be marked "with" or "without" including the projection. Both of the dimension data will be acceptable.

(2) In addition, **H/L** is a taxonomic feature at specific level. Thus it is calculated commonly and listed with the L, H and W in systematic description.

2.1.5 Adopted taxonomic classification (Fossil Ostracods) (Moore, 1961; Hou & Chen, 1962; LSP, 1981; Hao & Mao, 1993; Holmes & Chivas, 2002; Liebau, 2005; *)

Since 1961, many researchers have been contributing to perfect the classification (the milestones of ostradological development in early times summarized here in Tab. 2-1-5-A). It seems as if

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[*] www.ucl.ac.uk/GeolSci/micropal/ostracod.html

impossible to form a stable framework. Liebau (2005) proposed the preliminary revised classification of ostracoda. But the common result has not been made officially. In my work, I still followed mainly the Treatise classification (Moore, 1961) (Tab. 2-1-5-B) but distil the later achievements by other ostracodologists for some new taxa. At the same time, integrated with the study on living ostracoda, I agree with getting to the unified routine in taxa, e.g. "oidea" is adopted as the uniform postfix for Superfamily here (Holmes & Chivas, 2002, p.8).

Tab. 2-1-5-A Milestones of ostradological development in the early times (before 1961)

1776	Ostracoda was first discovered by Danish naturalist Müller who gave the oldest generic names *Cypris* and *Cythere*[*].
1806	"Ostracoda" was named by French scientist Latreille (derived from the Greek "ostrakon" which means "shell").
1821	Ostracoda has formally become a taxonomic nomenclature (order name).
1866	Based on the appendages, Sars proposed four suborders (Myodocopa, Podocopa, Platycopa and Cladocopa) mostly of which are still adopted now for recent ostracods. Until then ostracoda has had its rudiment of classification.
1953	Norwegian scientist Henningsmoen proposed Palaeocopa for straight dorsal ostracods.
1958	Czechish scientist Pokorný combined the Paleozoic and post-Paleozoic ostracod study and established the Subclass Ostracoda.
1961	Treatise adopted the classification by Sylvester-Bradley and gave the foundation of today's classification .

Tab. 2-1-5-B Classification adopted in this work (mainly modified after Moore, 1961)

- Phylum **Arthropoda** Siebold & Stannius, 1845
  - Subphylum **Crustacea** Pennant, 1777
    - Class **Ostracoda** Latreille,1806 (O-Rec.)
      - Order **Palaeocopida** Henningsmoen, 1953 (O-?P)
        - Suborder **Beyrichicopina** Scott, 1961
        - Suborder **Kloedenellocopina** Scott, 1961
      - Order **Podocopida** Mueller, 1894 (O-Rec.)
        - Suborder **Podocopina** Sars, 1866
        - Suborder **Metacopina** Sylvester-Bradley, 1961
        - Suborder **Platycopina** Sars, 1866
      - Order **Myodocopida** Sars, 1866 (O-Rec.)
        - Suborder **Myodocopina** Sars, 1866
        - Suborder **Cladocopina** Sars, 1866

There are two main reasons which influence the establishment of a new classification: (1) continuous designation of new taxa; (2) inflation or devaluation of known taxa. However, the root

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[*] www.ucl.ac.uk/GeolSci/micropal/ostracod.html

resulting from the disunity on taxonomy is the classification criteria. As mentioned above, the living ostracods are classified by variations in their appendages and other soft parts. Although exceptionally well preserved fossil ostracods with the soft parts intact have been found, these are very rare and therefore the morphological features of the shell have become vital in fossil ostracod classification (Holmes & Chivas, 2002, p.19). Furthermore, due to the ontogeny (instars and dimorphism), ostracods may have the two adult morphtypes and different stages of juveniles which may misunderstanding the single species in fossils. In a word, many indeterminate factors arise and result in the difficulties in the fossil identification.

Tab. 2-1-5-C Common criteria for ostracod identification in different levels

	ORDER	SUPERFAMILY	FAMILY	GENUS	SPECIES
Palaeocopida	Straight DB, small, fairly simple muscle scars, presence of one or more lobes or sulci, strong ornamentation and dimorphic structures, no duplicature	dimorphic structures, sulci and lobes, general outline and presence or absence of velum	dimorphic structures, ornamentation, degree of sulcation and lobation, and outline.	hinge character, muscle-scar patterns (primary among Platycopina, Podocopina and Metacopina), outline, lobe and sulcus (assistant value; but important in Hollinacea, Beyrichiacea and Kloedenellacea), and adventral structure	based on ornamentation, modification of outline, and the size and shape of various structural features (such as alae, sulci, pore canals and lobes).
Podocopida	type of hingement, muscle scar patterns and outline	hingement, muscle scar patterns and outline	variation in hingement and muscle-scar patterns		
Myodocopida		presence and nature of the rostrum			

The common features adopted in high level classification are listed in Tab. 2-1-4-A, Tab. 2-1-4-B and Tab. 2-1-5-C. For some taxa, there are easily recognizable features, e.g. Palaeocopida usually have typical ornamentation (lobe and sulcus) (Figs 2-1-3-G (a)-(c)), Kirkbyidae has well developed kirkbyan pit (Fig.2-1-3-G (a), (b)), *Bairdia* has typical rhombic lateral outline (bairdian shape) (Figs 2-1-3-A, 2-1-3-B(a), 2-1-3-C (a)), *Microcheilinella* has very inflated carapace and strong overlap (Figs .2-1-3-C (c), 2-1-3-G (f)). At the same time, there are some practical features such as the location of the maximum height and length and the position of the maximum curvature of AB and PB. In a word, general and certain objective features should be integratively considered in the practical identification.

§ 2.2 Methodology

2. 2. 1 Sampling

In this thesis, I focus on the important geological boundary interval and planed to discuss paleoenvironmental variation and extinction process. Thus I carried out the sampling bed by bed even sub-bed by sub-bed to get continuous and precise results along each section.

When sampling, I chose the fresh rocks without weathering and recrystallizing. The weight for each sample is about 400-500g (Lethiers, 1979). Each sample should be well enclosed in a sample bag and labelled by corresponding number to its horizon.

2. 2. 2 Extracting

The extracting method depends on the microfossil-bearing rock types and the type of microfossils themselves. The extracting method may be chemical or physical. In my work, the ostracod-bearing samples are siliceous rocks, muddy rocks or calcareous rocks. Chemical methods were mainly applied. As follows, the processing method for calcareous rocks will be thoroughly described at first. The description for the same steps such as sample crushing and rinsing will be simplified or left out in the two other methods.

Calcareous rocks & Calcareous ostracods

Generally, if the fossils and the matrixes have different compositions or different endurance to some reagents, the chemical method can be applied. Here, in the calcareous rocks, the ostracod shells are also composed of calcium carbonate. The adopted methodology, known as “hot-acetolysis”, was perfected and published by Lethiers and Crasquin-Soleau (1988), derived from Bourdon (1957, 1962). The dehydrated samples and application of pure acetic acid effectively avoid the corrosion to the fossils during the reaction. It is based on abundant experiments over 20 years on thousands of samples collected from the Devonian-Triassic strata in France, Belgium, Canada, China, Arabia and Turkey by Prof. Lethiers and Dr. Crasquin-Soleau. Compared with the methodology of Bourdon (1962), it is easier and more efficient. The most importantly is that the fossils will be released and retrieved without corrosion (Crasquin-Soleau & Kershaw, 2005; Crasquin-Soleau *et al.*, 2005).

Remarks:

Peng & Wang (2002) introduced the heating-acid-digestion method for sample preparation of ostracods from carbonate rocks. Generally speaking, there is not far difference from our method. It was also derived from Bourdon (1957, 1962). But they use the desiccant $CuSO_4$ to absorb the water produced during the disaggregation. According to Coen (1985), $CuSO_4$ has definite protection to the shells. And the condenser was adopted to maintain the concentration and the pressure of the container.

Equipments: heating-store, sand-bath in a ventilated cabinet, a battery of three sieves (2mm mesh, 0.5mm mesh and 0.1mm mesh), hammer, glass bottles with cover (acid and heat proof), several rockered petrie dishes (porcelain or Teflon), large container for acid recycling, aluminium foil, funnel, filter paper, rubber gloves, respirator.

Chemicals: pure acetic acid (purity>99.5%), blue methylene powder.

Step I: sample crushing

In order to increase the surface area and further accelerate the reaction, the sample should be crushed into fragments (several cubic centimetres, like the size of hazelnut) with hammer. Generally speaking, 400-500g sample is enough. It is suggested using paper to limit the shard loss. After crushing, the sample placed into a glass bottle labelled with the sample number (the bottle should be large and heatproof so as to be stable in the drier and provide enough space for the later reaction) (Fig. 2-2-A).

Step II: dehydration

To avoid destroying the fossils during the reaction, the sample should not contain any water. For this reason, after crushing, the bottle is placed in the heating-store or a heated sand-bath. The temperature should be controlled at lower than 100ºC (to avoid the boiling of the sample) (Fig. 2-2-B). It usually takes 2 or 3 days for most calcareous rocks.

Step III: acidization & disaggregation / acetolysis

The aim of acidization is to separate the fossils from the enclosing matrixes. Take the sample out of the heating-store or the heated sand-bath. If the temperature is too high to hold the pot in the hand, the operator should leave it cooling for a moment to avoid the breakage of the glass. Then carefully pour the pure acetic acid into the bottle making sure the acid has covered all of sample. When pouring the acid, the operator should observe the sample to see if there are bubbles and to hear if there is a tittering sound. If effervescence occurs, the pouring should be stopped and make the sample re-dried. The possible reasons are that the drying is insufficient or/and the purity of the acetic acid does not reach the requirement. Then cover the bottle but do not tightly and completely close so as to free the volatilizing of the acid vapours. To prolong the life duration of the bottle, the use of aluminium foil is suggested. Place the bottle on the sand-bath at a temperature of 60ºC -80ºC (lower than the boiling point of acetic acid which is 118ºC) (Fig. 2-2-C). There are a series of complex reactions. The reaction time also varies from 1 day to several weeks (months). Generally, the coarser the crystallinity, the quicker the reaction proceeds. For the health and safety, the operator should wear the rubber gloves and conduct this step under the ventilated cabinet.

Step IV: acid recycling and residua rinsing

From the beginning of acidization, the operator should examine the sample everyday to see if the reaction is enough or more acid should be added. When the solution is turbid and the rock has turned into very small fragments (without complete disaggregation) and there is enough muddy deposit at the

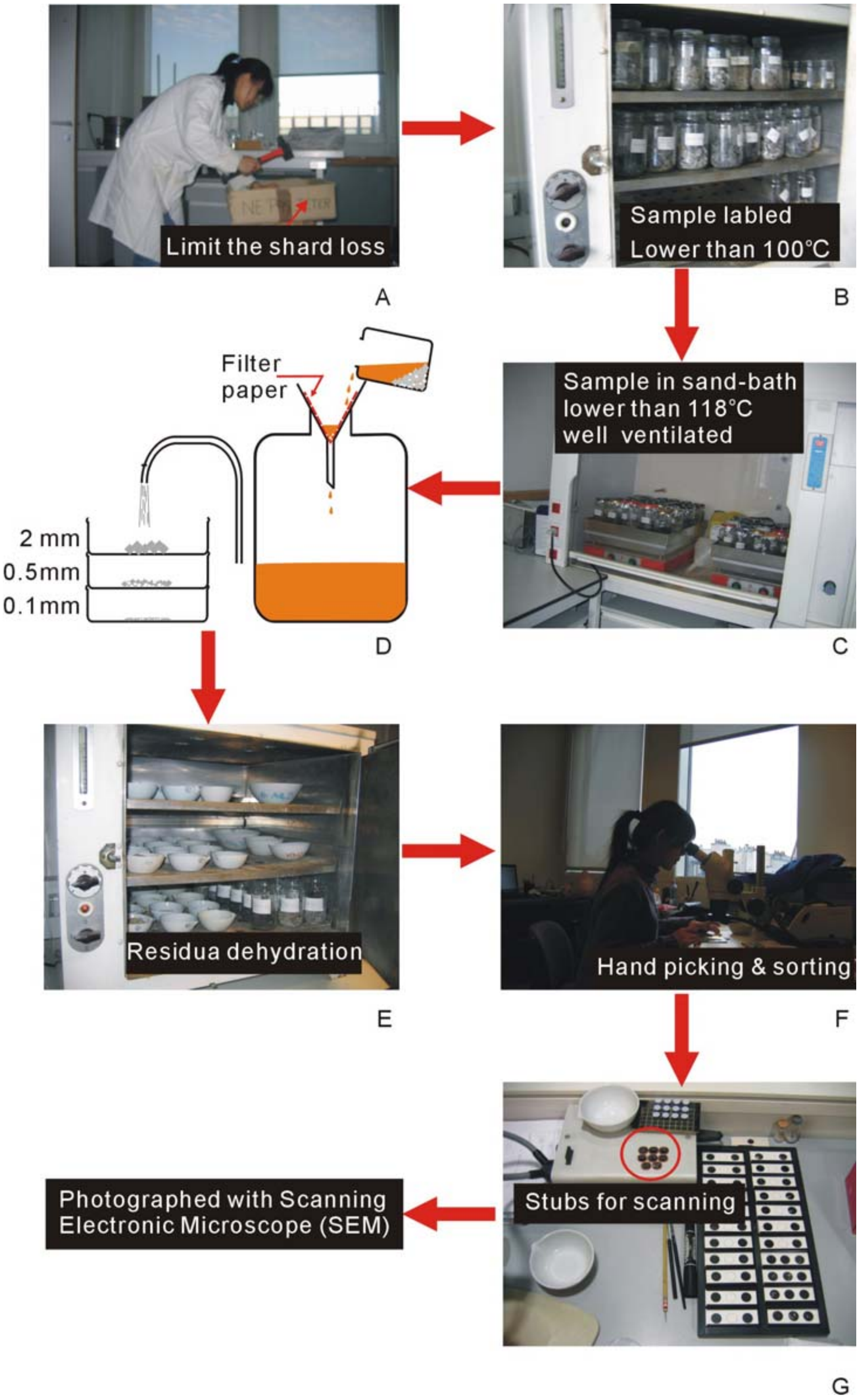

Fig. 2-2 shows the complete procedures of hot-acetolysis. A: sample crushing; B: sample dehydration in heater; C: sample acidization; D: acid recycling and residua rinsing with a battery of three sieves; E: residua dehydration; F: hand picking and sorting under a binocular stereoscope; G: stubs prepared for scanning.

bottom of the pot, the sample can be washed. Generally, if this kind of phenomenon has not occurred after three weeks, the sample should be washed and this step repeated. Before rinsing, the excess acid is poured off and filtered, using a funnel and filter paper, into a special container for recycling (Fig. 2-2-D). Althougu after the reaction, the acid has become red or yellow in colour, it can be reused with the same efficiency. The sample is then poured onto a battery of three sieves (2mm mesh for undisaggregated sediment, 0.5mm mesh for adults and large individuals and 0.1mm mesh for larvae and small specimens) (Fig. 2-2-D). To avoid reaction between the water and the sample, the rinsing should be conducted quickly. The part remaining on the 2mm sieve can be kneaded slightly and gently before being re-dried for the second acidization (make a signal of have been washed once). Successively rinse the residua remaining on the 0.5mm sieve and 0.1 mm sieve, until the escaping water from the sieve is clean. Sieve and place the two residua in different dishes with labels and place them in the heating-store (Fig. 2-2-E). When the residua are dry, they can be transferred to the little bags or bottles with labels. The dishes should be washed carefully and completely for the after use.

Before rinsing the next sample, clean the sieves in order to inhibit contamination of other samples. Usually, I immerse the sieves into the aqueous solution of methylene blue for a few minutes. This kind of solution can permeate into the rock and is very effective to dye the possibly mixed specimen (except the pyritized fossils) in the mesh so as to inhibit the contamination (Beckmann, 1959). During the operation, wearing gloves and the respirator even blinkers are needed to avoid the strong acid vapour. Then the second acetolysis is conducted. Generally the reaction is more quickly in the second operation. And it has been found that more specimens are obtained from the second operation. If it is necessary, i.e. more specimens are necessary for an important species, a third operation is needed.

Siliceous rocks & calcareous/silicified/pyritized ostracods

The ostracods studied here were obtained from the hydrofluoric acid (HF) technique, which is a special method for extracting the radiolarians from the cherts (Pessagno and Newport, 1972). Some detail procedures are improved in our own practical operation depending on the laboratory conditions and nature of rocks. In fact, the use of hydrofluoric acid in micropaleontology is not new, Wetzel (1921) recommended it as a preparatory technique to extract calcareous microfossils from non-calcareous rocks. The process, which transforms the opaque calcium carbonate into translucent calcium fluoride, was termed as “fluoridization” by Upshaw *et al.* (1957). The pseudomorphs of the fossils are believed to be a molecule-by-molecule replacement and reveal the calcareous skeletal and fine sculptures very well (Schallreuter, 1982).

Equipments: ventilated cabinet, hammer, plastic beakers, meshy bags, funnel, filter paper, large plastic container for acid recycling, large container for rinsing (e.g. basin), 300 mesh sieve, rubber gloves.
Chemicals: hydrofluoric acid, blue methylene powder, acetone.

Step I: sample crushing

The same as the calcareous rocks, the siliceous samples should be crushed into fragments (several cubic centimetres, like the size of walnut) so as to increase the surface area and further accelerate the reaction. After crushed, each sample was put into a meshy bag (made from nylon window screening or something like that. It provides convenience of changing the acid) and then place in a plastic beaker (beaker 1) labelled with the sample number. At the same time, for every sample, another plastic beaker (beaker 2) should be prepared and labelled for containing the residua.

Step II: acidization and acid recycling

All beakers 1, in which all samples are settled, are placed in the ventilate cabinet. According to the content of silica, generally 2% to 5% concentration of HF water solution was confected. During the process, the concentration can be changed according to the disaggregation status of samples.

First day: Samples in every beaker 1 are immerged with diluted HF solution.

Second day: The HF solution is very muddy and generally will not be recycled. If the sample contains much mud, it is necessary to gently rinse the meshy bag under the water. Then in the beaker 1, new diluted HF solution is poured to immerge the samples.

After about 12 hours: The excess HF solution is decanted to another container for recycling (considered as lower concentration e.g. half concentration in the next use). The meshy bag with samples is transferred to the beaker 2. The beaker 1 with the deposit is then filled with water (or add some soda ash) to reduce acidity so as to prevent destroying the fossils (water inpouring gently). The aggregate samples in beaker 2 are again immerged with new diluted HF solution.

After another 12 hours: The deposit in beaker 1 has sunk to the bottom. Pour out the water on the top of the deposit. Transfer the new deposits in beaker 2 to the beaker 1 and again fill with water. The aggregate samples in beaker 2 are immerged with the new diluted HF solution. Every 12 hours, this step is repeated until enough deposit is collected.

Step III: residua rinsing

The deposits are sieved through 300 meshes. Gently transfer the residua in beaker 1 onto the sieve. Immerge the bottom of the sieve into a large container (e.g. basin) filled with water. Shake the sieve gently with hand and accelerate the diffusion of the mud until the water flowing is clean. Transfer gently the residua into beaker 1. Place the beaker 1 in the heating-store or let it air-dry for picking. According to our experiment, if not used for next sample rinsing, the sieve with residua was directly put in the heating-store. This way effectively avoids the conglutination between residua and beaker/pot. The residua can be completely and readily collected. The more important is that the destroy to fossils due to multi-transmit was greatly reduced.

Muddy rocks

This method was introduced by Averbour in Wang (1987) for claystones and marlaceous rocks processing. Other than the former methods for calcareous and siliceous rocks disaggregating, the mechanism of this method is physical disaggregation under the force of chemical reaction. This method has been also widely used in conodont extracting.

Equipments: ventilated cabinet, beaker (plastic or vitreous), vitreous stick, 20 mesh and 300 mesh sieves, rubber gloves, respirator.

Chemicals: $Na_2S_2O_4$ water-free powder, H_2O_2, blue methylene powder.

Step I: samples crushing.

Crush the samples properly. Although in the introduction of Averbour (1962) it is said that the rocks are not necessary to be crushed, it will accelerate the reaction after crushing, especially for a little hard mudstone. Place the crushed rocks into the beaker.

Step II: reaction

Dissolve the $Na_2S_2O_4$ water-free powder in another beaker to get 10% $Na_2S_2O_4$ water solution (the vitreous stick is suggested for accelerating the dissolution). In the ventilated cabinet, pour the solution into the beaker with samples until immerge the samples. After about 30 minutes when the samples have been soaked by the $Na_2S_2O_4$ solution (during this time, prepare for 15% H_2O_2 solution), pour the H_2O_2 solution into the beaker. The reaction between the two chemicals starts immediately. At the same time, heat and gas will be produced (sometimes smelly H_2S volatizing). The force resulting from the reaction disaggregates the rocks and the samples become porridge-like.

Step III: rinsing

Gently transfer the sample onto the battery of two sieves. For the residua on the 20 mesh sieve, the rinsing method is same as that for calcerous rocks. The residua on the 300 mesh sieve can be rinsed according to the method for siliceous rocks.

2.2.3 Picking, scanning and identifying

Hand-picking and sorting

Equipments: a low-power binocular stereoscope, a picking tray/sheet (flat-bottom black-painted with lines, the distance between the lines should correspond approximately to the field of view seen under the microscope), a fine writing brush or a needle, several slides with covers.

After the residua are dried enough, they can be hand-picked and sorted. Scatter the residua on the sheet and make it be evenly distributed. Move the sheet slowly under the microscope and pick out the fossils using the bedewed brush or the needle into the labelled slides (Figs 2-2-F, G). For reducing the workload of identification, dividually place the specimens of each bed belonging to the same species or the same genus together. During picking, certain recording is suggested (e.g. Tab. 2-2-A made in Excel would be easy to make further statistics and graphs).

Tab. 2-2-A Date sheet used during ostracod picking

Sample Number	Picking weight of sample (g)	Amount of carapaces	Amount of valves	Sketch of typical specimens	Remarks
03 DP 3-16	3	6	77		less abundant than 03DP3-14, but more diverse, also yielding radiolarians and foraminifera

Mounting and photographing

Equipments: scanning electronic microscope (SEM), sputter coater, copper stub, double-faced adhesive tape or latex, a fine writing brush, pieces of paper.

For further identification, choose the well-preserved specimens for photography. When mounting the specimens, orient them according to the anterior-posterior to profit the next step. And ensure to choose enough characteristic specimens for each species (if it is possible) and orient them in different views. At the same time of mounting, draw the outline of the stub as well as the sketch figure of the specimens (this will avoid confusion if you do scanning rotation) and label the distinguished character (complete carapace or left or right valve, in lateral or ventral or dorsal or end view) (e.g. Tab. 2-2-B). Then the stub is coated with gold or carbon in vacuum status for several minutes. Carefully hold the stub and gently stick it on the stage of SEM for photography. Microfossils are generally scanned under strict work condition of vacuum (lower than 5e-3 atomospheric pressure) and high voltage (20 kV).

Tab. 2-2-B Data sheet used during ostracod scanning

Photo number	Amount of the same carapaces	Amount of the same valves	Bed number	Remarks

Identifying

The identification is a very complex work. It is the most important step of paleontological research. No machine is enabled to accomplish that. Researchers can not only rely on the fossils themselves, but consider the geological time, environment and region.

In the practical operation, print the photos and primarily classify them in high level. Then identify them group by group. The first step is to orientate, measure and describe the specimens (principles see 2.1.4). The next is to compare the specimens with those similar in as many related literatures as possible (principles see 2.1.5). When referring to the literature, making detailed record would save much time for writing the synonymy (derivation, namer, time, geological age, occurrences, environment, literatures etc.) and the later discussing. Each identified species should be described in certain format. There are not unified format for descriptions. Generally speaking, a regular systematic description should contain the items of **material, description, measurements/dimensions, remarks and occurrence**. In new taxa, **derivation, diagnosis** and **type** (**holotype, paratype**…) should be designated.

§ 2.3 Systematic descriptions

In this work, 43 genera and 128 species were identified, including 1 new genus (*Denticupachydomella* n.gen.) and 4 new species (*Bairdia dongpanensis* Yuan & Crasquin-Soleau, 2007, *Spinomicrocheilinella anterocompressa* Yuan & Crasquin-Soleau, 2007, *Denticupachydomella spinosa* n.gen. n.sp. and *Pseudobythocypris guiqianensis* n.sp.). It should be pointed out that the new genus and the latter two new species are proposed here. The proposition will be valid only after published in a research journal.

As mentioned above, the taxonomic classification of Moore (1961) is followed here. The new taxa after 1961 are mainly referred to the literatures of their original derivation.

Remarks:

For completely presenting the faunas, all the species from the Dongpan Section are also included in the systematic descriptions, but only with the specific name and the plate number. The detailed descriptions see the Appendix 3.

The main involved abbreviations in the following systematic descriptions:

RV: right valve; **LV:** left valve

AB: anterior border; **PB:** posterior border;

DB: dorsal border; **ADB:** anterodorsal border; **PDB:** posterodorsal border;

VB: ventral border; **AVB:** anteroventral border; **PVB:** posteroventral border;

L: maximum length; **H:** maximum height; **H/L:** ratio of maximum height to maximum length

CA: cardinal angle; **ACA:** anterior cardinal angle; **PCA:** posterior cardinal angle;

Class OSTRACODA Latreille, 1802
Order PALAEOCOPIDA Henningsmoen, 1953
Suborder BEYRICHICOPINA Scott, 1961
Superfamily TRIBOLBINOIDEA Sohn, 1978
Family TRIBOLBINIDAE Sohn, 1978
Genus *Tribolbina* Latham, 1932, emend. Sohn, 1978

Type species: *Tribolbina carnegiei* Latham, 1932

***Tribolbina* cf. *doescheri* Sohn, 1978**

Pl. 1, fig. 1

Material: One valve.

Measurements: L=774μm, H=553μm, H/L=0.71.

Remarks: Compared with the specimens from the Wuchiapingian strata of Hydra Island, Greece (Sohn, 1978), the PCA of the specimen here is less distinct, the hinge line shorter and curvature radius of PB smaller. Due to the poor preservation, the groove bordered by tubercles along free margins was not observed in the specimen here.

Occurrence: Latest Permian. Guangxi (bed LQ16, Dalong Formation of Liuqiao Section), South China.

Superfamily KIRKBYOIDEA Ulrich & Bassler, 1906
Family KIRKBYIDAE Ulrich & Bassler, 1906
Genus *Kirkbya* Jones, 1859

Type species: *Dithyrocaris permiana* Jones, 1850.

***Kirkbya* cf. sp. A *sensu* Becker & Wang, 1992**

Pl. 1, fig. 2

2007 *Kirkbya* cf.sp.A *sensu* Becker & Wang, 1992; Yuan *et al.*: p. 170, pl.1, fig.1.

Occurrence: Latest Permian. Guangxi (bed 03DP3, Dalong Formation of Dongpan section), South China.

***Kirkbya* aff. *wymani* Kellett, 1933**

Pl. 1, fig. 3

Material: One valve.

Measurements: L=1024µm, H=560µm, H/L=0.55.

Remarks: Compared with *Kirkbya wymani* Kellett, 1933 from the Early Permian of Kansas, here the specimen does not present the depressed area below the lobe and has not the anteroventral node. Note that I consider that the shoulder is posterior, so the orientation of the specimens in Kellett (1933, p.91, pl.15, figs 23-32) should be reversed.

Occurrence: Latest Permian. Guangxi (bed LQ9, Dalong Formation of Liuqiao Section), South China.

***Kirkbya* sp. 1 *sensu* Yuan *et al.*, 2007**

Pl. 1, figs 4-6

2007 *Kirkbya* sp.1; Yuan *et al.*: p. 170, pl.1, figs 4-6.

Occurrence: Latest Permian. Guangxi (beds 03DP3 and 03DP5, Dalong Formation of Dongpan section), South China.

Kirkbya sp.2

Pl. 1, fig. 7

Material: One valve.

Measurements: L=933µm, H=533µm, H/L=0.57.

Remarks: The strong hollow spine, obliquely downward pointed at the anterodorsal part, could lead to attribute the specimen to the genus *Tubulikirkbya* Kozur, 1985a. But the tubule-like spine here is not formed by the prolongation of the two marginal ridges, which is one of generic characteristics of the genus *Tubulikirkbya*.

Occurrence: Latest Permian. Guangxi (bed LQ7, Dalong Formation of Liuqiao Section), South China.

Kirkbya sp.3

Pl. 1, fig. 8

Material: One valve.

Measurements: L=883µm, H=517µm, H/L=0.58.

Remarks: According to the distinct kirkbyan pit surrounded by a rim, this specimen is assigned to the genus *Kirkbya* Jones, 1859.

Occurrence: Latest Permian. Guangxi (bed LQ16, Dalong Formation of Liuqiao Section), South China.

Genus *Aurikirkbya* Sohn, 1950

Type species: *Aurikirkbya wordensis* (Hamilton, 1942).

Aurikirkbya cf. *ultima* (Kozur, 1985a)

Pl. 1, fig. 9

Material: One valve.

Measurements: (without the lobe) L=757µm, H=414µm, H/L=0.55.

Remarks: In Kozur (1985a, p.33, pl.8, fig.1), the specimen, assigned to *Kellettina ultima*, has two faintely connected lobes and the kirkbyan pit just below the lobe at the mid-hight of the carapace. So I think that assignation of the former specimens to *Aurikirkbya* should be more reasonable. The present specimen here strongly resembles *Aurikirkbya ultima* (Kozur, 1985a) from the Late Permian (Abedahian) of Hungary by the sub-rectangular outline, reticulation and marginal rim. Compared with *Aurikirkbya ultima* (Kozur, 1985a), the specimen here has the AB and PB with larger curvature radius and well-developed marginal rim along whole free margins and the reticulation only around two lobes.
Occurrence: Latest Permian. Guangxi (bed LQ16, Dalong Formation of Liuqiao Section), South China.

***Aurikirkbya* sp. 1 *sensu* Yuan *et al.,* 2007**

Pl. 1, fig. 10

2007 *Aurikirkbya* sp.1; Yuan *et al.*: p. 171, pl.1, fig.2.

Occurrence: Latest Permian. Guangxi (bed 03DP2, Dalong Formation of Dongpan Section), South China.

***Aurikirkbya* sp.2**

Pl. 1, fig. 11

Material: One valve.
Measurements: (without the lobe) L=551μm, H=303μm, H/L=0.55.
Remarks: Compared with other *Aurikirkbya* species, the present specimen has a very obtuse CA. Due to the incomplete preservation of the other CA, it does not allow precise orientation and identification.
Occurrence: Latest Permian. Guangxi (bed LQ16, Dalong Formation of Liuqiao Section), South China.

Genus *Nodokirkbya* Kozur, 1991a

Type species: *Nodokirkbya striatoreticulata* Kozur, 1991a

***Nodokirkbya* ? cf. *striatoreticulata* Kozur, 1991a *sensu* Yuan *et al.,* 2007**

Pl. 1, fig. 12

2007 *Nodokirkbya* ? cf. *striatoreticulata* Kozur, 1991a; Yuan *et al.*: p. 171-173, pl.1, fig.3.

Occurrence: Latest Permian. Guangxi (bed 03DP5, Dalong Formation of Dongpan Section), South China.

Genus *Tubulikirkbya* Kozur, 1985a

Type species: *Coronakirkbya krecigrafi* Becker, 1978

***Tubulikirkbya* sp.1**

Pl. 1, fig. 13

Material: One valve.

Measurements: L=825μm, H=405μm, H/L=0.49.

Remarks: The main character of the present specimen is the presence of two carinae which do not converge at the CA. They form the step-like appearance, between which there are rows of reticulations. The inner carina projects beyond the DB. Although the two carinae are not well preserved, for each carina along their margins, the base of hollow tubercles can be clearly recognized. One broken hollow spine is present on the anterodorsal part. According to the characters above, this specimen is assigned to the genus *Tubulikirkbya* Kozur, 1985a, but is poorly preserved so that some characters can not be observed. Compared with the other *Tubulikirkbya* species, the present specimen has the peculiar type of carinae and ornamentation.

Occurrence: Latest Permian. Guangxi (bed LQ16, Dalong Formation of Liuqiao Section), South China.

Family AMPHISSITIDAE Knight, 1928

Amphissitidae sp.1

Pl. 1, fig. 14

Material: One valve.

Measurements: L=892μm, H=470μm, H/L=0.53.

Remarks: According to the sub-central node and the inner carina, this specimen is assigned to Amphissitidae Knight 1928.

Occurrence: Latest Permian. Guangxi (bed LQ16, Dalong Formation of Liuqiao Section), South China.

Amphissitidae sp.2

Pl. 1, fig. 15

Material: One valve.

Measurements: L=1200μm, H=612μm, H/L=0.51.

Remarks: Although this specimen is poorly preserved, the prominent sub-central and posterior nodes could be recognized, which make it be assigned to the family Amphissitidae Knight, 1928. The posterior denticules give an appearance of *Neoamphissites costatus* Becker & Wang, 1992 from the Late Permian of Sichuan and Fujian and *Amphissites biambonaria* Hao, 1992a from the Late Permian of Guizhou, South China (we think these two species should be one). But here the specimen has not the three carinae on the lateral surface.

Occurrence: Latest Permian. Guangxi (bed LQ35, Dalong Formation of Liuqiao Section), South China.

Genus *Permokegelites* Becker & Wang, 1992

Type species: *Permokegelites beichuanensis* Becker & Wang, 1992

Permokegelites cf. *beichuanensis* Becker & Wang, 1992

Pl. 2, fig. 3

Material: One valve.

Measurements: (without the lobe) L=624μm, H=271μm, H/L=0.43.

Remarks: According to the sub-semicircular and preplete outline, narrow dorsal surface, obscure sub-central lobe, projecting cone-shaped posterior lobe and the narrow furrow between the two lobes, the present specimen is compared to *Permokegelites beichuanensis* Becker & Wang, 1992 from the Late Permian of Sichuan and Fujian Provinces, South China. The present specimen differs from the latter by the absence of delicate inner carina and the anterolaterally located vertical ridge and by possessing larger anterior node.

Occurrence: Latest Permian. Guangxi (bed LQ16, Dalong Formation of Liuqiao Section), South China.

Family KELLETTINIDAE Sohn, 1954

Genus *Kellettina* Swartz, 1936

Type species: *Ulrichia robusta* Kellett, 1933.

Kellettina aff. *reticulata* Kozur, 1991a *sensu* Yuan *et al.*, 2007

Pl. 1, fig. 16

2007 *Kellettina* aff. *reticulata* Kozur, 1991a; Yuan *et al.*: p. 173, pl.1, fig.7.

Occurrence: Latest Permian. Guangxi (bed 03DP2, Dalong Formation of Dongpan Section), South China.

Kellettinidae indet. 1

Pl. 1, figs 17, 18

Material: Two valves.

Measurements: (without the lobe) L=735-757μm, H=375-400μm, H/L=0.51-0.53.

Remarks: Kirkbyan pit is absent or not preserved in the present specimens, so they are assigned to the family Kellettinidae.

Occurrence: Latest Permian. Guangxi (bed LQ16, Dalong Formation of Liuqiao Section), South China.

Family SCROBICULIDAE Posner, 1951

Genus *Roundyella* Bradfield, 1935

Type species: *Amphissites simplicissimus* Knight,1928

Roundyella ? *suboblanga* Wang, 1978

Pl. 2, fig. 1

1978 *Roundyella* ? *suboblanga* sp.nov.;Wang: p.285-286, pl.1, figs 20a-c.

Material: One valve.

Measurements: L=653μm, H=360μm, H/L=0.55.

Remarks: The specimen is larger than the specimen of *Roundyella* ? *suboblanga* from the Changhsingian of Guizhou, South China (Wang, 1978), however, both of them have the same H/L ratio (0.55).

Occurrence: Latest Permian. Guangxi (bed LQ22, Dalong Formation of Liuqiao Section) and Guizhou (Changxing Formation), South China.

Roundyella aff. *labaensis wangi* Kozur, 1985a

Pl. 2, fig. 2

Material: Two valves.

Measurements: L=650μm, H=350μm, H/L=0.54.

Remarks: According to the outline and papilliform on lateral surface and along margins, this specimen is compared to *Roundyella labaensis wangi* Kozur, 1985a from the Late Permian (early Dzhulfian) of the Bükk Mts., Hungary. *Roundyella labaensis* is distinguished with *Roundyella papilliformis* in having papillae along margins and longer papillae on lateral surface. I consider that the specimen figured and attributed to *Roundyella papilliformis* Wang 1978 in Yi (2004, p.558, tab.1, pl.2, fig.18) from the Late Changhsingian of Fujian, South China should be assigned to *R. labaensis wangi* by its projecting papillae along margins.

Occurrence: Latest Permian. Guangxi (beds LQ16 and LQ29, Dalong Formation of Liuqiao Section), South China.

Superfamily OEPIKELLOIDEA Jannusson, 1957

Family APARCHITIDAE Jones, 1901

Genus *Cyathus* Roth & Skinner, 1930

Type species: *Cyathus ulrichi* Roth & Skinner, 1930

Cyathus caperata (Guan, 1978)

Pl. 2, figs 4-6

1978 *Sinocoelonella caperata* gen. et sp.nov; Guan *et al.*: p.149, pl.37, fig.17, pl.38, fig.1.
1987 *Cyathus caperata* (Guan); Shi & Chen: p.32, pl.10, figs.10-18.

Material: One incomplete valve.

Measurements: L≈353μm, H=240μm, H/L≈0.68.

Remarks: This specimen is assigned to *Cyathus caperata* (Guan, 1978) from the Early Permian of Hunan, South China (Guan *et al.*, 1978) and the Late Permian of Zhejiang, South China (Shi & Chen, 1987) by the convex DB and VB, concave ADB, slightly upwardly raised ACA and the striated lateral surface.

Occurrence: Permian. Guizhou (sample SW13-3, Linghao Formation of Shaiwa Section), Guangxi (Maokou Formation of Tieqiao Section), Hunan (Maokou Formation) and Zhejiang (Changxing Formation), South China.

Genus *Macronotella* Ulrich, 1894

Type species: *Macronotella scofieldi* Ulrich, 1894.

***Macronotella* ? sp.1 *sensu* Yuan *et al.*, 2007**

Pl. 2, fig. 7

2007 *Macronotella* ? sp.1; Yuan *et al.*: p. 173, pl.1, fig.8.

Occurrence: Latest Permian. Guangxi (bed 03DP10, Dalong Formation of Dongpan Section), South China.

***Macronotella* ? sp. 2 *sensu* Yuan *et al.*, 2007**

Pl. 2, fig. 8

2007 *Macronotella* ? sp.2; Yuan *et al.*: p. 173, pl.1, fig.9.

Occurrence: Latest Permian. Guangxi (bed 03DP5, Dalong Formation of Dongpan Section), South China.

Genus *Libumella* Rozhdestvenskaya, 1959

Type species: *Libumella discoides* Rozhdestvenskaya, 1959.

? *Libumella athabascensis* Green, 1963 *sensu* Yuan *et al.*, 2007

Pl. 2, figs 10-12

1963 *Libumella athabascensis*, n.sp.; Green: p.120, pl. 7, figs 1-9.
1984 *Libumella athabascensis* Green, 1963; Crasquin: p.44, pl.4, figs 6, 7.
2007 ? *Libumella athabascensis* Green, 1963; Yuan *et al.*: p. 173, pl.1, figs 10-12.

Occurrence: Early Carboniferous ? - latest Permian. Alberta, Canada ?; Guangxi (beds 03DP3 and 03DP5, Dalong Formation of Dongpan Section), South China.

***Libumella* cf. *kargalensis* Rozhdestvenskaya, 1959 *sensu* Yuan *et al.,* 2007**

Pl. 2, figs 13, 14

2007 *Libumella* cf. *kargalensis* Rozhdestvenskaya, 1959; Yuan *et al.*: p. 173, pl.1, figs 13-14.

Occurrence: Latest Permian. Guangxi (bed 03DP3, Dalong Formation of Dongpan Section), South China.

Superfamily YOUNGIELLOIDEA Kellett, 1933
Family YOUNGIELLIDAE Kellett, 1933
Genus *Permoyoungiella* Kozur, 1985a

Type species: *Permoyoungiella bogschi* Kozur, 1985a.

***Permoyoungiella* ? sp. 1 *sensu* Yuan *et al.,* 2007**

Pl. 2, figs 16-18

2007 *Permoyoungiella* ? sp.1; Yuan *et al.*: p. 174, pl.1, figs 16-18.

Occurrence: Latest Permian. Guangxi (beds 03DP2-03DP5, Dalong Formation of Dongpan Section), South China.

Suborder KLOEDENELLOCOPINA Scott, 1961
Superfamily PARAPARCHITOIDEA Scott, 1959
Family PARAPARCHITIDAE Scott, 1959
Genus *Paraparchites* Ulrich & Bassler, 1906

Type species: *Paraparchites humerosus* Ulrich & Bassler, 1906.

***Paraparchites* sp. 1 *sensu* Yuan *et al.,* 2007**

Pl. 2, fig. 9

2007 *Paraparchites* sp. 1; Yuan *et al.*: p. 174, pl.1, fig. 15.

Occurrence: Latest Permian. Guangxi (bed 03DP3, Dalong Formation of Dongpan Section), South China.

Palaeocopida indet.

Pl. 2, fig. 15

Material: One valve.

Measurements: L=234µm, H=177µm, H/L=0.76.

Remarks: According to the straight and long DB and the rim along free margins, this specimen is assigned to the order Palaeocopida. There is not other preserved feature for further determination.

Occurrence: Latest Permian. Guizhou (sample SW13-12, Linghao Formation of Shaiwa Section), South China.

Order PODOCOPIDA Müller, 1894
Suborder PODOCOPINA Sars, 1866
Superfamily BAIRDIOIDEA Sars, 1888
Family BAIRDIIDAE Sars, 1888
Genus *Bairdia* McCoy, 1844

Type species: *Bairdia curta* McCoy, 1844.

Bairdia altiarcus Chen, 1958

Pl. 3, fig. 1

1958 *Bairdia altiarcus* Chen (sp.nov.); Chen: p.223, pl.3, figs 21-23, pl.4, figs 11, 12.
non 1985b *Cryptobairdia altiarca* (Chen); Kozur: p.231, tab.II, pl.3, fig.1.
2002 *Cryptobairdia altiarcus* (Chen); Shi & Chen: p.69, pl.7, figs 1-12.
2008 *Bairdia altiarcus* Chen; Crasquin-Soleau *et al.*:pl.2, figs 5-6.

Material: One valve.

Measurements: L=415µm, H=262µm, H/L=0.63.

Remarks: Compared with the specimens reported from other localities (see below in the "Occurrence"), the present specimen has a smaller size and larger H/L.

Occurrence: Permian. Jiangsu (Chihsia Formation of Longtan), Guangxi (Heshan Formation of Yishan, Heshan) and Guizhou (sample SW13-12, Linghao Formation of Shaiwa Section), South China; Sicily (Lercara Formation of Portella Rossa 1 Section), Italy.

?*Bairdia anbeedei* Belousova, 1965

Pl. 3, fig. 3

1965 *Bairdia anbeedei* Belousova, sp.nov.; Belousova: p.258-259, pl.48, fig.2.
1985b *Cryptobairdia anbeedei* (Belousova); Kozur: pl.11, fig.6.

Material: One valve.
Measurements: L>874μm, H=549μm, H/L<0.63.
Remarks: In Belousova (1965), for the new established species *Bairdia anbeedei,* only the external view of a left valve and dorsal view of a carapace were presented. In Kozur (1985b), assigned to *B. anbeedei*, only a left valve of the species was figured. It is not strict to present or assign a *Bairdia* specimen at specific level with only left valve. Here, for better comparison, the species *Bairdia anbeedei* is adopted with doubt.
Occurrence: Late Permian. Guangxi (bed LQ16, Dalong Formation of Liuqiao Section), South China; Bükk Mts., Hungary; Dzhulfa, Iran.

***Bairdia dongpanensis* Yuan & Crasquin-Soleau, 2007**

Pl. 3, figs 4-9

2007 *Bairdia dongpanensis* Yuan & Crasquin-Soleau n.sp.; Yuan *et al.*: p.174-176, pl.2, figs 7-12.

Occurrence: Latest Permian. Guangxi (beds 03DP2-03DP5, Dalong Formation of Dongpan Section; beds LQ3, LQ5, LQ7 and LQ16, Dalong Formation of Liuqiao Section) and Guizhou (sample SW13-12, Linghao Formation of Shaiwa Section), South China.

***Bairdia* sp.1 *sensu* Gründel & Kozur, 1975**

Pl. 3, fig. 15

1975 *Bairdia* sp.1; Gründel & Kozur: p.41, pl.2, figs 2-5.
1987 *Bairdia* sp.1 *sensu* Gründel & Kozur 1975; Bless: fig.6-J.

Material: One valve.
Measurements: L>908µm, H=551µm, H/L<0.61.
Occurrence: Permian. Timor (Kekneno series of Moetis region), Indonesia; Guangxi (bed LQ3, Dalong Formation of Liuqiao Section), South China.

Bairdia ? sp. 6 *sensu* Bless, 1987

Pl. 3, figs 10-12

1987 *Bairdia* ? sp. 6; Bless: 9, fig. 6C.
2007 *Bairdia* ? sp.6 *sensu* Bless, 1987; Yuan *et al.*: p.174, pl.2, figs 4-6.
2008 *Bairdia* ? sp. 6 *sensu* Bless; Crasquin-Soleau *et al.*: pl. 2, fig. 16.

Occurrence: Permian. Timor, Indonesia; Sicily (Lercara Formation of Portella Rossa 1 Section), Italy and Guangxi (beds 03DP2-03DP5, Dalong Formation of Dongpan Section), South China.

Bairdia aff. *birinae* Egorov, 1953 *sensu* Yuan *et al.*, 2007

Pl. 3, fig. 14

2007 *Bairdia* aff. *birinae* Egorov, 1953; Yuan *et al.*: p.174, pl.2, fig.2.

Occurrence: Latest Permian. Guangxi (bed 03DP3, Dalong Formation of Dongpan Section), South China.

Bairdia cf. *altiarcus* Chen, 1958

Pl.3, fig. 2

Material: One carapace.
Measurements: L=800µm, H=500µm, H/L=0.63.
Remarks: The specimen of *Cryptobairdia altiarcus* (Chen) figured in Kozur (1985b, pl.3, fig.1) from the Middle Permian of Bükk Mts., Hungary, having distinct overlap along AVB and PVB. It is not coincident with the diagnosis of species *Bairdia altiarcus* Chen 1958, is proposed here to assign to other species. The present carapace here is not well preserved and is compared with the species *B. altiarcus* Chen, 1958
Occurrence: Latest Permian. Guangxi (bed LQ9, Dalong Formation of Liuqiao Section), South China.

***Bairdia* cf. *austriaca* (Kollmann, 1963) *sensu* Gründel & Kozur, 1975**

Pl. 3, figs 16, 17

1975 *Bairdia* cf. *austriaca* (Kollmann 1963); Gründel & Kozur: p.41, pl.2, figs 7, 8.
2008 *Bairdia* cf. *austriaca* (Kollmann, 1963) *sensu* Gründel & Kozur, 1975; Crasquin-Soleau *et al.*: pl.2, figs 7-8.

Material: Two valves.

Measurements: (one specimen measured) L=786μm, H=400μm, H/L=0.51.

Remarks: As the specimens from the Early Permian of Timor, Indonesia (Gründel & Kozur, 1975), the specimens here have not the venterolateral ridge which is one of the two generic characters for *Urobairdia* Kollmann 1963.

Occurrence: Permian. Timor (Kekneno series of Moetis region), Indonesia; Sicily (Lercara Formation of Portella Rossa 1 Section), Italy; Guangxi (beds LQ3 and LQ16, Dalong Formation of Liuqiao Section), South China.

***Bairdia* cf. *szaszi* Crasquin-Soleau & Gradinaru, 1996**

Pl. 3, fig. 13

Material: Nine valves.

Measurements: (one specimen measured) L=709μm, H=273μm, H/L=0.38.

Remarks: Compared with *Bairdia szaszi* Crasquin-Soleau & Gradinaru, 1996 from the early Middle Triassic (Lower Anisian) of Romania (Crasquin-Soleau & Gradinaru, 1996, pl.2, fig.9), the PDB of the present specimens is not so concave. In Crasquin & Gradinaru (1996), *Praemacrocypris* sp. *sensu* Mirauta *et al.* (1993) was attributed to the synonymy with doubt. Here, I consider that the specimens in Mirauta *et al.* (1993, pl.2, figs 12a,b), which have more elongated carapace, straight PDB and more tapering PB with very low location of maximum curvature, should be excluded from the species *B. szaszi*.

Occurrence: Latest Permian. Anhui (sample CH 6-3-1, Dalong Formation of Chaohu Section), South China.

***Bairdia* sp. 1 *sensu* Yuan *et al.*, 2007**

Pl. 3, fig. 18

2007 *Bairdia* sp.1; Yuan *et al*.: p.176, pl.2, fig.13.

Occurrence: Latest Permian. Guangxi (bed 03DP3, Dalong Formation of Dongpan Section), South China.

***Bairdia* sp. 2 *sensu* Yuan *et al.,* 2007**

Pl. 4, fig. 1

2007 *Bairdia* sp.2; Yuan *et al*.: p.176, pl.2, fig.14.

Occurrence: Latest Permian. Guangxi (bed 03DP3, Dalong Formation of Dongpan Section), South China.

***Bairdia* sp.3 *sensu* Yuan *et al.,* 2007**

Pl. 4, fig. 6

2007 *Bairdia* sp.3; Yuan *et al*.: p.176, pl.2, fig.3.

Occurrence: Latest Permian. Guangxi (bed 03DP3, Dalong Formation of Dongpan Section), South China.

***Bairdia* sp. 4 *sensu* Yuan *et al.,* 2007**

Pl. 4, fig. 2

2007 *Bairdia* sp.4; Yuan *et al*.: p.176, pl.2, fig.1.

Occurrence: Latest Permian. Guangxi (bed 03DP3, Dalong Formation of Dongpan Section), South China.

***Bairdia* sp.5**

Pl. 4, fig. 3

Material: One valve.

Measurements: L=611µm, H=300µm, H/L=0.49.

Remarks: The present specimen is characterized by its long, acute and posteriorly pointed beak.

Occurrence: Latest Permian. Guangxi (bed LQ3, Dalong Formation of Liuqiao Section), South China.

***Bairdia* sp.6**

Pl. 4, figs 4, 5

Material: Two valves.

Measurements: L=795-990μm, H=420-495μm, H/L=0.50-0.53.

Remarks: The specimens are similar to *Bairdia* (*Bairdia*) sp., group *hypsela* Rome, 1971 from the Devonian-Carboniferous strata of Middle-Western Europe and North Africa (Becker, 1987, 1999; Becker *et al.*, 1993) by the sub-rhombic lateral outline, broadly arched DB, slightly concave VB and high and obtuse anterior beak with a sharp angle (about 120º) at the junction of AB and ADB. However, the present specimens have higher and more obtuse posterior beak and only the left valves were found. The overlap would not be observable. It does not permit making further determination at specific level.

Occurrence: Latest Permian. Guangxi (bed LQ16, Dalong Formation of Liuqiao Section), South China.

***Bairdia* sp.7**

Pl. 4, fig. 7

Material: One valve.

Measurements: L=780μm, H=315μm, H/L=0.40.

Occurrence: Latest Permian. Guangxi (bed LQ16, Dalong Formation of Liuqiao Section), South China.

***Bairdia* sp.8**

Pl. 4, fig. 8

Material: Two valves.

Measurements: L=260μm, H=139μm, H/L=0.53.

Remarks: These specimens have long and straight DB posteriorly inclined at about 30º, straight VB and slightly flattened AB and PB. The maximum curvature of AB is situated higher than mid-height. PB is obtuse with a very low location at about 1/8 of the maximum height.

Occurrence: Latest Permian. Guangxi (beds LQ3 and LQ45, Dalong Formation of Liuqiao Section), South China.

***Bairdia* sp.9**

Pl. 4, figs 9

Material: One carapace and two valves.

Measurements: L=247µm, H=174µm, H/L=0.7.

Remarks: The specimens have the similar overlap along whole margins as *Bairdia portellaensis* Crasquin-Soleau from the Middle-Late Permian of Sicily, Italy (Crasquin-Soleau *et al.*, 2008), but differ from the latter by larger H/L, nearly straight VB and having the maximum height near the mid-length.

Occurrence: Latest Permian. Guizhou (sample SW13-12, Linghao Formation of Shaiwa Section), South China.

***Bairdia* sp.10**

Pl.4, fig. 10

Material: One valve.

Measurements: L=275µm, H=183µm, H/L=0.67.

Remarks: This specimen is distinguished with *Bairdia* sp.9 by the higher location of maximum curvature of AB and the maximum height in front of mid-length.

Occurrence: Latest Permian. Guizhou (sample SW13-12, Linghao Formation of Shaiwa Section), South China.

***Bairdia* sp.11**

Pl. 4, figs 11, 12

Material: Two valves.

Measurements: L=250-280µm, H=183-200µm, H/L=0.71-0.73.

Remarks: Only with the left valves, it is difficult to make assignation at specific level.

Occurrence: Latest Permian. Guizhou (sample SW13-12, Linghao Formation of Shaiwa Section), South China.

***Bairdia* sp.12**

Pl. 4, fig. 15

Material: One incomplete valve.

Remarks: According to the upward beak, this specimen is assigned to the genus *Bairdia*. However, the poor preservation does not allow further identification.

Occurrence: Latest Permian. Guizhou (sample SW13-3, Linghao Formation of Shaiwa Section), South China.

***Bairdia* sp.13**

Pl. 4, fig. 13

Material: One valve.

Measurements: L=251μm, H=174μm, H/L=0.69.

Remarks: This specimen differs from other *Bairdia* species by very steep PDB and large curvature radius of AB.

Occurrence: Latest Permian. Guizhou (sample SW13-12, Linghao Formation of Shaiwa Section), South China.

***Bairdia* sp.14**

Pl. 4, fig. 16

Material: One carapace.

Measurements: L=367μm, H=200μm, H/L=0.55.

Occurrence: Latest Permian. Anhui (sample CH 6-3-4, Dalong Formation of Chaohu Section), South China.

***Bairdia* ? sp.15**

Pl. 4, fig. 17

Material: One valve.

Measurements: L=756μm, H=341μm, H/L=0.45.

Remarks: I assign this specimen to the genus *Bairdia* McCoy, 1844 by the upward AB and PB. The poor preservation makes the designation doubtful.

Occurrence: Latest Permian. Anhui (sample CH 3-4, Dalong Formation of Chaohu Section), South China.

Genus *Abrobairdia* Chen 1982

Type species: *Abrobairdia bitubera* Chen 1982

Abrobairdia sp.1

Pl. 5, figs 1, 2

Material: Two valves.

Measurements: (without nodes) L=714-759µm, H=486-489µm, H/L=0.65-0.68.

Description: Valve with bairdian shape in lateral view; DB gently arched with three nodes, ADB short and smoothly transitional to AB, PDB inclined posteriorly with an angle of 45°; VB slightly convex, ventral part compressed to make a blade-like view; AB rounded with the maximum convexity near the mid-height, PB pointed to make a blunt bairdian beak with the maximum curvature below the mid-height; two distinct nodes near dorsal part under which there is a circular depressed area, which may indicate the inner structure of adductor muscle scar; some small nodes on the posteroventral part, other part of surface smooth.

Remarks: The present specimens much resemble *Mirabairdia comisa* Chen, 1982 by the ornamentation (three dorsal nodes and two lateral nodes with the depressed area), however, distinguished with the latter in the absence of generic characters of *Mirabairdia*. In addition, *Petasobairida kozuri* Crasquin-Soleau, 1998 from the Late Permian of Hydra Island, Greece and *Ceratobairdia trispinosa* Chen, 2002 and *Petasobairdia tricornuta* Chen, 2002 from the Late Permian of Guangxi Province, South China also present three nodes at DB. The compressed venter makes the present specimens be assigned to the genus *Abrobairdia* Chen, 1982. The specimens here differ from other *Abrobairdia* species by the special ornamentation.

Occurrence: Latest Permian. Guangxi (bed LQ16, Dongpan Formation of Liuqiao Section), South China.

Abrobairdia sp.2

Pl. 5, fig. 3

Material: One valve.

Measurements: L=635µm, H=376µm, H/L=0.59.

Remarks: This specimen is characterized by the two spines at the extremities of DB and two spines (one broken) near DB. It differs from *Abrobairdia* sp.1 by strong spines instead of nodes on DB and the longer, pointed posterior beak.

Occurrence: Latest Permian. Guangxi (bed LQ22, Dongpan Formation of Liuqiao Section), South China.

Genus *Lobobairdia* Kollmann, 1963

Type species: *Lobobairdia salinaria* Kollmann, 1963

***Lobobairdia* cf. *rostriformis* Chen, 1982**

Pl. 5, fig. 6

Material: One valve.

Measurements: L=578μm, H=389μm, H/L=0.67.

Description: Valve with bairdian shape; DB strongly convex with the middle part nearly horizontal; VB slightly concave, a blade-like border extending along AVB and PVB; anterior beak indistinct, with maximum curvature at about mid-height; posterior beak short and relatively acute with maximum curvature below mid-height; surface smooth.

Remarks: Compared with species *Lobobairdia rostriformis* Chen, 1982 from the Late Permian of Zhejiang, Jiangsu and Guangxi (Heshan, Yishan), South China (Chen & Shi, 1982; Shi & Chen, 1987, 2002), the present specimen has not evident concave at the AVB.

Occurrence: Latest Permian. Guangxi (bed LQ16, Dongpan Formation of Liuqiao Section), South China.

Genus *Mirabairdia* Kollmann, 1963

Type species: *Mirabairdia pernodosa* Kollmann, 1963

***Mirabairdia comisa* Chen, 1982**

Pl. 5, figs 4, 5

1982 *Mirabairdia comisa* Chen sp.nov.; Chen & Shi: p.131, pl.8, figs 11-15.
2002 *Mirabairdia comisa* Chen; Shi & Chen: p.81, pl.12, fig.12.

Material: Four valves.

Measurements: (two specimens measured) L=694-705 μm, H=360-365μm, H/L=0.51-0.53.

Remarks: The present specimens are assigned to *Mirabairdia comisa* Chen, 1982 by the straight DB, slightly concave ADB and AVB, distinct venterolateral ridge and depressed ventral plane. Compared with the specimens from the Permian of Jiangsu and Guangxi, South China (Chen & Shi, 1982; Shi & Chen, 2002), the specimens here (only right valves) have compressed AB and a depressed arched zone extending from the middle of DB to antero-central part of the valve.

Occurrence: Late Permian. Jiangsu (Nantong) and Guangxi (Heshan Formation of Yishan, Heshan; beds LQ16 and LQ22, Dalong Formation of Liuqiao Section), South China.

Genus *Petasobairdia* Chen, 1982

Type species: *Petasobairdia bicornuta* Chen, 1982.

Petasobairdia bicornuta Chen, 1982

Pl. 5, figs 7, 8

1982 *Petasobairdia bicornuta* Chen gen. *et* sp. nov.; Chen & Shi: p.130, pl.6, figs.10-15.
1987 *Petasobairdia bicornuta* Chen; Shi & Chen: p. 46, pl.7, figs.17, 18, pl.20, fig.2.
1992a *Petasobairdia bicornuta* Chen; Hao: p.241-242, pl.2, figs7-9.
1994 *Petasobairdia bicornuta* Chen; Hao: p.88, Table 1, pl.1, figs.12, 17.
1996 *Petasobairdia bicornuta* Chen; Hao: p.26, pl.2, fig.1.
2004 *Petasobairdia bicornuta* Chen; Yi: p.558, Table 1.

Material: One valve.

Measurements: (without the spine) L=541µm, H=335µm, H/L=0.62.

Remarks: Compared with the types of *Petasobairdia bicornuta* Chen, 1982 from the Late Permian of Jiangsu and Hubei, South China, the specimen here has higher location of maximum curvature of anterior beak.

Occurrence: Late Permian. Jiangsu (Nantong), Hubei (Mianyang), Zhejiang (Changxing Formation), Guizhou (Changxing Formation of Zhenfeng), Fujian (Dalong Formation and Changxing Formation) and Guangxi (bed LQ16, Dalong Formation of Liuqiao Section; Dalong Formation of Xichang Section), South China.

Petasobairdia sp. 1 *sensu* Yuan *et al.*, 2007

Pl. 5, fig. 10

2007 *Petasobairdia* sp.1; Yuan *et al.*: p.176-177, pl.2, fig.17.

Occurrence: Latest Permian. Guangxi (bed 03DP5, Dalong Formation of Dongpan Section), South China.

Petasobairdia sp. 2 *sensu* Yuan *et al.*, 2007

Pl. 5, fig. 9

2007 *Petasobairdia* sp.2; Yuan *et al.*: p.177, pl.2, fig.18.

Occurrence: Latest Permian. Guangxi (bed 03DP2, Dalong Formation of Dongpan Section), South China.

Petasobairdia sp.3

Pl. 5, fig. 11

Material: One valve.

Measurements: L>473µm, H=300µm, H/L<0.63.

Remarks: Compared with other *Petasobairdia* species, the two spines in the present specimen are located near the dorsum instead of along DB.

Occurrence: Latest Permian. Guangxi (bed LQ22, Dalong Formation of Liuqiao Section), South China.

Petasobairdia sp.4

Pl. 5, fig. 12

Materials: One valve.

Measurements: L=616µm, H=389µm, H/L=0.63.

Remarks: This specimen is assigned to the genus *Petasobairdia* by the bairdian shape, smooth surface and knobs on DB.

Occurrence: Latest Permian. Guizhou (sample SW13-12, Linghao Formation of Shaiwa Section), South China.

Genus *Pustulobairdia* Sohn, 1960

Type species: *Bairdia*? *pruniseminata* Sohn, 1954

Pustulobairdia aff. *spinosa* (Cooper, 1946)

Pl. 5, fig. 14

Material: One valve.

Measurements: L>758μm, H=489μm, H/L<0.65.

Remarks: Compared with species *Pustulobairdia spinosa* (Cooper, 1946) from the Pennsylvanian of Illinois, United States and the Late Permian of Guangxi (Heshan, Yishan), South China, the present specimen has not angular junction between AB and DB and the lateral surface is not so granular.

Occurrence: Latest Permian. Guangxi (bed LQ16, Dalong Formation of Liuqiao Section), South China.

Pustulobairdia sp.1

Pl. 5, fig.13

Material: One valve.

Measurements: L=723μm, H=477μm, H/L=0.66.

Remarks: The specimen here resembles *Cryptobairdia postilonga* Chen, 2002 from the Late Permian of Guangxi (Shi & Chen, 2002), South China, but differs by larger H/L ratio, nearly vertical AB with very high location of maximum curvature and pustulous surface. This specimen is distinguished the *Pustulobairdia* aff. *spinosa* (Cooper, 1946) by the lateral outline.

Occurrence: Latest Permian. Guangxi (bed LQ16, Dalong Formation of Liuqiao Section), South China.

Pustulobairdia sp.2

Pl. 5, fig.15

Material: One broken valve.

Measurements: H=454μm.

Remarks: The present specimen has six (or more) knobs along DB and pustules on lateral surface. It is similar to *Ceratobairdia* species (e.g. *Ceratobairdia venterocosta* Wang, 1978 from the Permian of South China) due to the dorsal ornamentation. But the specimen here has not the ventral ala, one of the generic characters for the genus *Ceratobairdia* and is assigned to *Pustulobairdia* Sohn, 1961 according to the pustulate surface.

Occurrence: Latest Permian. Guizhou (sample SW13-12, Linghao Formation of Shaiwa Section), South China.

Genus *Spinobairdia* Morris & Hill, 1952

Type species: *Spinobairdia kellettae* Morris & Hill, 1952.

***Spinobairdia* sp. 1 *sensu* Yuan *et al.*, 2007**

Pl. 6, fig. 1

2007 *Spinobairdia* sp.1; Yuan *et al.*: p.177, pl.2, fig.15.

Occurrence: Latest Permian. Guangxi (bed 03DP2, Dalong Formation of Dongpan Section), South China.

Genus *Bairdiacypris* Bradfield, 1935

Type species: *Bairdiacypris deloi* Bradfield, 1935.

***Bairdiacypris* aff. *mirautaae* Crasquin-Soleau & Gradinaru, 1996 *sensu* Yuan *et al.*, 2007**

Pl. 6, fig. 2

2007 *Bairdiacypris* aff. *mirautaae* Crasquin-Soleau & Gradinaru, 1996; Yuan *et al.*: p.177, pl.3, fig.4.

Occurrence: Latest Permian. Guangxi (bed 03DP5, Dalong Formation of Dongpan Section), South China.

***Bairdiacypris* sp.1**

Pl. 6, fig. 3

Material: One valve.

Measurements: L=694µm, H=306µm, H/L=0.44.

Remarks: The presence of anterior beak suggests the assignation to family Bairdiidae. However, the declined PB does not display the characteristic of typical bairdiids. According to the elongate outline, slightly angulated and nearly straight DB and the only one typical beak, the specimen is assigned to the genus *Bairdiacypris* Bradfield, 1935.

Occurrence: Latest Permian. Guizhou (sample SW13-12, Linghao Formation of Shaiwa Section), South China.

Bairdiacypris sp.2

Pl. 6, fig. 4

Material: Two carapaces.

Measurements: (one specimen measured) L=526μm, H=274μm, H/L=0.52.

Remarks: These specimens are assigned to the genes *Bairdiacypris* Bradfield, 1935 by the sub-reniform carapace, evenly convex DB, slightly concave VB, rounded AB and PB and sub-uniform overlap along all margins. Compared with other species in this genus, the present specimens have slightly upswept PVB and have not very strongly concave VB.

Occurrence: Latest Permian. Anhui (sample CH 6-3-2, Dalong Formation of Chaohu Section), South China.

Bairdiacypris ? sp.3

Pl. 6, fig. 5

Material: One valve.

Measurements: L= 464μm, H=200μm, H/L=0.43.

Remarks: This specimen is similar in outline to *Bairdiacypris fornicata* Shi, 1982 from the Late Permian of Guangxi, Jiangsu and Zhejiang, South China (Chen & Shi, 1982; Shi & Chen, 1987, 2002). However, compared with the latter, the present specimen has more elongated valve and higher location of maximum curvature of AB. More material is necessary to make more precise designation.

Occurrence: Latest Permian. Anhui (sample CH6-2-4, Dalong Formation of Chaohu Section), South China.

Bairdiacypris ? sp.4

Pl. 6, fig. 6

Material: Two valves.

Measurements: L= 300μm, H=144μm, H/L=0.48.

Occurrence: Latest Permian. Anhui (sample CH6-2-2, Dalong Formation of Chaohu Section), South China.

Genus *Bythocypris* Brady, 1880

Type species: *Bythocypris reniformis* Brady, 1880

Bythocypris ? sp.1

Pl. 6, fig. 7

Material: Two valves.

Measurements: L=260-551µm, H=153-302µm, H/L=0.55-0.59.

Remarks: In outline, the present specimens are similar to Gen. et sp. 2 *sensu* Wang, 1978 from the Late Permian of Guizhou, South China (Wang, 1978). However, here, the PB is more acute. Due to the insufficient material, I assign them with doubt to the genus *Bythocypris* Brady 1880 by the elongate outline, arched DB, straight (slightly convex) VB and rounded AB and PB.

Occurrence: Latest Permian. Guizhou (sample SW13-12, Linghao Formation of Shaiwa Section), South China.

Genus *Fabalicypris* Cooper, 1946

Type species: *Fabalicypris wileyensis* Cooper, 1946.

Fabalicypris glennensis (Harlton, 1927) *sensu* Yi, 1993

Pl. 6, fig. 8

non 1927*Bairdia glennensis* Harlton, n.sp.; Harlton: p.210, pl.33, fig.10.
non *1935 Bairdia glennensis* Harlton; Kellett: p.133, pl.18, figs 4a-e.
non 1960 *Fabalicypris glennensis* (Harlton),1927; Sohn: p.62, pl.3, figs 9-10.
1993 *Fabalicypris glennensis* (Harlton); Yi: p.572, pl.1, fig.14.
? 2002 *Fabalicypris glennensis* (Harlton); Shi & Chen: p.86, pl.23, figs 1,2.

Material: Two valves.

Measurements: (one specimen measured) L=1076µm, H=441µm, H/L=0.41.

Remarks: The specimens are assigned to *Fabalicypris glennensis* (Harlton) *sensu* Yi 1993 from the Early Permian of Fujian, South China by the elongate and trapeziform outline, straight DB, substraight VB (parallel to DB), inclined ADB and PDB and very low location of maximum curvature of PB. However, I consider that our specimens and the specimen figured in Yi (1993) do not belong to the species *F. glennensis*. The holotype in Harlton (1927, pl.33, fig.10) and specimens figured in Sohn (1960, pl.3, figs 9-10) have broadly arched DB which is completely different with the present specimens and the figured specimen in Yi (1993). The specimens in Kellett (1935, pl.18, figs 4a-e) may not belong to this species also by its straight DB and parallel DB and PB. But the specimens here differ from those in Kellett (1935) by a very low location of maximum curvature of PB.

Occurrence: Permian. Fujian (Chihsia Formation of Guangping) and Guangxi (bed LQ16, Dalong Formation of Liuqiao Section; Heshan Formation of Yishan), South China.

Fabalicypris parva **Wang, 1978**

Pl. 7, figs 1-12

1978 *Fabalicypris parva* sp.nov.; Wang: p.293, pl.2, figs 12a,b, 13a,b.
1978 *Fabalicypris arcuata* sp.nov.; Wang: p.294, pl.2, figs 14a,b.
1985b *Fabalicypris parva* Wang; Kozur: p.231, tab.2, pl.9, fig.7.
1994 *Fabalicypris parva* Wang; Hao: p.89, tab.1.
2004 *Fabalicypris parva* Wang, 1978; Crasquin-Soleau *et al.*: p.286, tab.1, pl.3, figs 4,5.
? 2004 *Fabalicypris parva* Wang; Yi: tab.1, pl.2, fig.8.

Material: Sixteen carapaces and forty-six valves.

Measurements: (twelve specimens measured) L=416-729μm, H=190-326μm, H/L=0.36-0.46.

Remarks: The present specimens are assigned to *Fabalicypris parva* with the following characters: carapace elongate; DB broadly convex, ADB slightly concave, PDB convex; VB slightly concave to sub-straight, AVB sub-straight and inclined to meet with anterior beak; AB evenly rounded; PB acute and low; maximum height at or behind mid-length. In these specimens, compared to the specimens from the Late Permian of Guizhou, South China (Wang,1978) and Bükk Mts. of Hungary (Kozur, 1985b, Dzhulfian), some have much larger or smaller H/L ratio. But I consider it as the intraspecific variation. So the specimens in Wang (1978, pl.2, figs 14a, b) designated as *F. arcuata* by larger H/L and stronger overlap along DB are here assigned to *F. parva*. The specimen figured in Yi (2004, pl.2, fig.8) has much shorter carapace, convex ADB and sub-straight PDB which make its assignation to this species doubtful.

Occurrence: Middle-latest Permian; Guizhou (Longtan Formation and Changxing Formation of Anshun, Liuzhi and Qinglong) and Anhui (samples CH 6-1-1, CH6-1-2, CH6-1-3, CH 6-2-1, CH6-2-2, CH6-2-3, CH6-2-4, CH6-3-1, CH6-3-3, CH 6-3-4, CH6-3-5, CH6-4-4, Dalong Formation of Chaohu Section), South China; Bükk Montains, Hungary; Taurus, Turkey.

Fabalicypris **cf.** ***minuta*** **Cooper, 1946** ***sensu*** **Yuan** ***et al.*****, 2007**

Pl. 6, figs 10-13

2007 *Fabalicypris* cf. *minuta* Cooper, 1946; Yuan *et al.*: p.177, pl.3, figs 1-3.

Material: Eighteen carapaces and one valve.

Measurements: L=415-514mm, H=189-229μm, H/L=0.41-0.49, W/L=2.7.

Occurrence: Latest Permian. Guangxi (beds 03DP5 and 03DP10, Dalong Formation of Dongpan Section) and Anhui (sample CH 6-2-2, Dalong Formation of Chaohu Section), South China.

***Fabalicypris* sp.1**

Pl. 7, figs 13, 14

Material: Nine carapaces and four valves.

Measurements: (four specimens measured) carapace: L=500-514μm, H=227-238μm, H/L=0.45-0.46; valve: L=490-498μm, H=190-204μm, H/L=0.38-0.41

Remarks: These specimens are distinguished by their small size, broadly convex DB, sub-equally rounded AB and PB (with the maximum curvature below mid-height) and overlap along all margins except AB.

Occurrence: Latest Permian. Anhui (samples CH6-1-2 and CH 6-3-2, Dalong Formation of Chaohu Section), South China.

Bairdiidae sp.1

Pl. 6, figs 14-18

2007 *Absina* cf.*unispinosa* (Gründel, 1961); Yuan *et al.*: p.185, pl.5, figs 4-7.

Material: Six valves and one carapace.

Measurements: (only complete specimens measured) L=222–312μm, H=130–165μm, H/L=0.53–0.59.

Remarks: In Yuan *et al.* (2007), the specimens from the Dongpan section were assigned to *Absina* cf.*unispinosa* (Gründel, 1961) based on the upward "rostriform". However, as described in Yuan *et al.* (2007, p.185), the specimens have not the postero-ventral spine which is a generic character for *Absina*. The complete carapace found from the Xichang Section also do not possess the postero-ventral spine. It gives doubt to assign the specimens to the species *Absina* cf.*unispinosa* (Gründel, 1961). I assign the present specimens to the family Bairdiidae regarding the upward "rostriform" as the anterior beak.

Occurrence: Latest Permian. Guangxi (bed 03DP4, Dalong Formation of Dongpan Section; Dalong Formation of Xichang Section) and Guizhou (samples SW13-11 and SW13-12, Linghao Formation of Shaiwa Section), South China.

Bairdiidae sp.2

Pl. 6, fig. 9

Material: One valve.

Measurements: L=417µm, H=286µm, H/L=0.68.

Occurrence: Latest Permian. Guizhou (sample SW13-12, Linghao Formation of Shaiwa Section), South China.

Bairdiidae sp.3

Pl. 5, figs 16-18

Material: Three valves.

Measurements: L=292-526µm, H=142-244µm, H/L=0.47-0.49.

Remarks: In general outline, the present specimens are similar to *Bythocypris* sp. A *sensu* Crasquin-Soleau *et al.*, 2006 from the Early Triassic strata of Guangxi, South China, but differ from the latter by having lower maximum curvature of PB, convex PDB, slightly concave VB and the maximum height at mid-length.

Occurrence: Latest Permian. Guizhou (samples SW13-3, SW13-11 and SW13-12, Linghao Formation of Shaiwa Section), South China.

Bairdiidae sp.4

Pl. 4, fig. 14

Material: One fragment of a valve.

Occurrence: Latest Permian. Guizhou (sample SW13-12, Linghao Formation of Shaiwa Section), South China.

Bairdiidae sp.5

Pl. 4, fig. 18

Material: One fragment of a left valve.

Occurrence: Latest Permian. Guizhou (sample SW13-3, Linghao Formation of Shaiwa Section), South China.

Family ACRATIIDAE Gründel, 1962
Subfamily ACRATIINAE Gründel, 1962
Genus *Acratia* Delo, 1930

Type species: *Acratia typica* Delo, 1930

***Acratia* sp.1**

Pl. 7, fig. 16

Material: One valve.
Measurements: L>994µm, H=429µm, H/L<0.43.
Remarks: Due to the poor preservation, it is not permitted to give the specific assignation, although it is acratian without doubt.
Occurrence: Latest Permian. Guizhou (sample SW13-12, Linghao Formation of Shaiwa Section), South China.

Genus *Cooperuna* Gründel, 1962

Type species: *Acratia (Cooperuna) cooperi* Gründel, 1962.

***Cooperuna* cf. *tenuis* Kozur, 1985a *sensu* Yuan *et al.,* 2007**

Pl. 7, fig. 17

2007 *Cooperuna* cf.*tenuis* Kozur, 1985; Yuan *et al*.: p.177, pl.2, fig.16.

Occurrence: Latest Permian. Guangxi (bed 03DP4, Dalong Formation of Dongpan Section), South China.

Superfamily CYTHEROIDEA Baird, 1850
Family BYTHOCYTHERIDAE Sars, 1926

Bythocytheridae gen. et sp. indet. *sensu* Yuan *et al.,* 2007

Pl. 7, fig. 15

2007 Bythocytheridae gen et sp.indet; Yuan *et al*.: p.177-178, pl.3, fig.6.

Occurrence: Latest Permian. Guangxi (bed 03DP2, Dalong Formation of Dongpan Section), South China.

Bythocytheridae indet. 2

Pl. 7, fig. 18

Material: One valve.

Measurements: L=726μm, H=321μm, H/L=0.44.

Remarks: The poor preservation does not permit the further determination. This specimen is assigned to the family Bythocytheridae by its long and straight DB, sub-triangular outline and caudal process.

Occurrence: Latest Permian. Guizhou (sample SW 12-5, Linghao Formation of Shaiwa Section), South China.

Genus *Monoceratina* Roth, 1928

Type species: *Monoceratina ventrale* Roth, 1928.

Monoceratina sp. 1 *sensu* Yuan *et al.,* 2007

Pl. 8, fig. 1

2007 *Monoceratina* sp.1; Yuan *et al.*: p.179, pl.3, fig.8.

Occurrence: Latest Permian. Guangxi (bed 03DP5, Dalong Formation of Dongpan Section), South China.

Monoceratina ? sp. 2 *sensu* Yuan *et al.,* 2007

Pl. 8, fig. 2

2007 *Monoceratina* ? sp.1; Yuan *et al.*: p.179, pl.3, fig.7.

Occurrence: Latest Permian. Guangxi (bed 03DP2, Dalong Formation of Dongpan Section), South China.

Family TRICORNIDAE Blumenstengel, 1965

Genus *Bohemina* Snajdr, 1951

Type species: *Bohemina prantli* Snajdr, 1951

***Bohemina* (*Pokornina*) ? sp. 1 *sensu* Gründel & Kozur, 1975**

Pl. 8, fig. 3

1975 *Bohemina* (*Pokornina*) ? sp. 1; Gründel & Kozur: 41, pl. 1, fig. 10.
2007 *Bohemina* (*Pokornina*) ? sp. 1 *sensu* Gründel & Kozur; Yuan *et al*.: p.179, pl.3, fig.11.

Occurrence: Early Permian-latest Permian. Timor(Kekneno series of Moetis region), Indonesia; Guangxi (beds 03DP3 and 03DP5, Dalong Formation of Dongpan Section), South China.

***Bohemina* (*Pokornina*) ? cf. sp.1 *sensu* Gründel & Kozur, 1975**

Pl. 8, fig. 4

Material: One valve.
Measurements: L=450µm, H=217µm, H/L=0.48.
Remarks: This specimen is compared with *Bohemina* (*Pokornina*) ? sp.1 *sensu* Gründel & Kozur, 1975 by its triangular outline, straight DB and truncated AB.
Occurrence: Latest Permian. Guizhou (sample SW11-11, Linghao Formation of Shaiwa Section), South China.

Family BEROUNELLIDAE Sohn & Berdan, 1960

Genus *Paraberounella* Blumenstengel, 1965

Type species: *Paraberounella lobella* Blumenstengel, 1965.

***Paraberounella* ? cf. *laterospina* Kozur, 1991a *sensu* Yuan *et al.*, 2007**

Pl. 8, figs 5, 6

2007 *Paraberounella* ? cf. *laterospina* Kozur, 1991a; Yuan *et al*.: p.179, pl.3, figs 9-10.

Meterial: Three valves.
Occurrence: Latest Permian. Guangxi (bed 03DP5, Dalong Formation of Dongpan Section; bed LQ20, Dalong Formation of Liuqiao Section), South China.

Paraberounella sp. 1 *sensu* Yuan *et al.*, 2007

Pl. 8, fig. 7

2007 *Paraberounella* sp.1; Yuan *et al.*: p.179, pl.3, fig.13.

Occurrence: Latest Permian. Guangxi (bed 03DP2, Dalong Formation of Dongpan Section), South China.

Superfamily BAIRDIOCYPRIDOIDEA Shaver, 1961

Family RECTONARIIDAE Gründel, 1962

Rectonariidae gen. et sp. indet. *sensu* Yuan *et al.*, 2007

Pl. 8, fig. 8

2007 Rectonariidae gen.et sp. indet.; Yuan *et al.*: p.179, pl.3, fig.12.

Occurrence: Latest Permian. Guangxi (bed 03DP3, Dalong Formation of Dongpan Section), South China.

Genus *Rectonaria* Gründel, 1961

Type species: *Rectonaria muelleri* Gründel, 1961.

Rectonaria cf. *inclinata* Gründel, 1961 *sensu* Yuan *et al.*, 2007

Pl. 8, fig. 9

2007 *Rectonaria* cf.*inclinata* Gründel, 1961; Yuan *et al.*: p.179-180, pl.3, fig.14.

Occurrence: Latest Permian. Guangxi (bed 03DP2, Dalong Formation of Dongpan Section), South China.

Family PACHYDOMELLIDAE Berdan & Sohn, 1961

Denticupachydomella n.gen.

Derivation: From the character of the shell according to the Latin *denticulus/denticuli* - denticule.

Type species: *Denticupachydomella spinosa* n. gen. n. sp.

Diagnosis: A new Pachydomellidae genus with LV having straight DB, two hornlike dorsal spines erecting at the ACA, one stronger spine at the PCA, three denticles along DB, one posteroventral spine and pustulous lateral surface.

Remarks: *Denticupachydomella* n.gen. is distinguished with other genera of Pachydomellidae by the special dorsal and lateral ornamentation.

Occurrence: Latest Permian. South China.

Denticupachydomella spinosa n.gen. n.sp.

Pl. 8, figs 10-15

Derivation: From the Latin *spinosa*-spinous.

Diagnosis: The same as genus.

Holotype: One complete carapace from LQ 16 (pl. 8, fig. 10), collection number X0301-183.

Paratypes: One left valve from LQ 16 (pl. 8, fig. 11), collection number X0301-184; one right valve from LQ 5 (pl. 8, fig. 13), collection number X0301-185; one left valve from LQ 16 (pl. 8, fig. 12), collection number X0301-186.

Material: Four left valves, five right valves and one carapace from siliceous mudstones and muddy siliceous rocks.

Measurements: (without the denticles and spine)

Holotype: L=500µm, H=289µm, H/L=0.58

Paratypes: L=409-511µm, H=218-300µm, H/L=0.52-0.59

Description: Carapace small and tumid; LV larger than RV, LV overreach RV along whole margins, overlap reversed.

LV: DB straight and long, a little shorter than the maximum length of the carapace; CA distinct, ACA about 135°, PCA about 140°; two strong hornlike spines erecting at the ACA and one at the PCA, the posterior one larger, stronger and a little obliquely backward, another three smaller dorsal denticles protruding along the dorsum, evenly distributed between the cardinal spines; VB slightly convex; AB broadly rounded with the maximum curvature a little below mid-height; PB acutely rounded with the maximum curvature at mid-height, one or two spines protruding outward the valve at the posteroventral part; surface pustulous.

RV: DB broadly arched; VB slightly convex; AB evenly rounded and slightly compressed; PB acuminate and terminated by a strong, short and somewhat upwardly pointed spine; surface smooth or slightly pustulous.

Remarks: The spines protruding at the posteroventral part of LV may be different in numbers and strength. On the present valves, I have not found out the direct relationship between spine character and ontogeny. In addition, the tumid carapace and overlap type give appearance of the genus

Microcheilinella Geis, 1933 or *Spinomicrocheilinella* Kozur, 1985a, but the new genus and species can be easily distinguished by the very special ornamentation.

Occurrence: Latest Permian. Guangxi (beds LQ5-LQ16, Dalong Formation of Liuqiao Section), South China.

Genus *Microcheilinella* Geis, 1933

Type species: *Microcheilus distortus* Geis, 1932.

***Microcheilinella* cf. *elatus* (Lethiers, 1978) *sensu* Lethiers, 1981**

Pl. 9, fig. 1

1981 *Newsomites* cf. *elatus* Lethiers, 1978; Lethiers: 72, pl. 14, figs 136a, c.
2007 *Microcheilinella* cf. *elatus* (Lethiers, 1978) *sensu* Lethiers, 1981; Yuan *et al.*: p.180, pl.3, fig.5.

Occurrence: Late Devonian - latest Permian. NW Canada; Guangxi (beds 03DP3 and 03DP5, Dalong Formation of Dongpan Section), South China.

***Microcheilinella aculeata* Buschmina, 1975**

Pl. 9, fig. 2

1975 *Microcheilinella aculeata* sp.nov.;Buschmina: 44, pl. 2, fig. 11.
1981 *Microcheilinella aculeata* Buschmina; Olempska:45, pl. 7, figs 2a-c.
1988a *Microcheilinella aculeata* Buschmina; Wang: 280, pl. 2, figs 20-22.
1997 *Microcheilinella aculeata* Buschmina; Olempska: 318, pl. 17, figs C-E.
2007 *Microcheilinella aculeata* Buschmina, 1975; Yuan *et al.*: p.180, pl.4, fig.16.

Occurrence: Early Carboniferous - latest Permian. Kolyma Massif, Russia; Holy Cross Mountains, Poland; Guangxi (Wangyou Formation of Nandan; bed 03DP10, Dalong Formation of Dongpan Section), South China.

***Microcheilinella* sp.1**

Pl. 9, fig. 3

Material: One carapace.

Measurements: L=303μm, H=182μm, H/L=0.6.

Remarks: Although the specimen is poorly preserved, the strong overlapped and swollen carapace presents the prominent characteristics of the genus *Microcheilinella*.

Occurrence: Latest Permian. Guizhou (sample SW13-12, Linghao Formation of Shaiwa Section), South China.

Genus *Spinomicrocheilinella* Kozur, 1985a

Type species: *Spinomicrocheilinella spinosa* Kozur, 1985a.

Spinomicrocheilinella anterocompressa Yuan & Crasquin-Soleau, 2007

Pl. 9, figs 4-6

2007 *Spinomicrocheilinella anterocompressa* Yuan & Crasquin-Soleau n.sp.; Yuan *et al.*: p.180-182, pl.4, figs 1-3.

Material: Fifty-three carapaces and fifty-eight valves.

Occurrence: Latest Permian. Guangxi (beds 03DP2, 03DP3, 03DP5, 03DP7 and 03DP10, Dalong Formation of Dongpan Section; beds LQ16, LQ18 and LQ22, Dalong Formation of Liuqiao Section), South China.

Spinomicrocheilinella aff. *dargenioi* Kozur 1991a *sensu* Yuan *et al.*, 2007

Pl. 9, figs 7-9, 12

2007 *Spinomicrocheilinella* aff. *dargenioi* Kozur 1991a; Yuan *et al.*: p.182, pl.4, figs 5, 6.
non 2007 *Spinomicrocheilinella* aff. *dargenioi* Kozur 1991a; Yuan *et al.*: p.182, pl.4, figs 4, 7.

Material: Four valves.

Measurements: (with the spine) L=230-764μm, H=120-400μm, H/L=0.49-0.52.

Remarks: Due to the poor preservation of the only RV, the present specimens are compared to *Spinomicrocheilinella dargenioi* Kozur, 1991a from the late Middle Permian – early Late Permian of Sicily, Italy according to the elliptical and tumid valve and the posterior spine of RV. The specimens are the same as those figured in Yuan *et al.* (2007, pl.4, figs 5, 6). The other two specimens (figured in Yuan *et al.*, 2007, pl.4, fig.4, 7) are excluded from this assignation to *S.* aff. *dargenioi* by the PB with small curvature radius, broadly arched DB and straight hinge line.

Occurrence: Latest Permian. Guangxi (beds 03DP3 and 03DP2, Dalong Formation of Dongpan Section) and Guizhou (sample SW13-12, Linghao Formation of Shaiwa Section), South China.

***Spinomicrocheilinella* sp. 1 *sensu* Yuan *et al.,* 2007**

Pl. 9, figs 10, 11

2007 *Spinomicrocheilinella* sp.1; Yuan *et al.*: p.182, pl.4, figs 8, 9.

Occurrence: Latest Permian. Guangxi (beds 03DP2-03DP5, Dalong Formation of Dongpan Section), South China.

***Spinomicrocheilinella* sp. 2 *sensu* Yuan *et al.,* 2007**

Pl. 9, fig. 13

2007 *Spinomicrocheilinella* sp.2; Yuan *et al.*: p.182, pl.4, fig.10.

Occurrence: Latest Permian. Guangxi (bed 03DP5, Dalong Formation of Dongpan Section), South China.

***Spinomicrocheilinella* sp.3**

Pl. 9, figs 14, 15

Material: Two valves.
Measurements: (with the spine) L=285-378µm, H=140-185µm, H/L=0.49.
Remarks: These specimens are distinguished by the nearly vertical PB and long and sub-straight DB.
Occurrence: Latest Permian. Guizhou (sample SW13-12, Linghao Formation of Shaiwa Section), South China.

***Spinomicrocheilinella* sp.4**

Pl. 9, fig. 16

Material: One valve.
Measurements: (with the spine) L=378µm, H=193µm, H/L=0.51.

Remarks: According to its elliptical outline, arched DB, sub-straight VB and a posterior spine, the specimen is assigned to the genus *Spinomicrocheilinella* Kozur, 1985a.

Occurrence: Latest Permian. Guizhou (sample SW13-14, Linghao Formation of Shaiwa Section), South China.

Family BAIRDIOCYPRIDIDAE Shaver, 1961

Genus *Pseudobythocypris* Shaver, 1958

Type species: *Bythocypris pediformis* Knight, 1928.

***Pseudobythocypris concava* (Cooper, 1941)**

Pl. 9, figs 17, 18

1941 *Bythocypris concava* Cooper, n.sp.; Cooper: p.28, pl.3, figs 3-6.

Material: Three carapaces and five valves.

Measurements: (two specimens measured) L= 457-578µm, H=229-289µm, H/L=0.5.

Remarks: The present specimens are assigned to *Bythocypris concava* Cooper, 1941 from the Late Carboniferous (Upper Mississippian) of Illinois, United States by the elongate outline, arched DB, slightly concave VB, straight PB having a high angle with PVB and the overlap along all margins (strongest along VB). The species is changed to the genus *Pseudobythocypris* Shaver, 1958 due to its postero-ventral slope meeting PB in a sharp angle .

Occurrence: Late Carboniferous - latest Permian. Illinois, United States; Anhui (samples CH 6-1-1 and CH 6-1-3, Dalong Formation of Chaohu Section), South China.

***Pseudobythocypris guiqianensis* n.sp.**

Pl. 10, figs 1-8

2007 *Pseudobythocypris* aff. *procera* (Coryell & Billings, 1932); Yuan *et al.*: p.182, pl.4, figs 11-12.
2007 *Pseudobythocypris* cf. *centralis* (Coryell & Billings, 1932); Yuan *et al.*: p.182, pl.4, figs 13-15.

Derivation of name: The species is named after the abbreviation of the localities, Guangxi (gui) and Guizhou (qian), South China.

Diagnosis: A species of the genus *Pseudobythocypris* with rounded AB, posteroventral slope meeting with posterodorsal border in an angle about 110° and maximum height of the carapace in front or at mid-length.

Holotype: A complete carapace (pl. 4, fig. 13 in Yuan *et al*., 2007 and pl. 10, fig.1 here) from Dongpan section, Guangxi, collection number X0301-162.

Paratypes: A left valve (pl.4, fig.11 in Yuan *et al*., 2007 and pl. 10, fig. 2 here) from Dongpan section, Guangxi, collection number X0301-160; a right valve (pl. 10, fig. 3) from Shaiwa section, Guizhou, collection number X0301-228.

Material: Seven right valves and one left valve from siliceous mudstones of Shaiwa section, Guizhou; five carapaces and thirteen valves from siliceous mudstones of Dongpan section, Guangxi; one carapace and nine valves from siliceous mudstones of Liuqiao Section, Guangxi.

Measurements: Holotype: L=300μm, H=171μm, H/L=0.57; Paratypes: L=316-471μm, H=158-224μm, H/L=0.48-0.49.

Description: Carapace tumid, bean-shaped in lateral view; DB arched or slightly arched, inclined to anterior and posterior border; VB straight or gently convex in LV and slightly concave in RV, AVB upward bent to meet the AB in a broad curve, PVB meets the PB in a angular curve to form an obtuse and distinct posterior angle; AB evenly rounded with maximum convexity about mid-height; PB obliquely rounded with larger curvature radius than AB and ended in an obtuse and distinct posterior angle, with maximum convexity lower than mid-height; maximum height slightly in front of or at mid-length; LV, larger, overlaps RV along DB and VB; surface smooth.

Remarks: In Yuan *et al.* (2007), the discovered specimens were respectively attributed to *Pseudobythocypris* cf. *centralis* by having the maximum height at mid-length and to *Pseudobythocypris* aff. *procera* by having the maximum height in front of mid-length and small H/L ratio. Here, the specimens found in Shaiwa section present intermediate characteristics between *Pseudobythocypris* cf. *centralis* and *Pseudobythocypris* aff. *procera sensu* Yuan & Crasquin-Soleau, 2007 from the Dongpan section, Guangxi such as having the maximum height at mid-length as *P*. cf. *centralis* and small H/L ratio as *P*. aff. *procera*. So all the specimens found here and in the Dongpan section are assigned to unique species.

Occurrence: Latest Permian. Guangxi (beds 03DP2, 03DP3, 03DP5 and 03DP10, Dalong Formation of Dongpan Section; beds LQ3, LQ5, LQ16, LQ18, LQ22 and LQ51, Dalong Formation of Liuqiao Section) and Guizhou (samples SW13-10, SW13-11, SW13-12 and SW13-14, Linghao Formation of Shaiwa Section), South China.

***Pseudobythocypris* cf. *guiqianensis* n.sp.**

Pl. 10, fig. 9

Material: Two valves.

Measurements: L>313μm, H=157μm, H/L<0.5.

Remarks: According to the sharp angle formed between the posteroventral slope and the PB, the specimens are compared with *Pseudobythocypris guiqianensis* n.sp. Compared with the latter, these specimens have straighter PB and more acute posteroventral angle.

Occurrence: Latest Permian. Guizhou (sample SW13-12, Linghao Formation of Shaiwa Section), South China.

***Pseudobythocypris* sp. 1 *sensu* Yuan *et al.*, 2007**

Pl. 10, figs 10, 11

2007 *Pseudobythocypris* sp.1; Yuan *et al.*: p.183, pl.4, figs 17-18.

Occurrence: Latest Permian. Guangxi (beds 03DP2, 03DP5 and 03DP7, Dalong Formation of Dongpan Section), South China.

***Pseudobythocypris* sp.2**

Pl. 10, figs 13-15

Material: Five valves.

Measurements: (three specimens measured) L= 505-731μm, H=253-359μm, H/L=0.49-0.53.

Remarks: The specimens are assigned to the genus *Pseudobythocypris* Shaver, 1958 by an upswept postero-ventral slope meeting with PB in an angle. They are distinguished with other *Pseudobythocypris* species in the tumid valve, convex VB and somewhat tapering PB.

Occurrence: Latest Permian. Anhui (samples CH6-1-1, CH6-1-2 and CH 6-1-3, Dalong Formation of Chaohu Section), South China.

Suborder METACOPINA Sylvester-Bradley, 1961
Superfamily HEALDIOIDEA Hartlon, 1933
Family HEALDIIDAE Harlton, 1933
Genus *Healdia* Roundy, 1926

Type species: *Healdia simplex* Roundy, 1926.

***Healdia* sp.1 *sensu* Yuan *et al.,* 2007**

Pl. 10, fig. 16

2007 *Healdia* sp.1; Yuan *et al.*: p.183, pl.5, fig.1.

Occurrence: Latest Permian. Guangxi (beds 03DP2- 03DP4, Dalong Formation of Dongpan Section), South China.

***Healdia* sp.2**

Pl. 10, fig. 17

Material: One valve.

Measurements: L=385μm, H=223μm, H/L=0.58.

Remarks: This specimen is assigned to the genus *Healdia* Roundy, 1926 by its sub-triangular outline, arched DB, slightly convex VB, broadly rounded AB and truncated PB. The strong posteriorly pointed spine on lateral surface makes this specimen different from the other *Healdia* species.

Occurrence: Latest Permian. Guangxi (bed LQ16, Dalong Formation of Liuqiao Section), South China.

Genus *Healdiopsis* Gründel, 1962

Type species: *Healdia thuringensis* Gründel, 1961.

***Healdiopsis thuringensis thuringensis* (Gründel, 1961)**

Pl. 10, fig. 18

1961 *Healdia thuringensis* Gründel: 99, pl. 4, figs 3-5, pl. 14, fig. 4.
1962 *Healdiopsis thuringensis thuringensis* (Gründel, 1961); Gründel: 76, Tab. 2-4.
1981 *Healdiopsis thuringensis* (Gründel, 1961); Olempska: 42, pl. 5, fig. 4, Tab. 2.
1986 *Healdia thuringensis* Gründel; Bartzsch & Weyer: pl. 3, fig. 19.
1990 *Healdia thuringensis* Gründel; Becker: 35, pl. 1, fig. 4.
1990 *Healdia thuringensis* Gründel; Becker & Bless: 428, fig. 2-5.
1991 *Healdiopsis thuringensis thuringensis* (Gründel, 1961); Lethiers & Feist: 80, pl. 3, fig. 6.
1993 *Healdia thuringensis* Gründel; Becker *et al.*: 25, pl. 5, figs 1-9, pl. 6, figs 1-11.
1993 *Healdiopsis thuringensis thuringensis* Gründel, 1961; Blumenstengel: pl. 2, fig. 16.
1994 *Healdia thuringensis* Gründel, 1961; Blumenstengel: Tab.1.
1995b *Healdia thuringensis* Gründel; Becker & Blumenstengel: 69-71, figs 2-5, 4-4.
1997 *Healdia thuringensis* Gründel; Olempska: 316, figs 8D-F.
2007 *Healdia thuringensis thuringensis* (Gründel, 1961); Yuan *et al.*: p.183, pl.5, fig.2.

Occurrence: Late Devonian - latest Permian. Montagne Noire, France; Holy Cross Mountain, Poland; North Sauerland, Rhenish Massif; Thuringia, Germany; Guangxi (beds 03DP3, 03DP4 and 03DP5, Dalong Formation of Dongpan Section), South China.

Genus *Marginohealdia* Blumenstengel, 1965

Type species: *Marginohealdia marginata* Blumenstengel, 1965

Marginohealdia cf. sp.nov.2 *sensu* Crasquin-Soleau *et al.* 2008

Pl. 11, fig. 1

Material: One valve.

Measurements: L=321µm, H=217µm, H/L=0.68.

Remarks: This specimen is compared to *Marginohealdia* sp.nov.2 *sensu* Crasquin-Soleau *et al.*, 2008 from the Middle Permian of Sicily, Italy by the general outline, flattened AB and two strong spines at posterior part of the surface. The specimen here differs from the latter by the flattened PB, slightly concave VB and stronger spines.

Occurrence: Latest Permian. Guizhou (sample SW13-12, Linghao Formation of Shaiwa Section), South China.

Marginohealdia sp.1

Pl. 11, figs 4-9

Material: Nine valves.

Measurements: L=471-621µm, H=267-389µm, H/L=0.54-0.63.

Description: Valve sub-rectangular; DB straight and slightly inclined posteriorly, with length a little shorter than the maximum length; VB straight and parallel to DB, or slightly convex; AB rounded with the maximum curvature below mid-height; PB broadly rounded, having larger curvature radius than AB; all margins flattened, the forefront of AB a little thickened to make appearance of the ridge; one circular ridge (with some gap at anterior vertical connection) at the central-posterior part of the lateral surface, with the diameter about half of the maximum length, dorsal part parallel to DB, ventral part a little convex towards VB, two spines erecting at the junction points between dorsal/vertical and posterior/vertical parts; maximum height at anterior one third of the maximum length, maximum length at about mid-height; surface smooth.

Remarks: Due to the posterior spines, the ridge on the central-posterior part and the ridge at the forefront of AB, the specimens here are assigned to the genus *Marginohealdia* Blumenstengel, 1965.

Occurrence: Latest Permian. Guizhou (samples SW13-12, SW13-13 and SW13-14, Linghao Formation of Shaiwa Section), South China.

Genus *Waylandella* Coryell & Billings, 1932

Type species: *Waylandella spinosa* Coryell & Billings, 1932

Waylandella cf. *dartyensis* Benson & Collinson, 1958

Pl. 11, fig. 2

Material: One valve.

Measurements: L=830μm, H=430μm, H/L=0.52.

Remarks: The present specimen is compared to *Waylandella dartyensis* Benson & Collinson, 1958 from the Lower Mississippian of Illinois, United States by the elliptical outline, concave VB, rounded AB and posteroventral spine. But the specimen here differs from the latter in the straight DB and posterodorsal slope.

Occurrence: Latest Permian. Guizhou (sample SW13-12, Linghao Formation of Shaiwa Section), South China.

Genus *Triplacera* Gründel, 1961

Type species: *Triplacera triquetua* Gründel, 1961

Triplacera ? sp. 1

Pl.11, fig. 3

Material: One valve.

Measurements: L=484μm, H=316μm, H/L=0.65.

Remarks: According to the strong posterior hollow spine and sub-triangular outline in lateral view, this specimen is assigned to the genus *Triplacera* Gründel, 1961 with doubt. It is noticeable that the strong spine is converged by two ridges on the middle to posterior part of the lateral surface. Between the two ridges, the surface is hollow.

Occurrence: Latest Permian. Guizhou (sample SW13-14, Linghao Formation of Shaiwa Section), South China.

Family CAVELLINIDAE Egorov, 1950

Genus *Cavellina* Coryell, 1928

Type species: *Cavellina puchella* Coryell, 1928.

***Cavellina* cf. *nebrascensis* (Geinitz, 1867) *sensu* Yuan *et al.*, 2007**

Pl. 10, fig. 12

2007 *Cavellina* cf.*nebrascensis* (Geinitz, 1867); Yuan *et al.*: p.183, pl.5, fig.3.

Occurrence: Latest Permian. Guangxi (beds 03DP3 and 03DP10, Dalong Formation of Dongpan Section), South China.

Superfamily THLIPSUROIDEA Ulrich, 1894

Family QUASILLITIDAE Coryell & Malkin, 1936

Genus *Absina* Gründel, 1962

Type species: *Absina ectina* Gründel, 1962.

Remarks: The genus *Absina* was established by Gründel in 1962 with the type species and *Cypridina* ? *unispinosa* Gründel, 1961. In Gründel (1961, 1962), DB and VB are reversed so that the anterior beak was bent downward and considered as the myodocopid rostriform, consequently, the genus was assigned to the order Myodocopida. In 1979, Blumenstengel reversed the ventral and dorsal orientation of *Absina* (*Heterma*) *unispinosa*. Becker (1999), describing this genus in detail, gives it the present systematic position and this paper follows his assignation.

***Absina* ? sp. 1 *sensu* Yuan *et al.*, 2007**

Pl. 11, figs 10, 11

2007 *Absina* ? sp.1; Yuan *et al.*: p.185, pl.5, fig.8.

Material: Four valves.

Measurements: (two specimens measured) L=335-438μm, H=200-246μm, H/L =0.56-0.60.

Occurrence: Latest Permian. Guangxi (bed 03DP4, Dalong Formation of Dongpan Section; bed LQ51, Dalong Formation of Liuqiao Section), South China.

***Absina* ? sp. 2 *sensu* Yuan *et al.*, 2007**

Pl. 11, fig. 12

2007 *Absina* ?sp.2; Yuan *et al.*:p.185, pl.5, fig.9.

Occurrence: Latest Permian. Guangxi (bed 03DP4, Dalong Formation of Dongpan Section), South China.

Podocopida indet.1

Pl. 11, fig. 13

Material: One valve.

Measurements: L=270µm, H=183µm, H/L=0.68.

Remarks: This specimen is comparable to Genus 1 sp.1 *sensu* Crasquin-Soleau 1997 from the Early Permian (Artinskian) strata of Canada (South British Columbia) (Crasquin-Soleau, 1997, p.84, pl.7, fig.7.) by the lateral outline and the upwards bent PB. Our specimen has larger curvature radius of AB and straighter VB.

Occurrence: Latest Permian. Guizhou (sample SW13-12, Linghao Formation of Shaiwa Section), South China.

Podocopida indet.2

Pl. 11, fig. 14

Material: One incomplete valve.

Remarks: Maybe it is a fragment of *Spinomicrocheilinella* species. However, the preservation is too poor to do any precise assignation.

Occurrence: Latest Permian. Guizhou (sample SW13-13, Linghao Formation of Shaiwa Section), South China.

Podocopida indet.3

Pl. 11, fig. 15

Material: One incomplete valve.

Measurements: L>262µm, H≈196µm.

Remarks: Too poor preservation makes the precise assignation indeterminate.

Occurrence: Latest Permian. Guizhou (sample SW13-12, Linghao Formation of Shaiwa Section), South China.

Podocopida indet.4

Pl. 11, fig. 16

Material: Four valves.

Measurements: L=288-467μm, H=154-280μm, H/L=0.54-0.63.

Occurrence: Latest Permian. Guizhou (sample SW13-12, Linghao Formation of Shaiwa Section), South China.

Podocopida indet.5

Pl. 11, fig. 17

Material: Three valves.

Measurements: (one specimen measured) L=521μm, H=314μm, H/L=0.60.

Occurrence: Latest Permian. Guizhou (samples SW13-11, SW13-12 and SW13-14, Linghao Formation of Shaiwa Section), South China.

Podocopida indet.6

Pl. 11, fig. 18

Material: One carapace.

Measurements: L=210μm, H=145μm, H/L=0.69.

Occurrence: Latest Permian. Guizhou (sample SW13-14, Linghao Formation of Shaiwa Section), South China.

Podocopida indet.7

Pl. 12, fig. 1

Material: One valve.

Measurements: L= 576μm, H=252μm, H/L=0.44.

Occurrence: Latest Permian. Anhui (sample CH3-3, Dalong Formation of Chaohu Section); South China.

Order MYODOCOPIDA Sars, 1866
Suborder MYODOCOPINA Sars, 1866
Superfamily ENTOMOZOIDEA Přibyl, 1951
Family ENTOMOZOIDAE Přibyl, 1951
Genus *Waldeckella* Rabien, 1954

Type species: *Bertillonella subcircularis* Stewart & Hendrix, 1945.

***Waldeckella* ? *sphaerula* (Gründel, 1961) *sensu* Becker, 1999**

Pl. 12, figs 2, 3

1999 *Waldeckella* ? *sphaerula* (Gründel, 1961); Becker: 83, pl. 14, figs 5-6.

Occurrence: Late Devonian - latest Permian. North Sauerland, Rhenish Massif; Guangxi (bed 03DP3-03DP5, Dalong Formation of Dongpan Section), South China.

Suborder CLADOCOPINA Sars, 1866
Family POLYCOPIDAE Sars, 1866
Genus *Polycope* Sars, 1866

Type species: *Polycope orbicularis* Sars, 1866.

***Polycope* aff. *baudi* Crasquin-Soleau 1996 *sensu* Yuan *et al.*, 2007**

Pl. 12, figs 4, 5

2007 *Polycope* aff. *baudi* Crasquin-Soleau 1996; Yuan *et al.*: p.185, pl.5, fig.13.

Material: One valve.

Measurements: L=517µm, H= 550mm, H/L = 1.06.

Remarks: Due to the unpreserved hinge line, the orientation is difficult to the specimens including the ones from the Dongpan Section. The specimens are orientated by regarding the straight border as DB and the concentric ridges along free margins. The specimen from the Liuqiao Section has larger H/L than that of the Dongpan Section.

Occurrence: Latest Permian. Guangxi (bed 03DP3, Dalong Formation of Dongpan Section; bed LQ35, Dalong Formation of Liuqiao Section), South China.

Polycope sp. 1 *sensu* Yuan *et al.*, 2007

Pl. 12, fig. 6

2007 *Polycope* sp.1; Yuan *et al.*: p.186, pl.5, fig.12.

Occurrence: Latest Permian. Guangxi (bed 03DP2, Dalong Formation of Dongpan Section), South China.

Polycope sp.2

Pl. 12, figs 11-13

Material: Eleven valves.

Measurements: (three specimens measured) L=300-360μm, H=262-310μm, H/L=0.86-0.91.

Remarks: These specimens are assigned to the genus *Polycope* by the circular outline and sub-straight DB. In poor preservation, the specimens can not be designated at specific level.

Occurrence: Latest Permian. Anhui (samples CH 7-0, Dalong Formation of Chaohu Section), South China.

Polycope sp.3

Pl. 12. figs 7, 8

Material: Three valves.

Measurements: (two specimens measured) L=213-243μm, H=275-286μm, H/L=1.21-1.29.

Remarks: These specimens differ from *Polycope* sp.2 by more circular and higher valve without distinct sub-straight DB.

Occurrence: Late Permian. Anhui (samples CH 6-2-3 and CH 6-2-2, Dalong Formation Chaohu Section), South China.

Family Uncertain

Genus *Discoidella* Croneis & Gale, 1938

Type species: *Discoidella simplex* Croneis & Gale, 1938.

Discoidella xingyangensis Zhang, 1987

Pl. 12, figs 9, 10

1987 *Discoidella xingyangensis* Zhang sp. nov.; Zhang & Liang: p.307, pl.3, fig.5.
non 1991 *Discoidella xingyangensis* Zhang; Zhang & Liang: p.87, pl.1, fig.5.
2004 *Discoidella xingyangensis* Zhang; Yi: pl.1, fig. 12.
2007 *Discoidella xingyangensis* Zhang, 1987; Yuan *et al.*: p.186, pl.5, fig.14.

Material: Two valves.

Measurements: (one specimen measured) L= 356μm, H= 333μm, H/L = 0.94.

Remarks: The specimen figured in Zhang & Liang (1991, pl.1, fig.5) is excluded here from the species Discoidella henanensis Zhang, 1987. I consider that it is more proper to assign that specimen to *Discoidella henanensis* Zhang, 1987 by its chain-like ornamentation.

Occurrence: Late Carboniferous - latest Permian, Henan (Taiyuan Formation of Xingyang), Fujian (Changxing Formation) and Guangxi (beds 03DP2, 03DP3 and 03DP11, Dalong Formation of Dongpan Section; beds LQ15 and LQ35, Dalong Formation of Liuqiao Section), China.

Chapter 3 General features and distribution of ostracod faunas

§ 3.1 Ostracod distribution in studied sections

3. 1. 1 Dongpan Section (DP)

84 samples were collected from the Bed 2 to Bed 12 of the Dongpan Section (Fig.1-B). 41 samples from mudstones, siliceous mudtones, muddy siliceous rocks and bedded siliceous rocks yielded more than 1,600 ostracods (remarks: some samples were combined or added to samples in Yuan *et al.* (2007)). In general, ostracods were abundantly yielded and diverse in some samples but majority of them were in very poor preservation. 28 genera and 50 species with 2 new species *Bairdia dongpanensis* Yuan & Crasquin-Soleau, 2007 and *Spinomicrocheilinella anterocompressa* Yuan & Crasquin-Soleau, 2007 distributed in 26 samples (mainly below the Bed 6) were recognized (Fig.3-1-A). There are still many undetermined specimens excluded in this work.

3. 1. 2 Liuqiao Section (LQ)

38 samples were collected along the Liuqiao Section (Fig.1-B) and processed. About 480 ostracods were yielded from 20 samples of siliceous mudstones and muddy siliceous rocks. The ostracod fauna has not so high abundance as in the Dongpan Section, but has rather high diversity. 21 genera and 39 species (1 new genus *Denticupachydomella* n.gen. and 1 new species *Denticupachydomella spinosa* n.sp. are proposed) have been recognized (Fig.3-1-B).

3. 1. 3 Shaiwa Section (SW)

The Shaiwa section (Fig.1-B) was sampled according to each sub-bed, 87 samples collected in total. Only 16 samples from siliceous mudstones yielded few ostracods (about 250 individuals) in very poorly preservation. 14 genera and 37 species (1 new species *Pseudobythocypris guiqianensis* n.sp. is proposed) were identified (Fig.3-1-C). Some of them are still in open nomenclature due to the poor

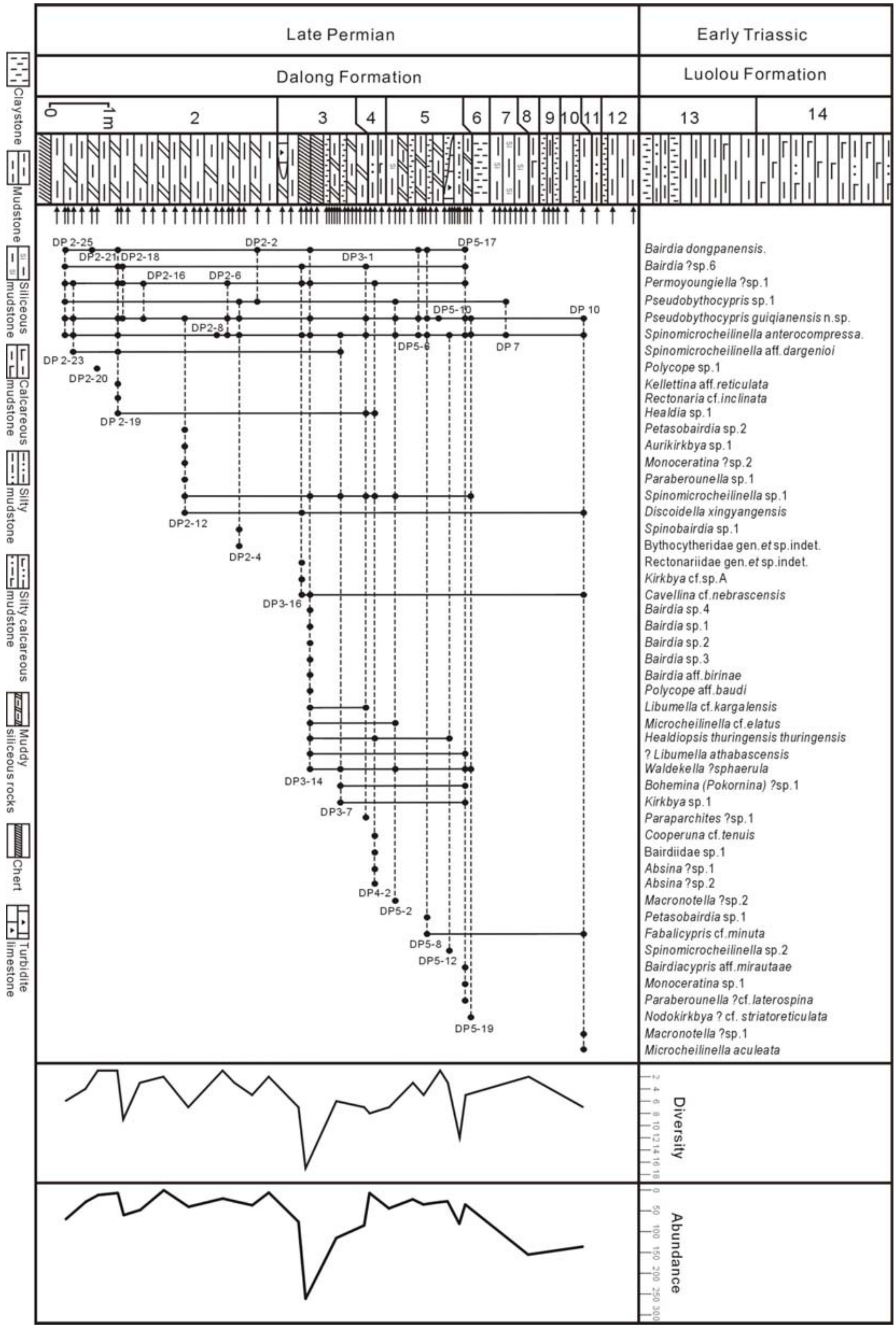

Fig. 3-1-A Ostracod distribution in the Dongpan Section.

preservation and too rare material. In all studied sections, the Shaiwa fauna has the lowest abundance.

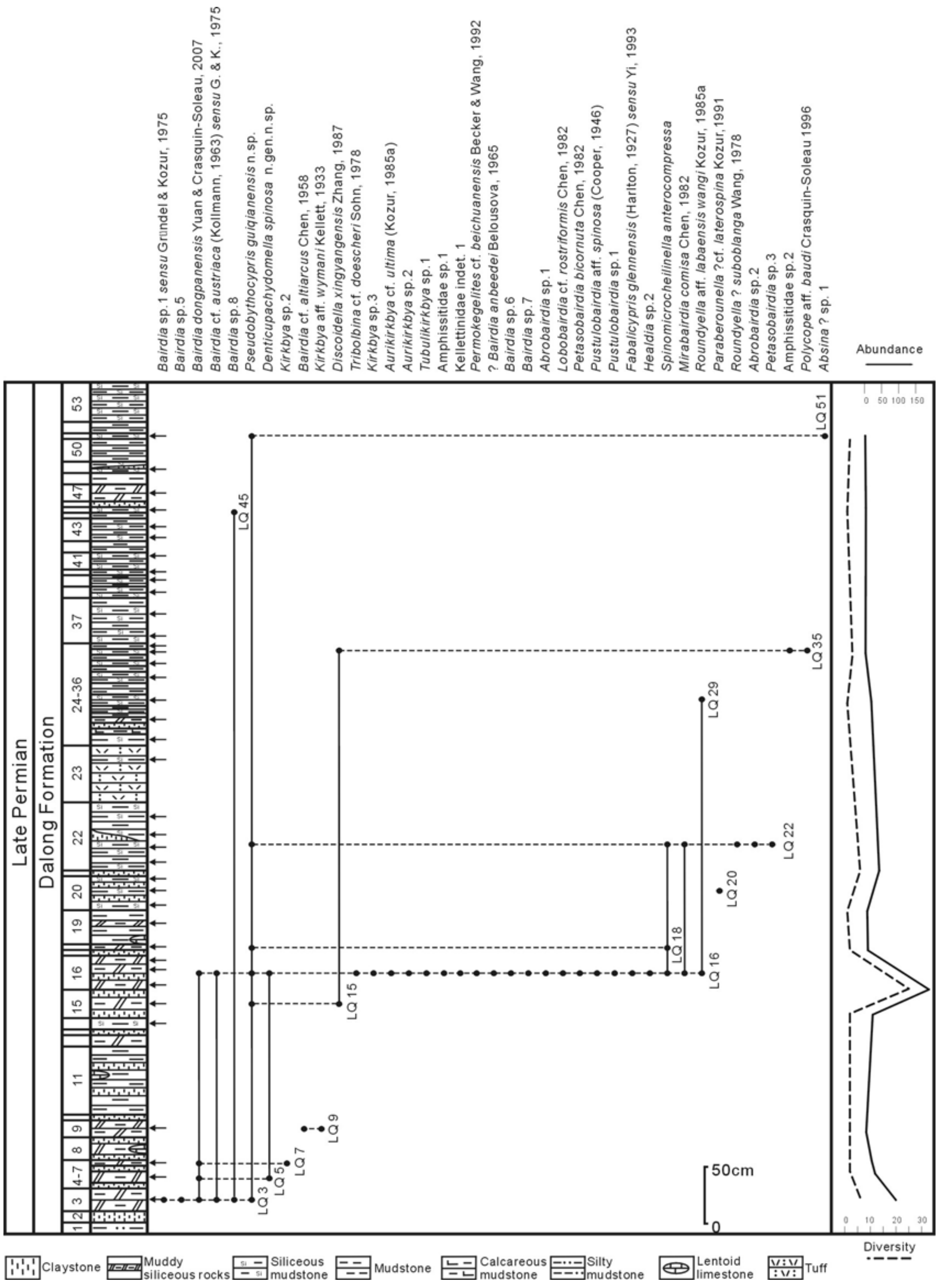

Fig. 3-1-B Ostracod distribution in the Liuqiao Section.

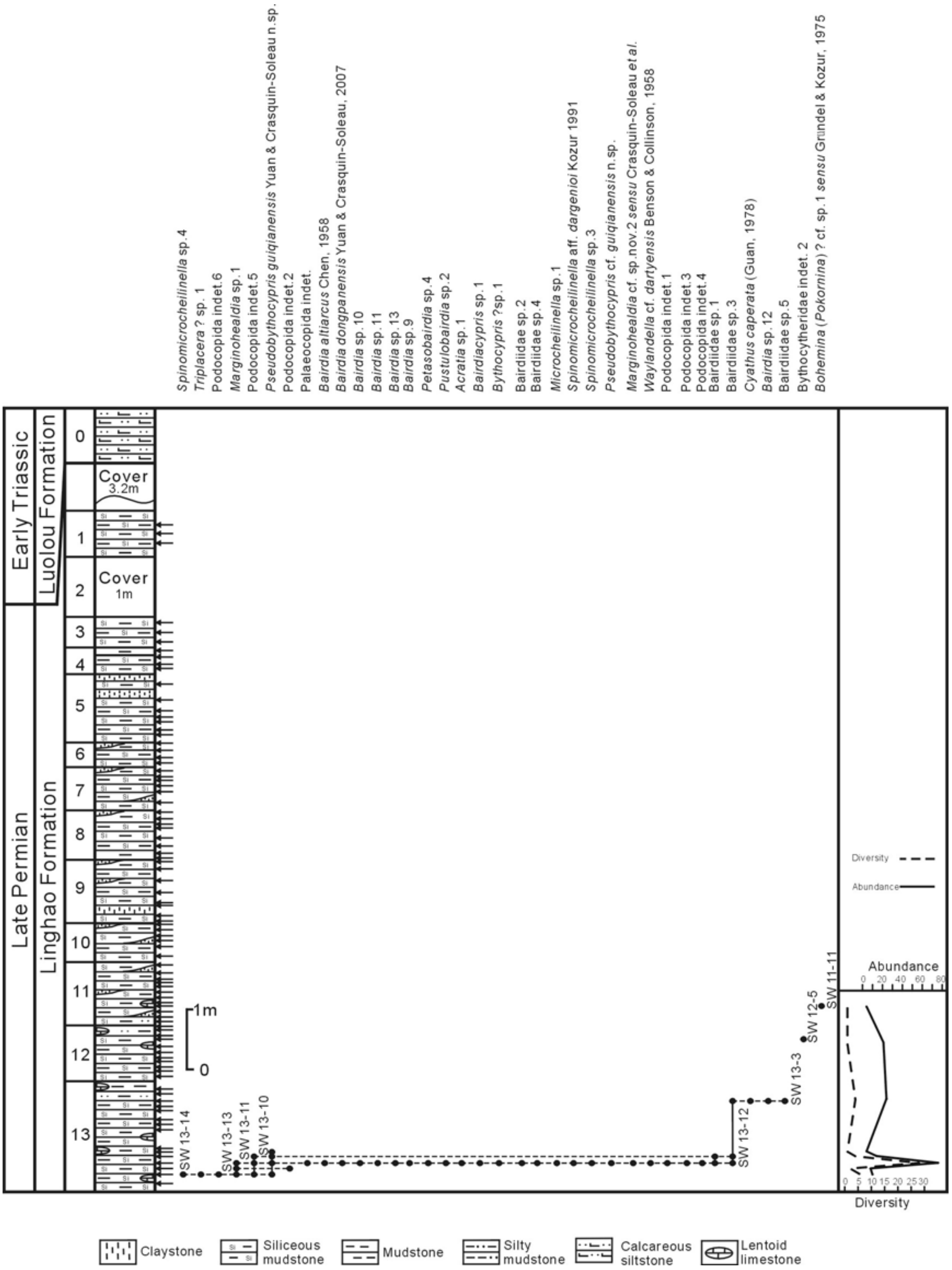

Fig. 3-1-C Ostracod distribution in the Shaiwa Section.

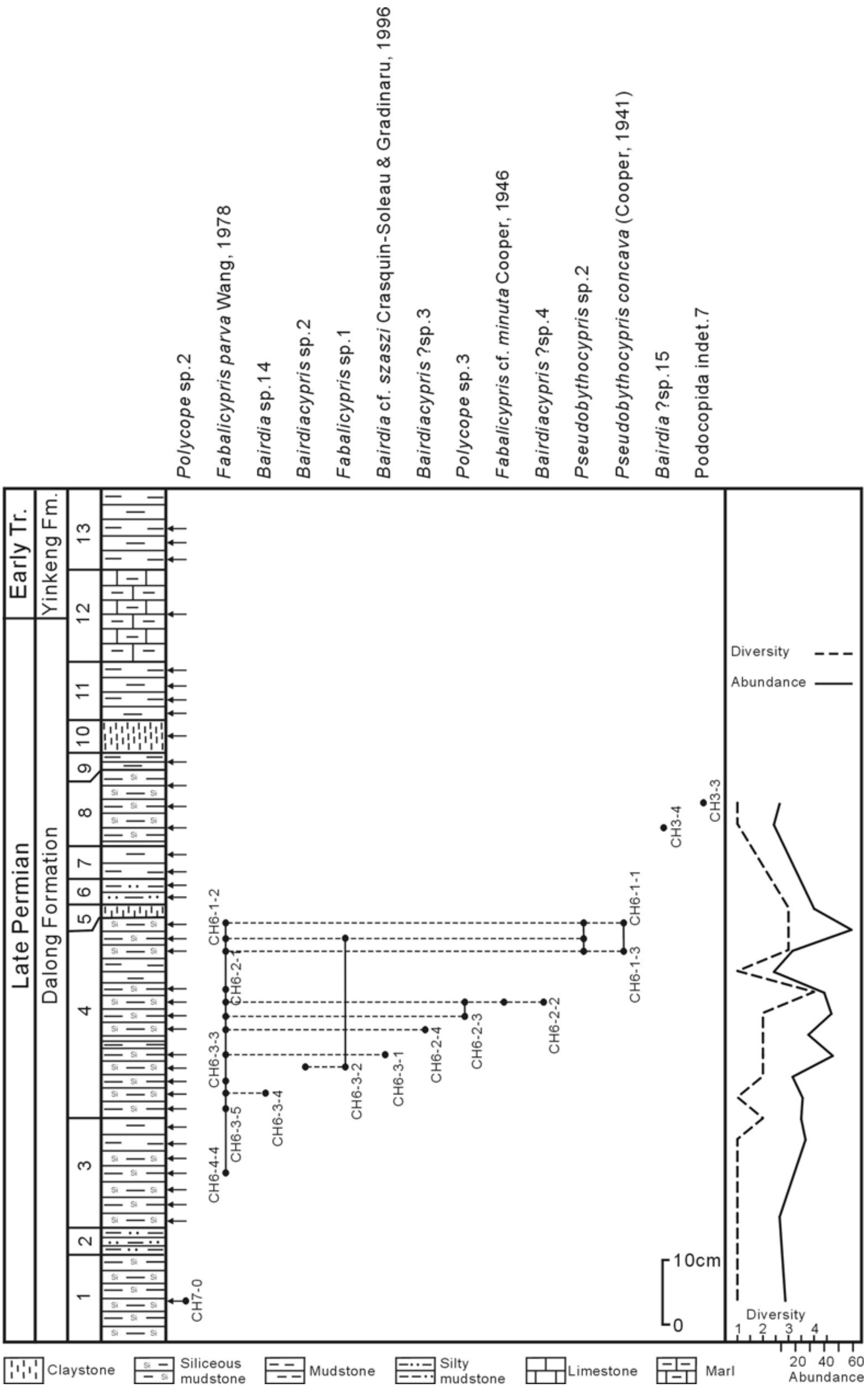

Fig. 3-1-D Ostracod distribution in the Chaohu Section.

3. 1. 4 Chaohu Section (CH)

25 samples and 12 samples were collected respectively from the siliceous mudstones and mudstones (marl) along the Chaohu section (Fig.1-B). The samples were extracted with two different methods according to the lithology (details see §3.2 Methodology). However, there was still not any microfossil found from the samples of mudstone. All the 420 specimens were yielded from 15 samples of siliceous mudstone. This ostracod fauna is very poor in diversity (5 genera and 14 species as shown in Fig.3-1-D).

Remarks: In the figures above, the numbers in the third row/column correspond to the bed numbers. The arrows indicate the positions of the studied samples. The numbers labeled in the ostracod distribution are sample numbers.

§ 3.2 General features and correlation with previous studies

The discovered material is exceptional because this is the first time that ostracods are extracted and identified from Latest Permian deep facies. In general, the discovered ostracod faunas are relatively diverse although many samples did not yield any species (especially in the Shaiwa Section). Some samples of siliceous mudstone and muddy siliceous rock yielded relatively high diversity of ostracods, for example, 11 species recognized in the sample 03DP2-19, 18 species in the sample 03DP3-14, 28 species in the sample SW13-12.

As the diversity, some samples yielded abundant specimens such as the sample 03DP 3-14, 278 individuals picked. In contrary, some samples are barren. Generally, in the relatively abundant horizons, the diversity is relatively higher. However, the diversity and abundance are not strictly corresponding. In most of case, the species are represented by very few specimens (one or two).

The ostracod faunas are dominated by small, thin-shelled individuals with length between 0.2mm-0.5mm, except most of Kirkbyoidea and some ornamented Bairdioidea which are larger than 0.6mm (<1.1mm). As mentioned above, many individuals are very poorly preserved. The faunas are mainly represented by single valves (e.g. in the Dongpan Section, only 139 carapaces vs. >1 500 valves), some of which are incomplete and thus indeterminate for identifying. One possible reason for the poor preservation is that the shells are so thin that they could not endure the complex process of sedimentation and laboratory extraction. However, the delicate ornamentations were still very well preserved in some specimens (e.g. very fragile spine and delicate striae presented in Bythocytheridae). This indicates that the faunas have not been transported. For the delicate specimens living a crawler life, the soft substrate may be needed. However, if the substrate was soft, there should be many complete carapace well preserved. But in fact, the discovered faunas are dominated by single valves. Thus the delicate specimens could be swimmer as proposed by Becker & Bless (1990, p.423). The substrate might be hard with very low sedimentation rate so that the delicate ornamentation can be preserved.

In the taxonomic view, the ostracod faunas are composed of three orders (Palaeocopida, Podocopida and Myodocopida). The species number and percentage for each order in studied sections are list in the table below (Tab.3-2-A). The Palaeocopids had been considered as the index Paleozoic ostracods, until recently they were reported from the lowermost Triassic strata of Australia, Pakistan, South China, Hungary and Turkey and considered as the survivors in the earliest Triassic (Jones, 1970; Sohn, 1970; Zheng, 1976; Wang, 1978; Kozur, 1985a; Hao, 1992a; Crasquin-Soleau *et al.*, 2004a, 2004b, 2007; Crasquin-Soleau & Kershaw, 2005). However, the generally low percentage of the palaeocopids indicates the clear decline of this order in the latest Permian. In the studied sections, the fauna in the Liuqiao Section has the highest percentage of Palaeocopids. This may imply that the Liuqiao Section was not only underlied the Dongpan Section but the earliest sedimented among the studied sections. If so, the percentage of Palaeocopida may be considered as an index for stratigraphic comparison during the Latest Permian. The higher the percentage of Palaeocopida is, the earlier the strata were deposited. The heavily shelled and strongly ornamented Bairdiidae (e.g. the genera *Mirabairdia*, *Abrobairdia*, *Lobobairdia*, *Petasobairdia*), which are the important Mesozoic representatives or affinities, are found here in the latest Permian strata. This type of Bairdiidae has been also reported from the Late Permian of other localities in South China and Turkey (Chen & Shi, 1982; Shi & Chen, 1987; Crasquin-Soleau *et al.*, 2004a, b). This indicates that the first new comers in the earliest Triassic have begun to appeare in the studied sections. The studied horizons should belong to the mixed interval during the Permian-Triassic transition.

Tab.3-2-A Species number, percentages of each order and the endemic proportion in studied sections

(DP: Dongpan Section; LQ: Liuqiao Section; SW: Shaiwa Section; CH: Chaohu Section)

Studied section	Total species	Endemic species		PALAEOCOPIDA		PODOCOPIDA		MYODOCOPIDA	
DP	50	42	84%	11	22%	35	70%	4	8%
LQ	39	31	79.5%	13	33.3%	24	61.5%	2	5.2%
SW	37	35	94.6%	2	5.4%	35	94.6%	0	0%
CH	14	12	85.7%	0	0%	12	85.7%	2	14.3%
TOTAL	128	109	85.2%	26	20.3%	96	75%	6	4.7%

To some extent, the faunas are endemic (Tab.3-2-A). There are 10 species in common between two or three of the four studied sections (Tab.3-2-B). Some of common species were also reported in the previous studies (Tab.3-2-C). *Cyathus caperata* (Guan, 1978) *sensu* Shi & Chen 1987 has been found from the Permian of Hunan, Guizhou and Zhejiang (Meishan Section) (Wang, 1978; Shi & Chen, 1987). *Discoidella xingyangensis* Zhang, 1987 has been reported from the Late Carboniferous of Henan, North China (Zhang & Liang, 1987, 1991) and Fujian (Yi, 2004). The *conformis* or *affinis* species have been found in the Early Carboniferous of United States (*Fabalicypris minuta* Cooper, 1946), the Late Permian of Italy (*Paraberounella* ? *laterospina* Kozur, 1991a) and the Middle Triassic of Romania

(*Polycope baudi* Crasquin-Soleau & Gradinaru, 1996). There are another 19 common species (Tab.3-2-C) and 23 *conformis*/*affinis* species between the studied sections and other occurrences. Of the 42 species, majority were reported from the Late Permian strata of other localities in South China (Jiangsu, Guizhou, Hubei, Zhejiang, Sichuan, Fujian, Guangxi), Iran (Dzhulfa), Indonesia (Timor), Hungary (Bükk Mts.), Italy (Sicily) and Turkey (Taurus). *Petasobairdia bicornuta* Chen, 1982 has been widely reported from the Changhsingian strata of South China, including the Meishan Section, and is regarded as a Changhsingian species (Chen & Shi, 1982; Shi & Chen, 1987; Hao, 1992a, 1994, 1996; Yi, 2004). *Fabalicypris parva* Wang, 1978 is an important species in the Changxing Formation (Changhsingian) of South China, Hungary and Turkey.

Tab.3-2-B Common species between two or three of the studied faunas (DP, LQ, SW and CH: the same as in Tab.3-2-A; +XC: discovered also in the Xichang Section; +TQ: discovered also in the Tieqiao Section)

	DP	**LQ**	**SW**	**CH**	**Remarks**
Bairdia dongpanensis Yuan & Crasquin-Soleau 2007	*	*	*		
Fabalicypris cf. *minuta* Cooper, 1946	*			*	
Bairdiidae sp.1	*		*		**+XC**
Paraberounella ? cf. *laterospina* Kozur, 1991a	*	*			
Spinomicrocheilinella anterocompressa Yuan & Crasquin-Soleau, 2007	*	*			
Spinomicrocheilinella aff. *dargenioi* Kozur, 1991a	*		*		
Pseudobythocypris guiqianensis n.sp.	*	*	*		
Absina ? sp.1	*	*			
Polycope aff. *baudi* Crasquin-Soleau, 1996	*	*			
Discoidella xingyangensis Zhang, 1987	*	*			
Cyathus caperata (Guan, 1978) *sensu* Shi & Chen 1987				*	+**TQ**
Petasobairdia bicornuta Chen, 1982		*			**+XC**

On the whole, 85.2% of the species are endemic. For the 19 common species, five of them have long stratigraphic repartition from the Late Devonian/Early Carboniferous (Mississippian) to the Late Permian, two existed from the Late Carboniferous (Pennsylvanian), seven have appeared in the Early Permian (Cisuralian), two occurred from the Middle Permian (Guadalupian) and three were reported only from the Late Permian (Lopingian). In a word, the discovered faunas are dominated by typical Paleozoic species accompanying with some first Mesozoic representatives and affinities.

Tab.3-2-C* Occurrences of the common species

Devonian	**Carboniferous**		**Permian**			**Common species**
Upper	**Mississippian**	**Pennsylvanian**	**Cisuralian**	**Guadalupian**	**Lopingian**	
					South China (Guangxi; Guizhou)	***Roundyella* ? *suboblanga* Wang, 1978**
			South China (Hunan)	South China (Guangxi)	South China (Guizhou; Zhejiang)	***Cyathus caperata* (Guan, 1978) *sensu* Shi & Chen 1987**
? Canada (Alberta)	? Canada (Alberta)				South China (Guangxi)	**? *Libumella athabascensis* Green, 1963**
			South China (Jiangsu)	Italy (Sicily)	South China (Guizhou; Guangxi)	***Bairdia altiarcus* Chen 1958**
					South China (Guangxi); Iran (Dzhulfa); Hungary (Bükk Mts.)	**? *Bairdia anbeedei* Belousova, 1965**
					South China (Guangxi; Guizhou)	***Bairdia dongpanensis* Yuan & Crasquin-Soleau 2007**
			Indonesia (Timor)		South China (Guangxi)	***Bairdia* sp.1 *sensu* Gründel & Kozur, 1975**
			Indonesia (Timor)	Italy (Sicily)	South China (Guangxi)	***Bairdia* ? sp. 6 *sensu* Bless, 1987**
			Indonesia (Timor)	Italy (Sicily)	South China (Guangxi)	***Bairdia* cf.*austriaca* (Kollmann, 1963) *sensu* Gründel & Kozur, 1975**
				South China (Guangxi)	South China (Guangxi; Jiangsu)	***Mirabairdia comisa* Chen, 1982**
					South China (Guangxi; Jiangsu, Zhejiang, Hubei, Guizhou, Fujian)	***Petasobairdia bicornuta* Chen, 1982**
			South China (Fujian)		South China (Guangxi)	***Fabalicypris glennensis* (Harlton, 1927) *sensu* Yi, 1993**
				Turkey (Taurus)	South China (Anhui; Guizhou) ; Turkey (Taurus); Hungary (Bükk Mts.);	***Fabalicypris parva* Wang, 1978**
					South China (Guangxi; Anhui)	***Fabalicypris* cf. *minuta* Cooper, 1946 *sensu* Yuan *et al*., 2007**
					South China (Guangxi; Guizhou)	***Bairdiidae* sp.1**
			Indonesia (Timor)		South China (Guangxi)	***Bohemina* (*Pokornina*) ? sp.1 *sensu* Gründel & Kozur, 1975**
					South China (Guangxi)	***Paraberounella* ? cf. *laterospina* Kozur, 1991a**

Tab.3-2-C (continued) Occurrences of the common species

Devonian	**Carboniferous**		**Permian**			**Common species**
Upper	**Mississippian**	**Pennsylvanian**	**Cisuralian**	**Guadalupian**	**Lopingian**	
NW Canada					South China (Guangxi)	***Microcheilinella* cf. *elatus*** **(Lethiers, 1978) *sensu* Lethiers,1981**
	Russia (Kolyma Massif); Poland (Holy Cross Mts.); South China (Guangxi); Belgium (cf.)				South China (Guangxi)	***Microcheilinella aculeata* Buschmina, 1975**
					South China (Guangxi)	***Spinomicrocheilinella anterocompressa*** **Yuan & Crasquin-Soleau 2007**
					South China (Guangxi; Guizhou)	***Spinomicrocheilinella* aff. *dargenioi*** **Kozur, 1991a**
		United States (Illinois)			South China (Anhui)	***Pseudobythocypris concava* (Cooper, 1941)**
					South China (Guangxi; Guizhou)	***Pseudobythocypris guiqianensis*** **Yuan & Crasquin-Soleau n.sp.**
Poland (Holy Cross Mts.); Germany (Thuringia); Rhenish Massif (North Sauerland)	Poland (Holy Cross Mts.); France (Black Mts.); Rhenish Massif (North Sauerland)				South China (Guangxi)	***Healdiopsis thuringensis thuringensis*** **(Gründel, 1961)**
					South China (Guangxi)	***Absina* ? sp.1**
Rhenish Massif (North Sauerland)	Rhenish Massif (North Sauerland)				South China (Guangxi)	***Waldeckella ? sphaerula* (Gründel, 1961)** ***sensu* Becker, 1999**
					South China (Guangxi)	***Polycope* aff. *baudi* Crasquin-Soleau, 1996**
		North China (Henan)			South China (Guangxi; Fujian)	***Discoidella xingyangensis* Zhang, 1987**

* The grey-filled area represents the stratigraphic repartition of the species. The localities projected in yellow indicate the common species between two or three of the studied sections.

Chapter 4 Paleoecological analysis

The widely spatial distribution (widespread in all aquatic and semi-terrestrial environments all over the world), long-range evolution (since the Ordovician) and rather rich and diverse fossil record (33 000 species) provide ostracods the opportunity on (paleo)eological research. The characters of ontogeny (4 to 8 moults before maturity), the various life styles (benthic, nektobenthic, pelagic) and the different alimentation/respiration modes (deposit-feeder, filter-feeder) destine inseperatable relationship between ostracods and the aquatic environments in which they lived. Both the ostracod individual (shell chemistry, composition, morphology etc.) and assemblage (diversity, abundance, composition, dominant species) are the direct and integrative reflection of all (paleo)physiochemical conditions of their habitats (Moore, 1961; Holmes & Chivas, 2002).

This chapter will focus on finding out the paleoecologic characters of the ostracod faunas during the latest Permian in studied area combining with evidences from other fossils, geochemistry and sedimentology. For each ecosystem, all the ecological factors (bathymetry, oxygen-level, substrate, salinity, temperature, etc.) interact with each other. Of the factors, the bathymetry is the most fundamental and important in (paleo)ecological reconstructions because nearly all other (paleo)physiochemical conditions changes with the water depth. The marine ecotopes are also divided upon the bathymetry (Yin *et al.*, 1995). Consequently, the paleobathymetric evaluation will be the first important topic of this chapter. In addition, the oxygen-level reconstruction based on ostracod faunas will be attempted since the anoxic or dysoxic event during the Permian-Triassic boundary interval has been widely paid attention for a long time.

§ 4.1 General paleoenvironmental interpretations with ostracod tool

The interpretation of paleoenvironment related to the family/superfamily has been undertaken by many pioneering researchers (e.g. Gründel, 1961; Blumenstengal, 1965; Peterson & Kaesler, 1980; Lethiers, 1982; Crasquin, 1984; Casier, 1987, 2004; Melnyk & Maddocks, 1988; Wang, 1988b; Kozur, 1991b; Casier *et al.,* 2003, 2005; Crasquin-Soleau *et al.*, 2006). The paleoenvironmental interpretation on the families and superfamilies here are based on studies by these authors.

The Youngiellidae are the indicator of onshore conditions (the environment see Fig.4-1)[*]. The Kirkbyidae are representatives of the inner platform. The Amphissitidae, Scrobiculidae, and Kellettinidae were the typical neritic ostracods. The Paraparchitidae were marine inhabitants and showed tolerance to some extreme environments such as with the abnormal salinity, but were absent beyond the outer shelf. The Bairdioidea exclusively represent neritic and shallow to deep open-marine environment with normal salinity. The heavily shelled and strongly ornamented bairdioids usually live in the shallow environment with high energy, whereas the elongated, thin-shelled or delicately spinose baridioids are found in the deeper environments (e.g. the acuminate *Acratia*). The heavily spined Bythocytheridae, Tricorninidae, Berounellidae and Rectonariidae are known as the paleopsychrospheric elements which indicate a deep (bathyal or abyssal), calm and cold environment (detail introduction see below **4.2**). The Cavellinidae are eurybathic. The large cavellinids were common in the nearshore environments with high terrigenous influx, whereas the smaller ones lived further offshore. The Healdioidea appear to prefer the relatively nearshore, muddy environments below the wavebase, but the healdiid species with strong spines are considered as the paleopsychrospheric elements. The Entomozoidea live a pelagic/nektobenthic life in open-marine, but not necessary deep, environments.

According to the fundamentals above, the proportion of the families/superfamilies found in this work can be grouped as below in the table (Tab.4-1-A) (at specific level).

Tab.4-1-A Proportions of families/superfamily in studied faunas

(DP, LQ, SW and CH: the same as in Tab.3-2-A; the numbers in the bracket represent the species numbers)

	Family/Superfamily	**DP (50)**		**LQ (39)**		**SW (37)**		**CH (14)**		**Whole (128)**	
Nearshore-offshore	**KIRKBYIDAE**	4	8%	6	15.4%	0	0%	0	0%	10	7.8%
	AMPHISSITIDAE	0	0%	3	7.7%	0	0%	0	0%	3	2.3%
	KELLETTINIDAE	1	2%	1	2.6%	0	0%	0	0%	2	1.6%
	SCROBICULIDAE	0	0%	2	5.2%	0	0%	0	0%	2	1.6%
	YOUNGIELLIDAE	1	2%	0	0%	0	0%	0	0%	1	0.8%
	PARAPARCHITIDAE	1	2%	0	0%	0	0%	0	0%	1	0.8%
	CAVELLINIDAE	1	2%	0	0%	0	0%	0	0%	1	0.8%
	Total	**8**	**16%**	**12**	**30.8%**	**0**	**0%**	**0**	**0%**	**20**	**15.6%**
Offshore to open-marine	**BAIRDIOIDEA**	14	28%	18	46.2%	17	45.9%	9	64.3%	54	42.2%
	ENTOMOZOIDEA	1	2%	0	0%	0	0%	0	0%	1	0.8%
	Total	**15**	**30%**	**18**	**46.2%**	**17**	**45.9%**	**9**	**64.3%**	**55**	**43%**
Deep environment (bathyal-abyssal)	**BYTHOCYTHERIDAE**	3	6%	0	0%	1	2.7%	0	0%	4	3.2%
	TRICORNINIDAE	1	2%	0	0%	1	2.7%	0	0%	2	1.6%
	BEROUNELLIDAE	2	4%	1	2.6%	0	0%	0	0%	2	1.6%
	RECTONARIIDAE	2	4%	0	0%	0	0%	0	0%	2	1.6%
	HEALDIIDAE	2	4%	1	2.6%	3	8.1%	0	0%	6	4.7%
	Total	**10**	**20%**	**2**	**5.1%**	**5**	**13.5%**	**0**	**0%**	**16**	**12.5%**
	Total	**33**	**66%**	**32**	**82.1%**	**22**	**59.5%**	**9**	**64.3%**	**91**	**71.1%**

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[*] For the same environments, different terms have been used in previous studies. For better discussing the paleoenvironmental reconstruction, the unified terminology is shown in Fig.4-1.

The Bairdioidea are the most abundant in the studied faunas. In this superfamily, some recognized species are thick-shelled (e.g. *Bairdia dongpanensis*) or strongly ornamented (e.g. *Petasobairdia bicornuta*, *Abrobairdia* sp.1, *Pustulobairdia* spp.), whereas the others are acuminate and thin-shelled (e.g. *Acratia* sp.1, *Cooperuna* cf.*tenuis*). This may suggest an alternant environment of inner shelf and outer shelf with normal salinity. The low percentages of the Kirkbyidae, Amphissitidae, Kellettinidae, Scrobiculidae, Youngiellidae, Paraparchitidae and Cavellinidae indicate that the environments were not so favorable for their development. The proportion of Bythocytheridae, Tricorninidae, Berounellidae and Rectonariidae is low but gives the signal of the presence of the deep-water environment, mainly in the Dongpan and the Shaiwa Sections. Consequently, on the whole, the ostracod faunas here were inhabitants from the outer of inner platform to the upper part of bathyal environments.

In the four studied faunas, the Dongpan fauna contains the highest percentage of the paleopsychrospheric species and the lowest Bairdioidea which include some acuminate and thin-shelled species. This may indicate that the Dongpan fauna was the deepest inhabitants. The Shaiwa fauna seems the second deepest among the four faunas by the absence of typical neritic species and presence of paleopsychrospheric elements. The Chaohu fauna takes the third place due to the nearly absolute composition by the Bairdioidea. But the Bairdioidea is dominanted by the acuminate and thin-shelled *Bairdiacypris* and *Fabalicypris* and thus may imply an outer shelf environment. The Liuqiao fauna may present the shallowest environment by the common presence of the kirkbyid and amphissitid species and ornamented bairdiids. Interestingly, the ornamented Bairdioidea with the Mesozoic characters have occurred in the lower part of the Liuqiao Section but were rarely discovered in the Dongpan Section, the overlying strata of the Liuqiao Section.

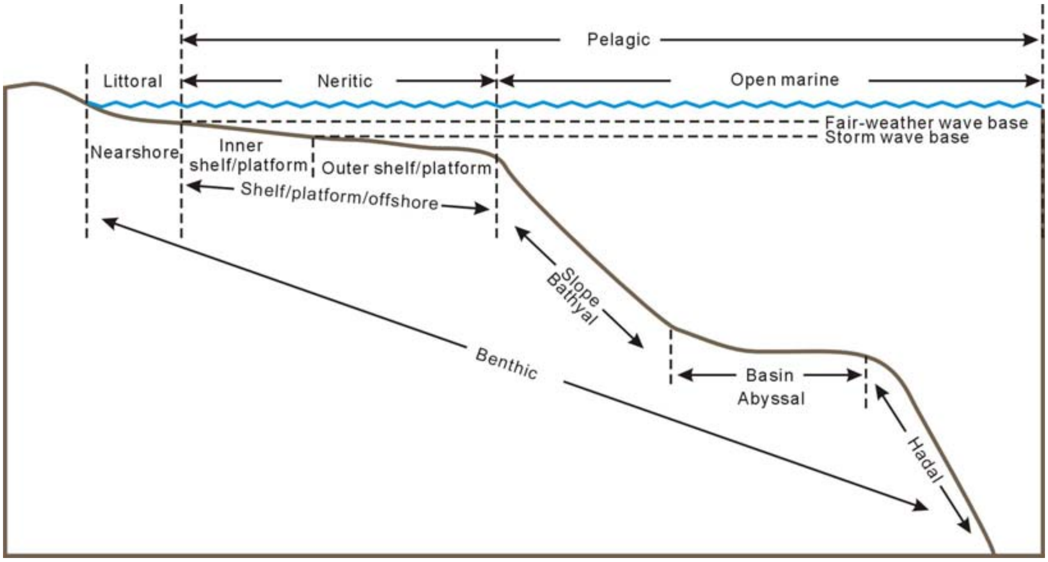

Fig.4-1 Sketch map showing the marine zonation (after Yin *et al.*, 1995, Fig.1-4).

§ 4.2 Paleobathymetric variation

In this section, the adopted concept of **paleopsychrospheric species** and **triangular model** will be introduced. Then the paleobathymetric evaluation will be carried out according to the model and integrated with other data from geochemistry, sedimentology and other fossils.

4. 2. 1 Introduction of concept

Kozur (1972) initially introduced the word "psychrospheric" to indicate the Triassic ostracods of Alps which present strong similarities to the modern psychrospheric ostracods (presence of the archaic forms, thin-shelled specimens and /or very well-developed spines). Gründel & Kozur (1975) also found these similarities when studied the Early Permian ostracods of Timor, Indonesia. When Kozur (1991a, b) studied the Middle Permian ostracods of Sicily, Italy, he erected the name "paleopsychrospheric" for distinguishing the pre-Jurassic ostracod assemblage from the modern psychrospheric ostracod faunas. The ocean was thermospheric during the Jurassic and Cretaceous. The paleopsychrospheric assemblage corresponds to the Thüringian ecotype. Then why the term "paleopsychrospheric" is adopted instead of the Thüringian ecotype? A brief review on the Thüringian ecotype and its related ecotypes are presented and then the rejected reasons will be explained.

The Thüringian ecotype is mainly mentioned by Bandel & Becker (1975), Olempska (1979, 1997), Bless *et al.* (1987), Casier (1987, 2004), Wang (1988b), Lethiers & Feist (1991), Wei (1993) , Becker (2000, review) and Casier & Préat (2003) . These different authors proposed different nomenclatures and more transitional ecotypes or subecotypes. Becker (in Bandel & Becker, 1975) firstly proposed the Eifelian **ecotype**, Thüringian ecotype and Entomozoacean ecotype for the Carboniferous ostracods. Based on the Carboniferous-Permian ostracod studies, Bless *et al.* (1987) divided five marine **groups**: brackish, shallow marine, deep marine shelf, Thüringian and Entomozoan. Wang (1988b) concluded the paleoecologic significance of the Late Paleozoic ostracods in South China and proposed also five **associations**[*], i.e. leperditiid association, palaeocopid association, smooth-podocopid association, spinose-podocopid association and entomozoacean association. The "spinose-podocopid association" is equivalent to the Thüringian ecotype. Then during the studies on the Devonian-Carboniferous ostracods in southwestern China, Wei (1993) furtherly subdivided into eight ecotypes which are leperditiid ecotype, leperditiid-Eifelian ecotype, Eifelian ecotype I, Eifelian ecotype II, Eifelian-Bairdioidean ecotype, Bairdioidean-Thüringian ecotype, Thüringian-Entomozoacean ecotype and Entomozoacean ecotype. The distribution and composition of each ecotype of the Late Paleozoic ostracods in South

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[*] Note that during the previous studies, different terms were proposed (ecotype, association, group…). The name of "assemblage" is adopted here to indicate the ostracod community. An "ecotope" is the environment where one or more ostracod assemblages are adapted to live. Each ostracod assemblage and its ecotope constitute an "ecosystem" (refer to Yin *et al.,* 1995).

China can be synthetized as below (Tab. 4-2-A) (Wang, 1988b; Wei, 1993). However, Casier (1987, 2004) and Casier & Préat (2003) demonstrated that the word "ecotype" describes the plants within a single species in a particular habitat and thus proposed a new system i.e. Eifelian Mega-Assemblage (=Assemblages 0-III in Casier & Préat, 2003), Thüringian Mega-Assemblage (=Assemblage IV *ibid*) and Myodocopid Mega-Assemblage (=Assemblage V *ibid*).

Tab.4-2-A Late Paleozoic ostracod ecotypes in South China (after Wang, 1978; Wei, 1993)

Ecotype	Distribution	Composition	Abundance	Diversity	Shell morphology	Life style
Leperditiid ecotype	lagoon	leperditiids	high	low	large, smooth and thick	crawler
Eifelian ecotype	littoral-platform	Palaeocopida, leperditiids, Healdiidae	high	high	large and hevily ornamented	crawler, burrower
Bairdioidean ecotype	platform-open-marine	Bairdioidea, Kirkbyoidea, Paraparchitoidea	high	high	smooth and large	crawler
Thüringian ecotype	slope-basin	Bairdioidea, Healdiidae	high	high	thin, fragile and spinose	nektobenthic, crawler
Entomozoacean ecotype	basin	Entomozoacea		low	thin and with finger-print	pelagic, swimmer

Among the mentioned ostracod ecotypes, the division criteria are the the composition, diversity, abundance, shell morphology, life style and their favorable ecotope, which is mainly associated with the paleobathymetry and the water-energy. The three key concepts are Eifelian ecotype, Thüringian ecotype and Entomozoacean ecotype. The Eifelian ecotype is dominated by the diverse, thick-shelled and sculptured Palaeocopida, Platycopida and Metacopida in a benthic life and indicates the shallow water and high water-energy environment. The Thüringian ecotype is composed of the thin, smooth or delicately spinosed species with relatively low diversity. During the Late Devonian–Early Carboniferous, such cosmopolitan forms in the Paleotethys are associated with the bathyal facies, in low energy cold water, and probably with low oxygen content and high amount of dissolved silica (Lethiers & Crasquin, 1987; Crasquin-Soleau *et al*., 1989; Lethiers & Feist, 1991). But some authors considered this ecotype was more indicative of low-energy environments than the bathymetry since this ecotype was also found from shallower environments (Bless, 1987; Becker & Bless, 1990; Olempska, 1997; Becker, 2000). In South China, this ecotype was discovered in the Devonian of lower part of slope to shallow basin (trough) environments (Wang, 1988b and personal communication). The Entomozoacean ecotype is formed by the pelagic finger-print entomozoids. The bathymetric significance for this ecotype is ambiguous. Some researchers considered it as deep basin indicator (e.g. Bandel & Becker, 1975), whereas the others reported this ecotype from the shallow environments (e.g. Lethiers, 1982).

For adopting the term “paleopsychrospheric”, there are three important reasons.

(1) This term is chosen to point out the analogies in morphology (i.e. archaic, thin-shelled, smooth or delicated ornamented and with one or more (generally <4) developed spines) and assemblage (high diversity, few individuals per species) with the the modern psychrospheric ostracods occurring from the

Eocene to Present. In another word, instead of the “locality designation” (both the Thüringian ecotype and the Eifelian ecotype were named by their first reported locality in Germany), this nomenclature is considered as genetic designation (Kozur, 1991b).

(2) The presence of paleopsychrosphere has been proved by the paleoceangeographic studies. Raymond & Lethiers (1990) proposed that the installation of the Thüringian ecotype in the Late Famennian Paleotethys was correlated to an invasion of cold deep-water currents that originated in the glacial north-Gondwanian area. Kozur (1991b) demonstrated that the Thüringian ecotype began to settle down during the glaciation in the latest Ordovician to Silurian and disappeared during the Jurassic/Cretaceous, since when the world ocean became to the whole thermospheric. Until the Eocene, the modern two-layered striated ocean was reestablished*. Thus the appearance of the Thüringian ecotype and the existent psychrosphere pre-Jurassic seems closely correlated. Then the analogies between the Thüringian ecotype and the modern psychrospheric ostracods could be easily understand due to the similar habitat.

(3) The “Eifelian” and “Thüringian” have been more early designated as the stage name respectively in the Devonian and Permian (Tab.4-2-B (a), (b)). Then the name of the “Eifelian” and “Thüringian” could be misunderstanded as the assemblage belonging to the correspondent geological interval and lost their paleoecological significance. And the term “paleopsychrospheric” can avoid the unnecessary confusion with the stratigraphic unit.

Tab.4-2-B (a) International Stratigraphic Chart; (b) European Stratigraphic Chart by Bless *et al.*, 1987

Devonian	Upper	Famennian
		Frasnian
	Middle	Givetian
		Eifelian
	Lower	Emsian
		Pragian
		Lochkovian

(a)

Permian		**Thuringian**
		Saxonian
		Autunian
Carboniferous	Silesian	Stephanian
		Westfalian
		Namurian
	Dinantian	Visean
		Tournaisian

(b)

Consequently, the term “paleopsychrospheric” has prominent advantages and is adopted here. During the previous studies, many paleopsychrospheric taxa have been proposed according to the characters of their morphology and the yielding strata (Gründel, 1962; Blumenstengel, 1965; Bandel &

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[*] The modern ocean is thermally stratified into two-layers, thermosphere (surface layer) and psychrosphere (deep ocean), separated by the thermocline (metalimnion). In the thermosphere, with the water lighter and warmer (more than 10°C), the physicochemical factors are influenced by the external conditions. The depth of the thermocline is not fixed which is variable along with the latitude and the season. In the psychrosphere below the thermocline, the temperature decreases rapidly to lower than 8°C and the water is denser. This cold layer is very stable (e.g. the temperature around 4-8°C, without variation in salinity, etc.) and connected with a global ocean supplied by cold water from ice caps (Benson & Sylvester-Bradley, 1971; Benson, 1972, 1975).

Becker, 1975; Gründel & Kozur, 1975; Bless, 1987; Lethiers & Crasquin-Soleau, 1987; Wang, 1988b; Becker & Bless, 1990; Becker, 1991; Kozur, 1991b; Lethiers & Feist, 1991; Lethiers & Raymond, 1991; Becker & Wang, 1992; Becker & Blumenstengel, 1995a, b; Casier, 2004). The paleopsychrospheric taxa reported in this work and the above mentioned references are synthesized as follows (Tab. 4-2-C).

Tab. 4-2-C Paleopsychrospheric taxa from previous literatures and this work

Family	**Genera**	**References**
HOLLINELLIDAE	*Hollinella (Keslingella)*	Becker & Blumenstengel, 1995a
KIRKBYIDAE	*Kirkbyites*	Becker, 1991
AMPHISSITIDAE	*Kullmannissites, Sinessites* and other thin-shelled amphissitids	Lethiers & Crasquin-Soleau, 1987; Lethiers & Raymond, 1991
ARCYZONIDAE	*Villozona*	Lethiers & Raymond, 1991
BAIRDIIDAE	*Krausella, Costabairdia, Tubulibairdia, Processobairdia* and other thin-shelled bairdiids	Lethiers & Crasquin-Soleau, 1987; Wang, 1988b; Kozur, 1991b; Lethiers & Raymond, 1991; Becker & Blumenstengel, 1995a
ACRATIIDAE	*Bispinacratia, Ceratacratia, Clinacratia, Cooperuna* and acuminate *Acratia*	Lethiers & Crasquin-Soleau, 1987; Yuan *et al.*, 2007
BYTHOCYTHERIDAE	*Bythoceratina, Monoceratina, Nemoceratina, Tuberoceratina, Triceratina*	Bless, 1987; Lethiers & Crasquin-Soleau, 1987; Wang, 1988b; Kozur, 1991b; Yuan *et al.*, 2007
BEROUNELLINIDAE	*Paraberounella, Berounella*	Wang, 1988b; Kozur, 1991b; Lethiers & Crasquin-Soleau, 1987; Yuan *et al.*, 2007
TRICORNINIDAE	*Bohemina, Ovornina, Saafeldella, Spinella, Tricornina*	Blumenstengel, 1965; Bandel & Becker, 1975; Lethiers & Crasquin-Soleau, 1987; Wang, 1988b; Kozur, 1991b; Yuan *et al.*, 2007
RECTONARIIDAE	*Cristanaria, Orthonaria, Rectonaria, Rectoplacera, Triplacera*	Gründel, 1962; Lethiers & Crasquin-Soleau, 1987; Wang, 1988b; Yuan *et al.*, 2007
PACHYDOMELLIDAE	*Karinadomella, Grammia,* spinosed *Microcheilinella, Spinomicrocheilinella; Denticupachydomella*	Bandel & Becker, 1975; Wang, 1988b; Becker & Bless, 1990; Lethiers & Raymond, 1991; Yuan *et al.,* 2007; in this work
HEALDIIDAE	*Marginohealdia,Paragerodia, Healdiopsis, Timorhealdia, Waylandella* and other strongly spined and thin-shelled healdiids	Wang, 1988b; Lethiers & Feist, 1991; Lethiers & Raymond, 1991; Yuan *et al.*, 2007; in this work
QUASILLITIDAE	*Absina*	Lethiers & Raymond, 1991; Yuan *et al.*, 2007
ENTOMOZOIDAE	*Richterina, Waldeckella*	Becker & Blumenstengel, 1995b; Yuan *et al.,* 2007
POLYCOPIDAE	*Polycope*	Becker & Blumenstengel, 1995b; Yuan *et al.*, 2007
BEECHERELLIDAE	*Acanthoscapha, Beecheroscapha, Tuberoscapha* and *Bulcosohnia*	Bandel & Becker, 1975; Lethiers & Crasquin-Soleau, 1987; Wang, 1988b; Kozur, 1991b; Becker & Wang, 1992
GERODIIDAE	*Gerodia*	Bandel & Becker, 1975; Lethiers & Crasquin-Soleau, 1987; Wang, 1988b; Lethiers & Raymond, 1991
BAIRDIOCYPRIDIDAE	*Baschkirina* (with ventral incisures)	Bandel & Becker, 1975; Wang, 1988b; Becker & Wang, 1992
Family unknown	*Discoidella*	Yuan *et al.*, 2007; in this work

4. 2. 2 Adopted model

The discovered paleopsychrospheric species are usually accompanied with the neritic species. The **triangular model** proposed by Lethiers & Raymond (1991) is applied to evaluate the paleobathymetry by virtue of the relative proportion of paleopsychrospheric and neritic species (Fig.4-2-A).

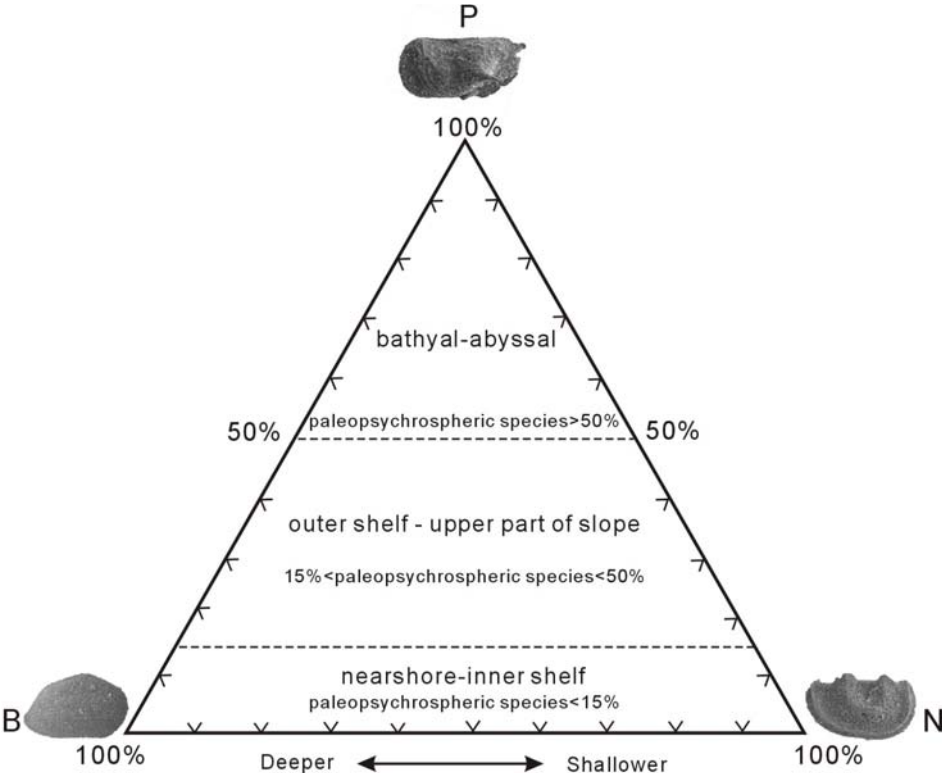

Fig.4-2-A Diagram showing the triangular model proposed by Lethiers & Raymond (1991) (after Lethiers & Raymond, 1991).

According to this model, the benthic ostracod species are divided into three ecological groups, the paleopsychrospheric species (P) (indicator of deep-water environments, bathyal to abyssal), the bairdiid species (B) (inhabitants of neritic to open-marine environments, the bathymetry varies with the different morphology as mentioned above) and other neritic species (N) (preferring to shallower environments, littoral to inner shelf), which are corresponding to three points of the triangular. The relative proportion of P, B and N can give the paleobathymetric interval. A percentage of P higher than 50% is indicative of a bathyal to abyssal environment. With a percentage of P between 15% and 50%, the environments of outer platform to the upper part of slope can be presumable. If the percentage of P is lower than 15% and dominated by B and N, the fauna is considered as living in inner platform. In this instance, the higher the percentage of B is, the deeper the environment may be. In addition, since bairdiids indicate the environments with normal salinity and oxygen-level, the environment could have relatively poor oxygen and different salinity if B% is lower.

4. 2. 3 Paleobathymetric evaluation on ostracod faunas

The first step of the paleobathymetric evalution is to group all discovered species respectively into P, B and N. Based on the morphology and referred to the paleopsychrospheric taxa, 38 species in this work are regarded as the paleopsychrospheric species, belonging to the spinose Bairdiidae, Bythocytheridae, Tricorninidae, Berounellinidae, Rectonariidae, Pachydomellidae, Healdiidae, Quasillitidae, Polycopidae, *Discoidella* and the two undetermined species Podocopida indet.2 and Podocopida indet.3. There are 51 non-spinosed, thick-shelled and smooth/heavily ornamented bairdiid species. The other 39 species, of the family Kirkbyidae, Amphissitidae, Kellettinidae, non-spinosed Pachydomellidae etc., are considered as “other neritic species” (Tab.4-2-D). Then, the proportions of paleopsychrospheric, bairdiid and other neritic species are respectively calculated[*] at specific level for the bed/sub-bed with more than 3 species and 15 individuals. The statistic results are presented here in two forms, the proportion of the P, B and N and their projections in the triangular diagram.

Dongpan Section

The 19 paleopsychrospheric species were yielded in 20 sub-beds, whereas in the other 6 sub-beds the fauna is completely composed of the bairdiid and/or other neritic species (and Myodocopid species). 14 sub-beds are here considered as the valid horizons according to the statistic standard for the triangular model (Tab.4-2-E, Fig.4-2-B, C). With the highest 80% and lowest 17% of paleopsychrospheric species, the triangular diagram indicates that the Dongpan Section was situated in the outer shelf to bathyal environments. The sub-bed 03DP2-25, in the lowest horizon of the section, presents a rather shallow environment of outer shelf with normal salinity. Then the environment became deeper to the top of the bed 03DP2. In this course, the percentage of the Bairdiidae altered between 0% and 34%, which may imply the variation of the oxygen level and salinity. There is a shoaling between 03DP2-4 and 03DP3-1 before the paleobathymetry attained the maximum among the statistic horizons in 03DP3-7, in which the bairdiid species were not discovered. And then the general shoaling occurred until 03DP5-8, comprising high percentage of bairdiid species and reprenting an outer shelf environment with normal salinity and rich oxygen. From this horizon up, the percentage of paleopsychrospheric species increased and bairdiid species rapidly decreased until 03DP5-19, which may indicate an unsuitable environment for the living of bairdiids. Then, the paleobathymetry became shallower in 03DP10 and the bairdiids re-occurred.

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[*] The presence of a species is only considered as valid in the beds where the species was discovered. The beds, which was sedimented in the virtual range zone but did not yield this species (not discovered yet), is not accounted here.

Tab.4-2-D List of paleopsychrospheric, bairdiid and other neritic species in this work

paleopsychrospheric species (P) (38)	**bairdiid species (B) (51)**	**other neritic species (N) (39)**
Spinobairdia sp. 1 *sensu* Yuan *et al*., 2007	*Bairdia altiarcus* Chen 1958	*Tribolbina* cf. *doescheri* Sohn, 1978
Acratia sp.1	? *Bairdia anbeedei* Belousova, 1965	*Kirkbya* cf. sp. A *sensu* Becker & Wang, 1992
Cooperuna cf. *tenuis* Kozur, 1985a *sensu* Yuan *et al*., 2007	*Bairdia dongpanensis* Yuan & Crasquin-Soleau 2007	*Kirkbya* aff. *wymani* Kellett 1933
Bythocytheridae gen. *et* sp. indet. *sensu* Yuan *et al*., 2007	*Bairdia* sp.1 *sensu* Gründel & Kozur, 1975	*Kirkbya* sp. 1 *sensu* Yuan *et al*., 2007
Bythocytheridae indet. 2	*Bairdia* ? sp. 6 *sensu* Bless, 1987	*Kirkbya* sp.2
Monoceratina sp. 1 *sensu* Yuan *et al*., 2007	*Bairdia* aff. *birinae* Egorov, 1953 *sensu* Yuan *et al.*, 2007	*Kirkbya* sp.3
Monoceratina ? sp. 2 *sensu* Yuan *et al*., 2007	*Bairdia* cf.*altiarcus* Chen, 1958	*Aurikirkbya* cf. *ultima* (Kozur, 1985)
Bohemina (*Pokornina*) ? sp.1 *sensu* Gründel & Kozur, 1975	*Bairdia* cf.*austriaca* (Kollmann 1963) *sensu* Gründel & Kozur, 1975	*Aurikirkbya* sp.1 *sensu* Yuan *et al*., 2007
Bohemina (*Pokornina*) ? cf. sp.1 *sensu* Gründel & Kozur, 1975	*Bairdia* cf. *szaszi* Crasquin-Soleau & Gradinaru, 1996	*Aurikirkbya* sp.2
Paraberounella ? cf. *laterospina* Kozur, 1991a *sensu* Yuan *et al*., 2007	*Bairdia* sp.1 *sensu* Yuan *et al*., 2007	*Nodokirkbya* ? cf. *striatoreticulata* Kozur, 1991a *sensu* Yuan *et al*., 2007
Paraberounella sp. 1 *sensu* Yuan *et al*., 2007	*Bairdia* sp.2 *sensu* Yuan *et al*., 2007	*Tubulikirkbya* sp.1
Rectonariidae gen. *et* sp. indet. *sensu* Yuan *et al*., 2007	*Bairdia* sp.3 *sensu* Yuan *et al*., 2007	Amphissitidae sp.1
Rectonaria cf. *inclinata* Gründel, 1961 *sensu* Yuan *et al.*, 2007	*Bairdia* sp.4 *sensu* Yuan *et al*., 2007	Amphissitidae sp.2
Denticupachydomella spinosa Yuan & Crasquin-Soleau n.gen.n.sp.	*Bairdia* sp.5	*Permokegelites* cf. *beichuanensis* Becker & Wang 1992
Microcheilinella aculeata Buschmina, 1975	*Bairdia* sp.6	*Kellettina* aff. *reticulata* Kozur, 1991a *sensu* Yuan *et al*., 2007
Spinomicrocheilinella anterocompressa Yuan & Crasquin-Soleau, 2007	*Bairdia* sp.7	Kellettinidae indet.
Spinomicrocheilinella aff. *dargenioi* Kozur, 1991a *sensu* Yuan *et al.*, 2007	*Bairdia* sp.8	*Roundyella* ? *suboblanga* Wang, 1978
Spinomicrocheilinella sp. 1 *sensu* Yuan *et al*., 2007	*Bairdia* sp.9	*Roundyella* aff. *labaensis wangi* Kozur 1985
Spinomicrocheilinella sp. 2 *sensu* Yuan *et al*., 2007	*Bairdia* sp.10	*Cyathus caperata* (Guan 1978) *sensu* Shi & Chen 1987
Spinomicrocheilinella sp.3	*Bairdia* sp.11	*Macronotella* ? sp.1 *sensu* Yuan *et al.*, 2007
Spinomicrocheilinella sp.4	*Bairdia* sp.12	*Macronotella* ? sp.2 *sensu* Yuan *et al.*, 2007
Healdia sp. 1 *sensu* Yuan *et al*., 2007	*Bairdia* sp.13	? *Libumella athabascensis* Green, 1963 *sensu* Yuan *et al*., 2007
Healdia sp.2	*Bairdia* sp.14	*Libumella* cf. *kargalensis* Rozhdestvenskaya, 1959 *sensu* Yuan *et al.*, 2007
Healdiopsis thuringensis thuringensis (Gründel, 1961)	*Bairdia* ? sp.15	*Permoyoungiella* ? sp. 1 *sensu* Yuan *et al*., 2007
Marginohealdia cf. sp.nov.2 *sensu* Crasquin-Soleau *et al*., 2008	*Abrobairdia* sp.1	*Paraparchites* sp. 1 *sensu* Yuan *et al.*, 2007
Marginohealdia sp.1	*Abrobairdia* sp.2	Palaeocopida indet.
Waylandella cf.*dartyensis* Benson & Collinson 1958	*Lobobairdia* cf.*rostriformis* Chen, 1982	*Pseudobythocypris concava* (Cooper, 1941)
Triplacera ? sp. 1	*Mirabairdia comisa* Chen, 1982	*Pseudobythocypris guiqianensis* Yuan & Crasquin-Soleau n.sp.
Absina ? sp.1 *sensu* Yuan *et al*., 2007	*Petasobairdia bicornuta* Chen, 1982*Petasobairdia* sp. 1 *sensu* Yuan *et al*., 2007	*Pseudobythocypris* cf. *guiqianensis* n.sp.
Absina ? sp.2 *sensu* Yuan *et al*., 2007	*Petasobairdia* sp. 2 *sensu* Yuan *et al*., 2007	*Pseudobythocypris* sp.1 *sensu* Yuan *et al*., 2007
Podocopida indet.2	*Petasobairdia* sp.3	*Pseudobythocypris* sp.2
Podocopida indet.3	*Petasobairdia* sp.4	*Cavellina* cf. *nebrascensis* (Geinitz, 1867) *sensu* Yuan *et al*., 2007
!!! The following myodocopid species are usually present with the paleopsychrospheric species, however their bathymetric significance is ambiguous.	*Pustulobairdia* aff.*spinosa* (Cooper 1946)	*Microcheilinella* cf. *elatus* (Lethiers, 1978) *sensu* Lethiers,1981
Waldeckella ? *sphaerula* (Gründel, 1961) *sensu* Becker, 1999	*Pustulobairdia* sp.1	*Microcheilinella* sp.1
Polycope aff. *baudi* Crasquin-Soleau, 1996 *sensu* Yuan *et al.*,2007	*Pustulobairdia* sp.2	Podocopida indet.1
Polycope sp. 1 *sensu* Yuan *et al*., 2007	*Bairdiacypris* aff. *mirautaae* Crasquin-Soleau, 1996 *sensu* Yuan *et al.*, 2007	Podocopida indet.4
Polycope sp. 2	*Bairdiacypris* sp.1	Podocopida indet.5
Polycope sp. 3	*Bairdiacypris* sp.2	Podocopida indet.6
	Bairdiacypris ? sp.3	Podocopida indet.7
	Bairdiacypris ? sp.4	
	Bythocypris ? sp.1	
	Fabalicypris glennensis (Harlton 1927) *sensu* Yi, 1993	
	Fabalicypris parva Wang, 1978	
	Fabalicypris cf. *minuta* Cooper, 1946 *sensu* Yuan *et al.*, 2007	
	Fabalicypris sp.1	
	Bairdiidae sp.1	
	Bairdiidae sp.2	
	Bairdiidae sp.3	
	Bairdiidae sp.4	
	Bairdiidae sp.5	

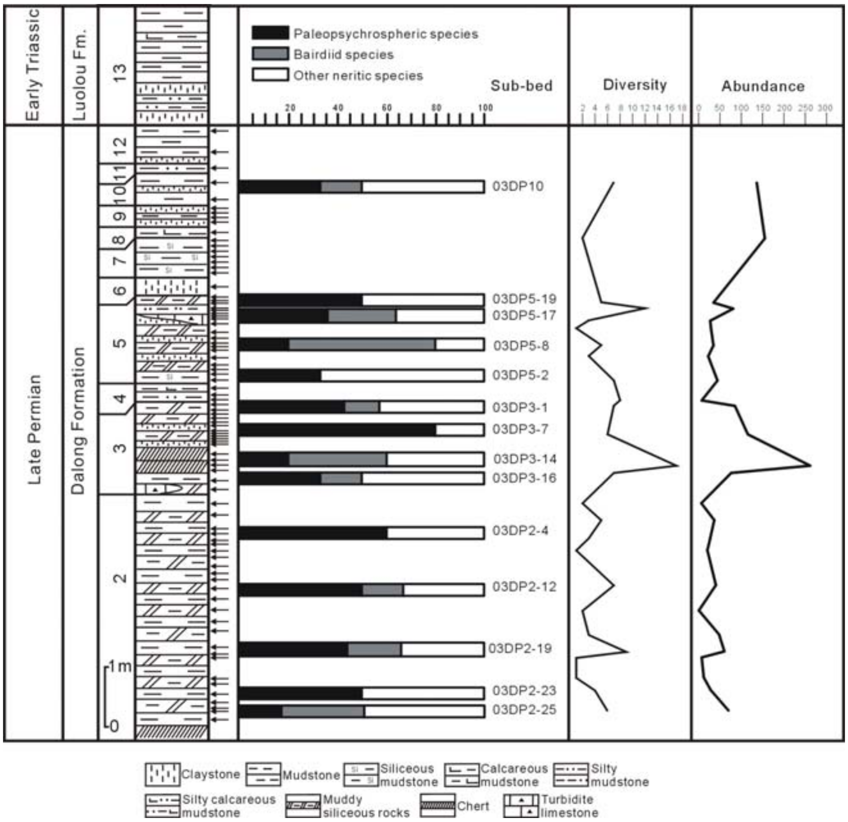


Fig.4-2-B Proportions of paleopsychrospheric, bairdiid and other neritic species by sub-bed (14 valid horizons according to the statistics standard of triangular model) along the Dongpan Section.

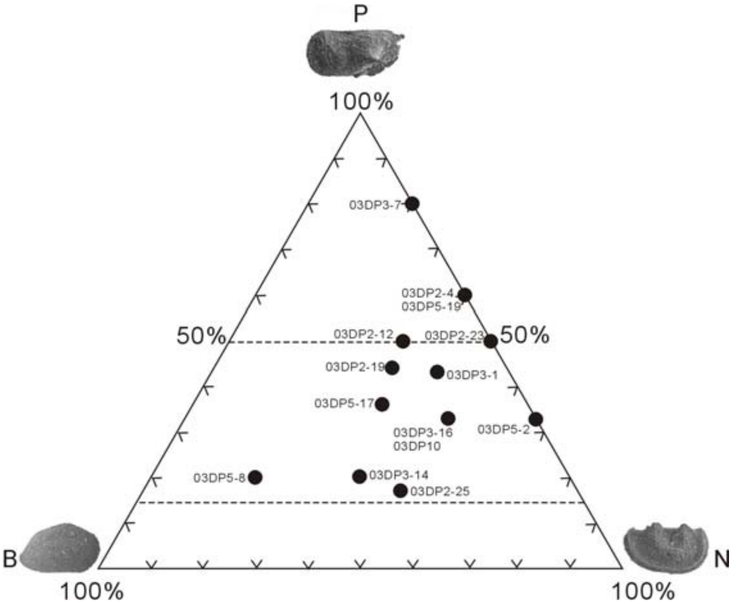


Fig.4-2-C Projecting based on the Dongpan ostracod compositions by sub-bed (14 valid horizons according to the statistics standard of triangular model) in the triangular diagram.

Liuqiao Section

Only 5 out of the total 39 species are considered as the paleopsychrospheric species. These species are distributed in eight beds of the whole section. However, there are only three beds could reach the statistic standard and thus discussed here (Tab. 4-2-E). The other beds have 1-3 species or less than 10 individuals. The percentages of the paleopsychrospheric species show a deepening from the bottom up along the Liuqiao Section, shifting from the inner shelf to the outer shelf (Fig.4-2-D). The impressively high proportions of the bairdiid species are mostly ornamented and thick-shelled, whereas mainly acuminate or thin-shelled species in the Dongpan Section. Both the triangular analysis and the morphological characters attribute a shallower environment than the Dongpan Section. And the environment should have normal salinity and high oxygen level by virtue of yielding abundant bairdiids.

Shaiwa Section

Among the 37 species, 12 of them are recognized to be paleopsychrospheric. The Shaiwa Section yielded rare ostracods. In the Shaiwa Section, only two beds, SW13-3 and SW13-12, attain the conditions for statistics (Tab. 4-2-E, Fig.4-2-D). The sub-bed SW13-12 is the most abundant and diverse horizon. The high diversity even exceeds any other horizons in this work, although with very low abundance. The proportions of the three components indicate an inner shelf to outer shelf environment and have a trend of deepening from SW13-3(bottom) to SW13-12 (up). Similar to the Liuqiao Section, the Shaiwa fauna is composed of abundant bairdiids (>50%) but distinguished from the former by dominance of thin-shelled species. Thus the environment in the Shaiwa Section is deeper than the Liuqiao Section.

Tab. 4-2-E Data showing the diversity, abundance and percentages of paleopsychropheric, bairdiid and other neritic species in the valid horizons of the studied sections

Section	Bed/sub-bed	Diversity	Abundance	P%	B%	N%
Dongpan Section	03DP10	7	146	33%	17%	50%
	03DP5-19	5	39	50%	0%	50%
	03DP5-17	12	88	36%	28%	36%
	03DP5-8	5	39	20%	60%	20%
	03DP5-2	7	49	33%	0%	67%
	03DP3-1	7	92	43%	14%	43%
	03DP3-7	6	124	80%	0%	20%
	03DP3-14	17	278	20%	40%	20%
	03DP3-16	7	83	33%	17%	50%
	03DP2-4	5	41	60%	0%	40%
	03DP2-12	7	45	50%	17%	33%
	03DP2-19	9	66	44%	22%	34%
	03DP2-23	4	32	50%	0%	50%
	03DP2-25	6	76	17%	34%	49%
Liuqiao Section	LQ22	6	43	17%	50%	33%
	LQ16	25	189	12%	48%	40%
	LQ3	6	92	0%	83%	17%
Shaiwa Section	SW13-3	4	24	0%	75%	25%
	SW13-12	28	76	25%	50%	25%

Chaohu Section

The Chaohu fauna is characterized by the absolute dominance of bairdiids (9 species), accompanied by 2 polycopid species and 3 other neritic species. As mentioned in **4.2.1** and the Tab.4-2-D, the polycopid species are usually found with the paleopsychrospheric species, whereas themselves have not the bathymetric significance. However, the bairdiids in the Chaohu Section usually have very thin and elongated shells which may indicate a relatively deep environment, maybe open-marine. And the composition of simple taxa (Bairdiidae and Bairdiocyprididae) and no-evident variation along the section imply that the environment was stable in the studied area. The composition and species morphology support that the Chaohu Section represented shallower environment than the Dongpan Section and Shaiwa Section. The paleobathymetric relationship between the Chaohu Section and the Liuqiao Section seems difficult to determine. According to the analysis based on the families/superfamilies in **4.1**, the Liuqiao Section should be shallower than the Chaohu Section. And the dominance of thin-shelled bairdiids in the Chaohu Section may also indicate deeper environment than the Liuqiao Section yielding most of the ornamented bairdiids.

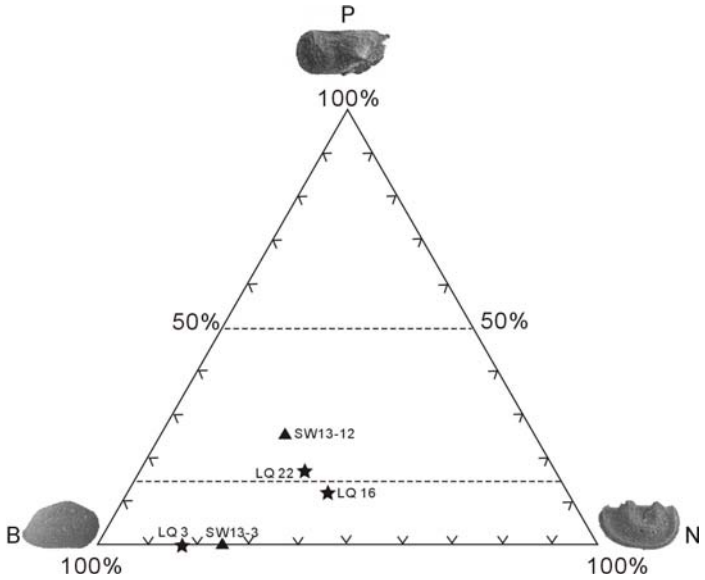


Fig.4-2-D Projecting according to the Shaiwa (2 valid horizons) and Liuqiao (3 valid horizons) ostracod composition in the triangular diagram.

4. 2. 4 Integration with other data

In the section above, the paleobathymetric variation is interpreted and presumed on ostracod faunas. As is known, the organism is the direct reflection of its habitat controlled by complex and interdependent factors. However, the interpretation resulted in one aspect is sometimes hard to exclude or distinguish the influence caused by another aspect. In addition, different groups of organism have variable extent of response to different environmental factors. In the paleoecological studies, the inevitable loss of original information calls in more risk of the interpretation based on a single group of organism. Thus a multi-proxy analysis is necessary for better understanding the paleoenvironmental features. In this section, the evaluation by ostracoda and other fossils, geochemistry and sedimentology is compared. The integration is evolved mainly in the Dongpan Section which is the most comprehensively studied section in this work.

Sedimentary facies

In the Dongpan Section, the paleobathymetry evaluated by ostracod analysis reaches mostly external platform to the upper part of slope. For consummating the evaluation, analysis on sedimentary facies, clay mineralogy and other fossils are discussed here.

The strata of the Dongpan Section have an evidently lithological shift in the bed 03DP6. From the bed 03DP2 to 03DP5, the strata are dominanted by muddy siliceous rocks and siliceous mudstones with bearing abundant radiolarians. The latest Permian strata above 03DP7 changed to silty and calcareous mudstones intercalated with siliceous mudstones (Meng *et al.*, 2005a). This means that the siliceous content descreases from the bottom up along the Dongpan Section and announces the end of the chert event. The bed 03DP6 is considered as deposit during a regression and the the transitional horizon of the environments from being bathyal to neritic (He *et al.,* 2007).

It is noticeable that there are two layers of turbid limestones with the Bauma sequence in the sub-beds 03DP3-18 and 03DP5-16. The turbid current should have origined from shallow and high-energy environment, which can be inferred from the shallow water foraminiferas and the ceratoid intraclastics in the turbiditic limestones. The overlying sub-beds (i.e. 03DP3-16, 03DP3-14 and 03DP 5-17) yielded more diverse and abundant ostracods than the other horizons (Fig.3-1-A). And the proportion of the neritic species increases (Fig. 4-2-A). Especially in the sub-beds 03DP3-16 and 03DP3-14, many neritic species gave their first occurrences along the Dongpan Section, e.g. *Cavellina* cf. *nebrascensis*, *Kirkbya* sp.1, *Libumella* spp. and *Bairdia* spp.. The “new occurring” species are only discovered in the two beds or disappeared until the top of the bed 03DP5 where the presumable regression began. Thus it seems probable that the new neritic comers in the sub-beds 03DP16 and 03DP3-14 were brought by the turbid current from the shallow water environment. Their coming elevated the percentage of neritic species between 03DP3 and 03DP5. In other words, the turbid current may have transported the allochthonous faunas and thus distort the original composition of the assemblage. So it could be inferred that the paleobathymetry of the beds 03DP3 and 03DP5 should have been deeper than that evaluated by the triangular model and may shift to the bathyal stage from the present interpreted depth.

Radiolarian assemblage

The radiolarian assemblage is regarded as an important indicator in paleobathymetric evaluation. For example, the Albaillellaria began to appear in the open marine environment with a water depth of

200-500m and thus indicate bathyal to abyssal settings (Kozur, 1993). The Latentifistularia preferred outer shelf or bathyal environment (Fang & Feng, 1996).

In the Dongpan Section, the radiolarians were abundantly yielded and assemblage alterations present the paleobathymetric variation. The following interpretation is based on the published group work and personal communication (Feng *et al.,* 2007a; He *et al.,* 2007; Jin *et al.*, 2007). The radiolarian fauna from beds 03DP2 to 03DP5, named as "Albaillellaria assemblage", is dominanted by the Spumellaria, Latentifistularia and Entactinaria, accompanied by abundant Albaillellaria. This composition indicates a bathyal environment. A rapidly decline of the Albaillellaria occurred in the bed 03DP6, which implies a drastic change of sea-level. The radiolarian fauna became to be composed of Latentifistularia, Spumellaria and Entactinaria. With a percentage of 39% Latentifistularia, this fauna also presents an outer shelf environment. In the bed 03DP7, the Albaillellaria completely disappeared and the Latentifistularia occupied 50% of all species in the fauna, which may suggest a water depth around 200m. Then the Latentifistularia disappeared in the bed 03DP8, above which the fauna is only comprised of the Entactinaria and Spumellaria. Thus the upper part of the Dongpan Section was deposited in the inner shelf environment. He *et al.* (2007) proposed that "at least 150 m of sea-level fall" during the deposition of beds 03DP5 to 03DP12 by comparing the other radiolarian faunas in South China (see p.154 in He *et al.,* 2007).

Then turning back to the results from ostracods, the good consistency can be observed between interpretations by the two groups. Both of the ostracod and radiolarian assemblages indicate a bathyal environment below the bed 03DP6 (if the influence of turbidite is considered for the ostracods) and much shallower settings in the upper horizons. However, there are also some differences between the two interpretations. (1) The interpretation by ostracod assemblage displayed the environments of external platform to the upper part of slope in the bed 03DP10, whereas the radiolarian assemblage presented the characters of inner shelf fauna. The divarication between the two results doubts about the opinion of "150 m of sea-level fall" based on radiolarian assemblage. (2) The ostracod assemblage recorded more detailed fluctuation of paleobathymetry (? sea-level), although some of which should be used very cautiously.

For better integrating, the comparision with radiolarian fauns from the Chaohu Section will be briefly described herein. The ostracod faunas in the Chaohu Section, as mentioned above (Fig.3-1-D & Fig.4-2-H), nearly 90% of species are neritic. Only 2 indetermined polycopid species were yielded. No typical deep water indicators were discovered. The general environment is presumed to be shallow open-marine according to the dominance of thin-shelled and elongated bairdiids. The radiolarian faunas in the Chaohu Section are dominated by Entactinaria and Spumullaria, associated with a few Latentifistularia. This radiolarian fauna is distinguished with the Dongpan radiolarian fauna by the absence of the Albaillellaria and low diversity of the Latentifistularia. Apparently, without yielding the bathyal indicator, the Chaohu radiolarian faunas indicate shallower environments than the Dongpan fauna. Anyhow, the thin-shelled microfossils including ostracods and lithology of siliceous mudstones still suggest a deeper environment than the Meishan Section. Thus the water depth of 60-200m was proposed by Gui *et al.* (submitted). The analysis from radiolarians agrees the interpretations of ostracods.

Mineralogy & Geochemistry

The sea-level flunctuation may result in more exposure of the shallow area and then enhance the weathering in the terrestrial region. Thus the increase of terrestrial materials in the sediment can indirectly imply the sea-level change.

In the Dongpan Section, the common minerals are argillaceous minerals (illite, smectite and illite/smectite) and detritus (quartz and feldspar) (Meng *et al.,* 2005b). The X-Ray diffraction analysis indicated that the content of feldspar increases discontinuously in the lower part and evidently above the bed 03DP7 along the section. Generally, the feldspar is transported by the terrestrial influx, although it also possibly results from the volcanic activity. However, in the Dongpan Section, the feldspar was rarely observed in the claystones with volcanic origin and thus considered as the terrestrial material. Then, the increase of the feldspar exactly implies the influx increase of terrestrial material, which means the weathering was enhanced in the terrestrial domain of the studied area.

The influx increase of terrestrial material was also suggested by the geochemistrical analysis. The elements Ti and Al are generally not soluble in the water so that their abundance is not easily affected by post-depositional processes (Brookins, 1988). Thus Ti and Al are considered as excellent indicators to diagnose the source of argillaceous materials. In the Dongpan Section, the concentrations of Al_2O_3 and TiO_2 show a negative correlation with that of SiO_2 and increase evidently from the bed 03DP7 upwards. This implies that the increasing of the terrestrial material influx (He *et al.*, 2007).

In general, the paleobathymetric evaluation interpreted by ostracods is accordant to that presumed through other evidences. Especially in the Dongpan Section, the research on ostracods, radiolarians, sedimentary facies and mineralogy imply the presence of regression. In the Chaohu Section, the ostracod fauna suggest a shallower environment, which is well reflected on radiolarian assemblages.
However, during the interpretation of the triangular model, the necessity of integrating multi-disciplinary research is outstanding. The data may not represent the characters of the original fauna, which could have been disturbed and changed by some geoevents, e.g. the influx of the turbid current. Thus, the interpretation should be made cautiously.

§ 4.3 Oxygen level reconstruction

The anoxic events have been widely considered as an important reason resulting in the Permian-Triassic mass extinction (e.g. Wignall and Hallam, 1992; Isozaki, 1997). However, the anoxic duration and extent are various in different regions (Wignall & Twitchett, 2002). Thus, there is not a completely unified rule for defining the anoxic events in a section before the related analysis is carried out.

In order to investigate if the anoxic event occurred in the Dongpan Section, the studies on geochemistry, foraminifera assemblage and trace fossils have been already put in practice. In this section, to testify the validity of ostracod faunas in oxygen-level reconstruction, the FF% method, which has been successively applied in neritic ostracod faunas (detailed introduction see below **4.3.2**), is firstly attempted here for the deep-water fauna.

4. 3. 1 Oxygen level reconstruction by other data

The studies on geochemistry, foraminifera assemblage and trace fossils have been conducted in the Dongpan Section. However, the data educed different results for the oxygen level flunctuation. As follows, the different analyses will be presented.

In the Dongpan Section, several redox-sensitive trace elements were chosen for analysis, including Co, Cr, Cu and V. Generally, these elements concentrate in sulphides or become adsorbed by organic compounds. Therefore, the high concentration of these elements indicates low oxygen concentration in the sea water. In the practical interpretation, the ratios of these elements to Al are considered as the indicators for oxygen concentration. The ratio of V/Cr is also indicative to the redox conditions (in anoxic conditions: $V/Cr>4.25$; dysoxic conditions: $2<V/Cr<4.25$; oxic conditions: $V/Cr<2$) (Johns & Manning, 1994). In the Dongpan Section, neither of the ratios of Co, Cr, Cu and V to Al indicate consistent decrease in oxygenation along the section. From the bed 03DP2 to the lower part of 03DP5, the value of V/Cr is between 2.00 to 4.00, indicating dysoxic conditions. During this interval, there is a peak value at the top of the bed 03DP4 to the lower part of bed 03DP5. Above this anoxic peak, the value of V/Cr decreases to lower than 2.00, indicating a normal oxygenation (Fig.4-3-A) (He *et al.,* 2007).

In addition, the negative abnormity of Ce is indicative to the oxygen deficiency. The rare earth element Ce has two variable valencies. In the oxygen conditions, Ce^{3+} is usually oxygenated to Ce^{4+} and deposited in the form of unsolvable CeO_2. Thus the content of Ce in the sea water will be greatly depleted and appears as the negative anormity (Wright & Holser, 1987). $Ce_{anomy}<-0.1$ indicates the normal oxygenate conditions and $Ce_{anomy}>-0.1$ implies the anoxic environments. In the Dongpan Section, the analysis of Ce indicated two evident negative abnormities which indicate the possible oxygen deficiency, respectively in 03DP2 and 03DP6 to the lower part of 03DP7 (Fig.4-3-A) (Zhang, 2006).

The role of foraminifer assemblage in oxygen level reconstruction is effective in composition of the test. In modern Oxygen Minimum Zone (OMZ), the calcareous foraminifers dominate instead of the agglutinated foraminifer. The ratio of calcareous to agglutinated foraminifers drops with the oxygen increase (Gooday *et al.*, 2000). Thus the calcareous foraminifers seem prefer the low oxygen conditions. In the Dongpan Section, below the bed 03DP4, the foraminifers have low diversity. In the beds 03DP4 and 03DP5, the foraminifers are dominated by the calcareous species. Above the bed 03DP6, the agglutinated foraminifers increase and become dominant. In the bed 03DP10, there are only agglutinated foraminifers. Consequently, there may be an oxygen deficiency in the beds 03DP4 and 03DP5, above which the oxygen level increased and thus would be suitable for the living of agglutinated foraminifers

(Zhang, 2006; He *et al.,* 2007).

The trace fossils were collected between 03DP5 and 03DP8. Abundant *Chondrites* and a few small-sized *Zoophycos* were recognized (unpublished group work). The *Chondrites* is considered as a common trace fossil during the change of oxic-anoxic-oxic conditions. In the Dongpan Section, *Chondrites* was yielded in the whole investigated interval. The other taxa were discovered between the upper part of 03DP5 and 03DP7. Thus this indicated the occurrence of anoxic event between 03DP5 and 03DP7. And the small size of the *Zoophycos* and other taxa may also imply the oxygen deficiency.

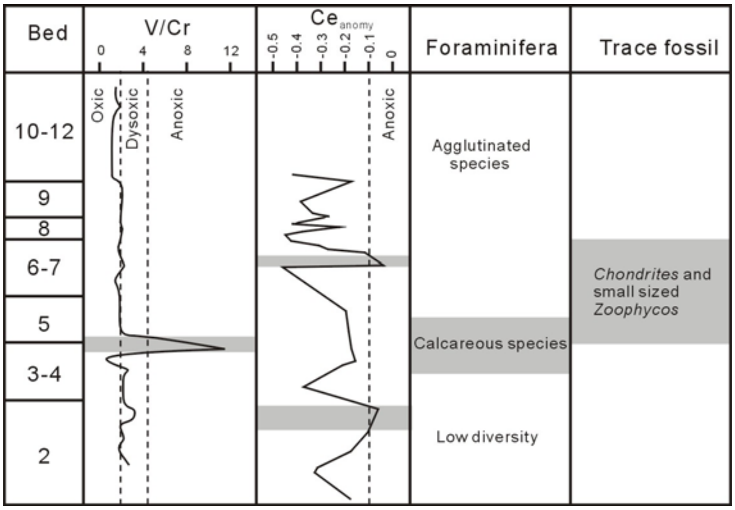


Fig.4-3-A Comparison of oxygen-level reconstruction based on different methods

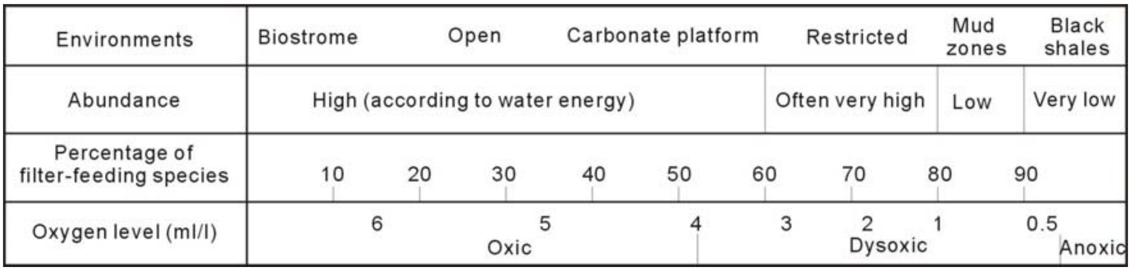
(grey zones indicate the interval of oxygen deficiency; curves of V/Cr and Ce modified from He *et al.,* 2007; foraminifer and trace fossils data from group work).

In general, the interpretations based on different data indicate the presence of oxygen deficiency in certain horizons of the Dongpan Section. However, the analysis is not completely accordant with each other. The trace elements and foraminifers indicate that the oxygen deficiengy took place in the horizon of 03DP4 and lower part of 03DP5, whereas the negative abnormity of Ce and trace fossils prefer an anoxic event in 03DP6 and 03DP7. As follows, the interpretation on ostracods will be attempted for oxygen-level reconstruction and then compared with the results above.

4. 3. 2 Generality on ostracod alimentation mode

Whatley (1991, 1995, 2003) showed the relationship between the alimentation mode and oxygen level in the water based on the observation of post-Paleozoic ostracods from the anoxic events which can be indicated by the “**Platycopid signal**”.

The Platycopida, which have a filter-feeding mode of alimentation and respiration, are found out the great potential of survive during the anoxic event. The filter-feeding mode is considered as enhancing the respiration during the oxygen reduction. Ostracods lack of the specific respiratory organs (except the Mydocopida with gills). The oxygen interchange takes place in the venter by the brachial plates. The Platycopida possesses larger numbers of branchial plates than the Podocopida. For the alimentation of the Platycopida, the branchial plates circulate the water over their ventral respiratory surface. Then the numerous tufts of setae of the appendages sieve the suspension and transport the fine particles to the mouth. In other words, besides the normal respiration, the Platycopda could also access the oxygen from the circulated water during the feeding. In the anoxic conditions, evidently, this feeding mode greatly enhances the respiration of the Platycopida than the Podocopida with the deposit-feeding mode. In addition, the reproduction of Platycopida as described in **2.1.2**, retain the eggs and nauplius in the expanded posterior brood space. This means that the platycopid individual began to benefit the feeding mode since hatch and in the earliest instars and then greatly increases the survival potential in anoxic conditions. The third advantage for the Platycopida is that, during the anoxic conditions, there are more organic suspensions in the water which supplies more food for the filter-feeders and thus enhances their survival potential.



Environments	Biostrome Open Carbonate platform	Restricted	Mud zones	Black shales
Abundance	High (according to water energy)	Often very high	Low	Very low
Percentage of filter-feeding species	10 20 30 40 50 60	70 80	90	
Oxygen level (ml/l)	6 5 4 Oxic	3 2 1 Dysoxic	0.5	Anoxic

Fig.4-3-B The percentage of filter-feeding ostracod species and approximately calculated oxygen levels in relationship to paleoenvironments and individual abundance proposed by Lethiers & Whatley (1994)*.

Through the studies on neritic Devonian ostracods, Lethiers & Whatley (1994) demonstrated the availability of the ostracod feeding way in paleo-oxygen level reconstruction. This model was attempted in the area where the environment was well studied. Compared with the post-Paleozoic studies, the Palaezoic filter-feeders contain the Palaeocopida, Platycopida and Metacopida (the Kloedenelloidea and Paraparchioidea were additionally listed in Lethiers & Whatley (1994) and assigned to the Palaeocopida here). The Bairdioidea and Bairdiocypridoidea were regarded as deposit-feeders. Then the relationship between the percentage of filter-feeding species and oxygen level was proposed accordant to the abundance of ostracod fauna and sedimentary facies (Fig.4-3-B). This method is abbreviated as the **FF% method** herein.

Before applying the model to the studied area, it is necessary to unify the criteria of dividing the oxygen level. Whatley *et al.* (2003) divided different oxygen levels according to the percentages of the Platycopid specimens. Yan & Liu (2007) proposed the division based on the biofacies. In the modern ocean, the normal oxygen concentration is around 5-6ml/l at the atmosphere pressure and a temperature

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* The FF% model was firstly applied on modern ostracods and then on Cenozoic-Jurassic ostracods.

between 10° and 20°and falls to less than 4ml/l in the oxygen maximum zone (3ml/l is typical) (Whatley, 1991; Garrison, 1998). In this work, the concepts proposed by Yan & Liu (2007) are adopted and the division interval is referred to the modern ocean data, i.e. the oxygen concentration of more than 4ml/l is regarded as the oxic condition, between 4ml/l and 0.2ml/l dysoxic condition and less than 0.2ml/l the anoxic conditions (Tab.4-3-A).

Tab.4-3-A Percentages of Platycopid specimens and corresponding oxygenic conditions

Percentages of Platycopid specimens	**Oxygen level**	**Environments**		
		in this work	**Whatley *et al.* (2003)**	**Yan & Liu (2007)**
80 - >90%	<0.2ml	anoxic		anoxic
	0.2-1 ml/l	dysoxic		dysoxic
	2-1 ml/l		very low oxygen	
60 - 80%	3-2 ml/l		low oxygen	oxic
40 - 60%	4-3 ml/l		medium oxygen	
20 - 40%	5-4 ml/l	oxic	high oxygen	
< 20%	>5 ml/l		very high oxygen	

4. 3. 3 Oxygen level reconstruction on ostracods

Until now, the FF% method has not been applied in interpretation of deep water ostracod faunas. In Lethiers & Whatley (1994), the paleopsychrospheric species are excluded from the test of the FF% method since it is difficult to decide to which alimentation mode (deposit-feeding or filter feeding) they belong according to the morphology. It is true that some paleopsychrospheric species belong to the deposit-feeding in higher taxa level (e.g. *Spinomicrocheilinella* spp.), but some to the filter-feeders (e.g. *Healdia* spp.) and the others are ambiguous in alimentation mode (e.g. Polycopidae). There is not certain correlation between paleopsychrospheric species and filter-feeders, two concepts based on different division criteria. And there is neither data of modern species (psychrospheric) and nor of paleopsychrospheric species in geological time.

In this work, I try to reconstruction the oxygen level in studied area with also consideration of paleopsychrospheric species. Following to Lethiers & Whatley (1994), the Palaeocopida are regarded as filter-feeders. The Metacopina ostracods, also belonging to paleopsychrospheric elements in this work, *Healdia* spp. (with long spines), *Healdiopsis, Marginohealdia, Waylandella, Triplacera, Absina*, are designated to the filter-feeders. All the bairdiid species including the paleopsychrospheric elements *Spinobairdia*, *Acratia, Cooperuna* are assigned as the deposit-feeders by their bow-shaped ventral projection. The Bairdiocypridoidea genera *Microcheilinella*, *Spinomicrocheilinella, Denticupachydomella* n. gen., *Rectonaria,* most species of which are paleopsychrospheric elements, are considered as the deposit-feeding ostracods. The seven undetermined Podocopida species are assigned as deposit-feeders. Ballent & Whatley (2000) demonstrated that the Cytheroidea live in shallow marine conditions with clear and well-oxygenated water. This indicates that the Cytheroidea may be used to oxic conditions. So the cytherids (Bythocytheridae indet., *Monoceratina*, *Bohemina*, *Paraberounella*) are considered as the deposit-feeders. As to the Myodocopida, the modern Myodocopa possess the gills/longitudinal canals for oxygen interchange and some lives the filter-feeding life (e.g. Cylindroleberidoidea, Holmes & Chivas, 2002). In the studies on Devonian ostracods, Lethiers *et al.* (1998) indicated that Entomozoidea thrive in dysoxic waters but leave when anoxia takes place. Then it seems be of filter-feeders. However, due to their pelagic life style, the Entomozoidea and Polycopidae are here excluded from the primary statistics and will be taken into account as referrible materials for discussion.

Tab. 4-3-B Species number for each feeding mode in studied sections

(DP, LQ, SW and CH: the same as in Tab.3-2-A)

Alimentation Mode	**Taxa**	**DP**	**LQ**	**SW**	**CH**	**TOTAL**
Filter feeder	**Palaeocopida** **Metacopina**	16	15	6	0	36
Deposit feeder	**Bairdioidea** **Bairdiocypridoidea** **Cytheroidea**	30	22	31	12	86
?	**Myodocopida**	4	2	0	2	6
Percentage of filter-feeders		32%	38.5%	16.2%	0%	28.1%

Tab. 4-3-B shows the species number for each feeding mode. Generally, in studied area, the percentage of the filter-feeders is very low with an average value of 28.1%. In the Liuqiao Section, the fauna is composed of 38.5% of filter-feeders, the maximum value in studied area. In the Chaohu fauna, there was not any filter-feeder discovered. According to the FF% model, the dissolved oxygen concentration can be interpretaed as higher than 4.8ml/l. This means that the studied area is not anoxic at all and even not dysoxic. The following statistics are carried out for the bed/sub-beds with more than 2 species and 10 individuals.

The Dongpan fauna, with an average composition of 32% filter-feeders, is analysed for 19 sub-beds (Fig. 4-3-C). The maximum percentage is 62.5% in the bed 03DP4. In the next place, the sub-beds 03DP3-16 yielded 50% and 03DP3-1 composes of 42.9% filter-feeders. In the other sub-beds, the percentages are lower than 33%. Interpreted by the FF% model, the “most drastic dysoxia” in the Dongpan Section occurred in the bed 03DP4 with an oxygen concentration of about 3.2ml/l. The sub-bed 03DP3-16 has an oxygen concentration around 4.1ml/l and 03DP3-1 of 4.6ml/l. In the other sub-beds, the oxygen concentration is over 5ml/l. In other words, in the Dongpan Section, except the bed 03DP4 in which a moderate dysoxic condition is interpreted, the general environment is oxic. In addition, the increase of terrestrial influx may disturb the normal metabolism as indicated by He *et al.* (2007). They demonstrated that the input of terrestrial materials was a reason inducing the brachiopod miniaturization. Brachipods are sessile filter-feeders. They use their lophophore to filter organic particles from the sea water. The influx of inorganic terrestrial material may clog the lophophore and then decrease its filter efficiency, which leads to the brachiopod miniaturization. For the ostracod fauna, there is not the phenomenon of general miniaturization was observed in studied sections. However, the input of terrestrial materials may have also influenced the living of filter-feeders because the anoxic event in the bed 03DP6, implied by the Ce abnormity and trace fossils, was not reflected in the ostracod fauna (based on applicability of the FF% model in the deep-water fauna).

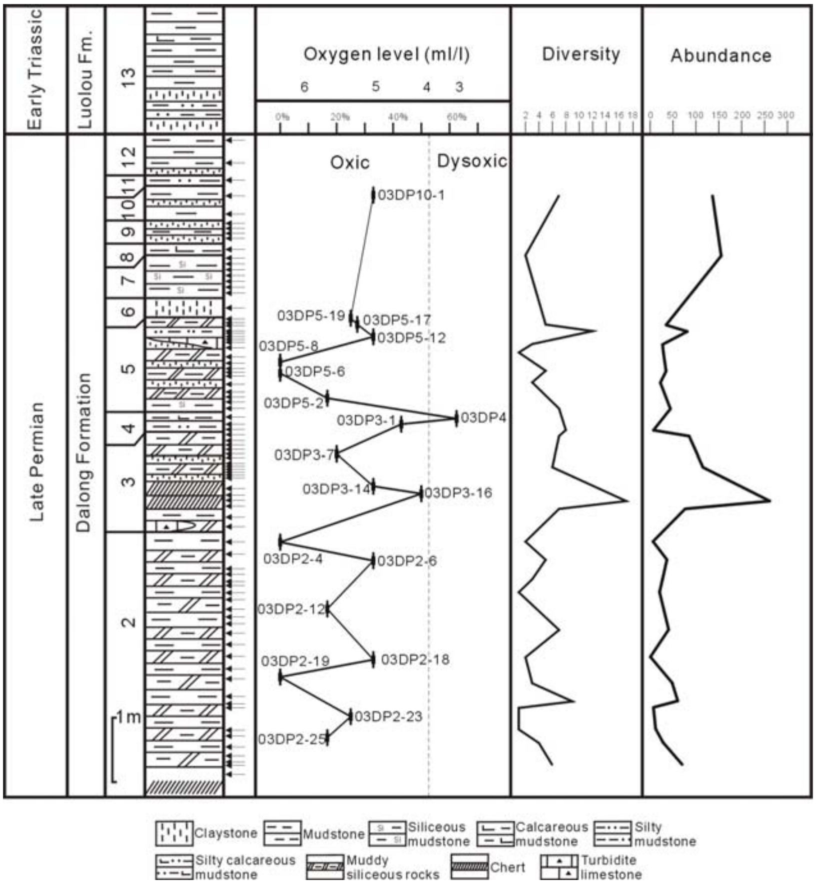

Fig.4-3-C Diagram showing changes in the percentage of filter-feeders in the Dongpan Section (19 valid sub-beds) (the data of oxygen level according to Lethiers & Whatley, 1994).

Among the studied sections, the Liuqiao Section has the highest general composition of filter-feeders (38.5%) although it also indicates the oxic condition. There are only three beds satisfying the statistic possibility (Tab.4-3-C). The highest percentage of the filter-feeders is 40% in the bed LQ16, which yielded the most diverse fauna in the Liuqiao Section. The bed LQ3 did not comprise filter-feeder and indicate a rather well-oxygenated environment. The general high percentage of the filter-feeders in the Liuqiao Section results from the 100% filter-feeders in some beds with only the single filter-feeding species. Consequently, the oxic conditions are concluded for the Liuqiao Section, whereas several times of oxygen depletions might occurr.

In the Shaiwa Section, there is a rather low percentage of filter-feeders (16.2%). Four of the eight sub-beds are chosen here for statistics (Tab.4-3-C). The sub-bed SW13-12, yielding 28 species in total, has a percentage of 14.3% filter-feeders. The other two sub-beds have respectively 25% and 33% of filter-feeders. All of them indicate an oxygen level of more than 5ml/l which indicates a normal marine environment.

Tab.4-3-C Percentages of filter-feeders in the valid horizons of the Liuqiao and Shaiwa Sections

Section	Bed/sub-bed	Diversity	Abundance	Filter-feeder	Deposit-feeder	Filter-feeder%
Liuqiao Section	LQ22	6	43	1	5	16.7%
	LQ16	25	189	10	15	40%
	LQ3	6	92	0	6	0%
Shaiwa Section	SW13-3	4	24	1	3	25%
	SW13-11	4	14	0	4	0%
	SW13-12	28	76	4	24	14.30%
	SW13-14	6	10	2	4	33%

For the Chaohu Section, 12 of all the 14 species belong to the Bairdoidea and Bairdiocypridoidea and thus are deposit-feeders. The other 2 species are polycopids and not considered here. Then this means that the benthic Chaohu fauna are completely deposit-feeding and represents an oxic environment.

4. 3. 4 Discussion

In general, from the ostracod fauna, three points can be summarized from the oxygen level reconstruction as follows:

(1) A general oxic condition was indicated with unique exception in the bed 03DP4 of the Dongpan Section, yielding 62.5% of filter-feeders. The dysoxic event might have occurred in this bed.

(2) The oxygen concentration is not stable in studied area. Although there is possibly not evident dysoxic or anoxic event have fallen, the relatively low oxygen level existed discontinuously.

(3) It is notable that in the relatively "dysoxic" beds here, the Myodocopida rarely appeared. Especially in the Chaohu Section, which did not yield any filter-feeder, two polycopids were discovered. Thus the here discovered Myodocopid species may not be the inhabitants in oxygen deficient conditions.

Compared with the other results mentioned in **4.3.1**, the interpretation on ostracods seems more in accordance with results of trace elements and foraminifers (Fig.4-3-D). According to these analyses, the bed 03DP4 has the lowest oxygen concentration and return to normal upwards in the Dongpan Section, however, the bed 03DP6 seems more possibly to suffer from the anoxic event in the view of Ce abnormity or trace fossils. In the Dongpan Section, the mineralogical analyses show abundant tuff yielding in the beds 03DP4 and 03DP6. The claystones just overlying the tuff composed of the zircon, apatite, hexagonal dipyramide quartze and other materials origining from the acidic lava. Thus the occurrence of volcanic activities could be inferred for the two horizons, 03DP4 and 03DP6. In addition, the above discussed paleobathymetric evaluation showed that the regression occurred in the bed 03DP6 and the influx of terrestrial materials consequently increase upwards. That is to say the two special horizons were conducted by different events. The bed 03DP4 was mainly influenced by the volcanic activities and 03DP6 by both the regression and volcanic activities. In this view, the different results of oxygen deficiency could be understood as the variable response of the different groups of fossils, although the reason needs more detailed investigations. Anyhow, the first attempt of FF% model in oxygen level reconstruction seems reliable.

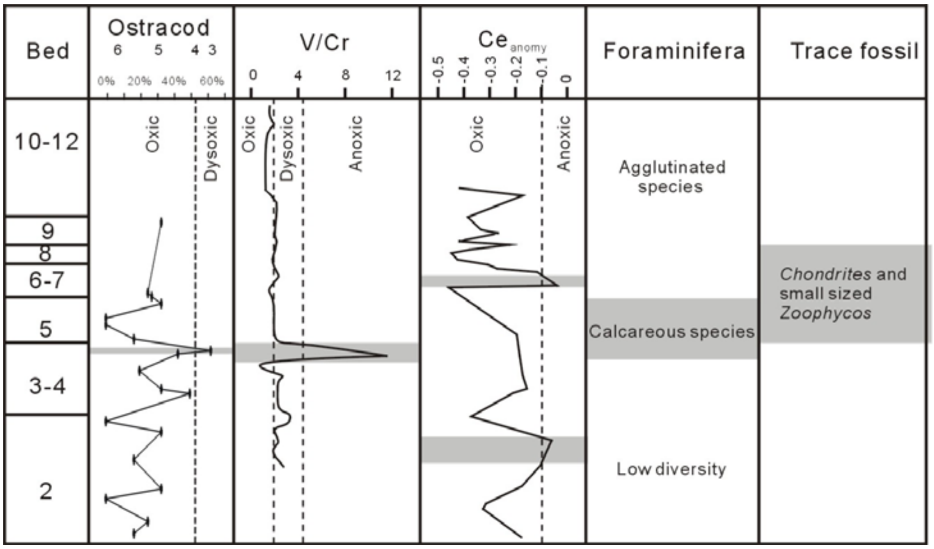

Fig.4-3-D Comparison of oxygen-level reconstruction interpreted by ostracods and other analyses (grey zones indicate the interval of oxygen deficiency; the data of oxygen level in the column of ostracod according to Lethiers & Whatley, 1994).

In conclusion, as discussed above, the different methods for reconstructing the oxygen-level were not corresponding to each other (although there are some consistencies between some methods). Thus for the deep environments, it is still difficult to establish an oxygen-level in precise. Additional work is need for making sure the effective tool for oxygen-level reconstruction.

Chapter 5 Was there an "Extinction Event*" in Deep Water Ostracod Faunas?

§ 5.1 Review on ostracod extinction during Permian-Triassic events

As the other marine organisms, ostracods suffered great change during the end-Permian events (Wang, 1978; Hao, 1994, 1996; Wang & Wang, 1997; Crasquin-Soleau *et al.*, 2004, 2007; Yi, 2004).

The change of the ostracod fauna in the assemblage, diversity, abundance and measurements of individuals brought some researchers the idea of "sudden extinction". Jin *et al.* (2000) applied the statistical method on the ostracod fauna of the Changxing Formation, Meishan Section (GSSP), Zhejiang. They found that the sudden extinction of ostracod fauna occurred at the base of the bed 25 with an extinction rate of 83.3% in specific level (Fig.2 (C) in Jin *et al.*, 2000). But the original data on ostracod taxa were not mentioned and thus it is far from clearly understanding the ostracod extinction process. In addition, the Changhsingian ostracods in the Meishan Section have been systematically studied and abundant data were available, whereas the data on Permian-Triassic boundary and lowermost Triassic ostracods were very poorly known. Thus the "sudden extinction" is really questionable and needs validating at least. In fact, the only achieved data of ostracod faunas, spaning the Permian-Triassic boundary in South China, were only those reported from western Guizhou, northeastern Yunan, south Guizhou, Jiangxi and Fujian (Wang, 1978; Yi, 1992, 2004; Hao, 1994, 1996; Wang & Wang, 1997). And only the base of the early Triassic was sampled. During this boundary interval, the other data were only focused on either the Late Permian (Chen & Shi, 1982; Shi & Chen, 1987, 2002; Becker & Wang, 1992; Hao, 1992a, 1993; Yuan *et al.,* 2007) or the Triassic (Zheng, 1976, 1988; Wei, 1981; Guan, 1985; Hao, 1992b; Crasquin-Soleau & Kershaw, 2005; Crasquin-Soleau *et al.*, 2006). Thus, the relatively poor knowledge on ostracods during the Permian-Triassic event in South China makes it difficult to confirm the extinction process in this group.

Crasquin-Soleau *et al.* (2007) proposed the extinction and recovery patterns of ostracods through the Permian-Triassic boundary. According to their opinion, the extinction in ostracod faunas has begun

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[*] There is not unified opinion on general extinction in ostracod faunas at present due to the lack of data and quantitive analyses. Most published literatures were focused on local or regional change during the Permian-Triassic boundary interval. To some extent, these changes are not strictly equal to the real extinction before the comparison of worldwide data is carried out. So the quotation mark is used here.

since the early Changhsingian (the end of extinction stage is undetermined for the time being) before the appearance of the Mesozoic forms. During the later period of the Changhsingian, ostracods were represented by the mixed fauna, which was defined as the survival stage, and then experienced the maximum of poverty in the Early Griesbachian (early Induan). From the Spathian (late Olenekian) to Anisian, the ostracods entered into the recovery stage and finally into the radiation stage. The last Paleozoic survivors disappeared in the Spathian. The patterns represent the most systematic cognition in ostracod extinction and recovery during the Permian-Triassic interval up to date. However, the precondition of these patterns is based on and thus applied in the neritic ostracod faunas, as mentioned by the authors “In this paper, we take into account only the neritic forms.” (p.14 in Crasquin-Soleau *et al.,* 2007). The reasons, that the deep water benthic ostracods were excluded, are the relative stability of the deep water habitats and lack of data in this boundary interval.

To sum up the previsous studies, the data on ostracod faunas during the Permian-Triassic boundary interval are insufficient to make the general conclusion on extinction/recovery. Nevertheless, some common understandings on ostracods during the Permian-Triassic boundary have been acquired by previous studies (Wang, 1978; Yi, 1992, 2004; Hao, 1994, 1996; Wang & Wang. 1997; Crasquin-Soleau *et al.,* 2004, 2007).

(1) The faunas in the Permian-Triassic boundary interval were mixed with Paleozoic and Mesozoic forms. The Paleozoic forms did not totally disappear at the Paleozoic-Mesozoic boundary and survived after the mass extinction. The last Paleozoic survivors were found in the early Anisian. The typical Mesozoic forms, as *Petasobairdia, Lobobairdia, Mirabairdia*, appeared during the Wuchiapingian and completely replaced the Paleozoic relicts in the Anisian (Crasquin-Soleau *et al.,* 2007). The Changhsingian faunas discovered in Jiangsu and Hubei (Chen & Shi, 1982), Zhejiang (Shi & Chen, 1987) and Guangxi (Shi & Chen, 2002) also display the phenomenon of “mixed fauna”.

(2) In the view of the fauna in each locality, the “extinction” is evident both in generic and specific levels.The general visage of the lowermost Triassic ostracod fauna was poorly yielded in very low diversity and abundance. However, if consider the survivors occurring in other localities, the incomplete statistics at present shows that the extinction rate in generic level is less than 50% in the mentioned faunas. Thus, the real extinction nature and mode are still not clear, even for the relatively well studied shallow water ostracods. In addition, Shi & Chen (2002) demonstrated that the diversity and abundance have begun declined from the Wuchiapingian through the Changhsingian. In their studies, only 6 of 22 genera and 7 of 75 species continued to the Changhsingian of Heshan, Guangxi. It seems that the extinction began much early than other localities. Then the extinction duration is also pendent.

(3) The changes of faunas in the boundary interval are represented by the decline not only in diversity and abundance but also of measurements and ornamentations in some faunas. Hao (1994, 1996) found that the ostracods surviving in the Triassic have small size and simple ornamentation, whereas Wang (1978) discovered the “miniaturization” has begun in the late Changhsingian. Some

Healdia species were smaller than 0.5mm. But in the Meishan Section, the ostracods were small in the lower Changxing Formation, dominated by larger ones in the middle part and composed of individuals with different sizes in the upper Changxing Formation.

In a word, the known discussion about extinction of ostracod faunas during the Permian-Triassic boundary interval in South China was only concentrated in the shallow-water environment (nearshore-platform-upper part of slope, mainly carbonate facies). Many materials have been achieved by previous studies, although are still insufficient for drawing a general conclusion on ostracod extinction mode. The further investigations on more faunas completely spaning the boundary interval and from different facies are indispensable.

§ 5.2 "Extinction event" in the studied ostracod faunas

5. 2. 1 Discussion on several hotspots related to the extinction event

Presence of Mesozoic forms

43 genera and 128 species, belonging to the Palaeocopida, Podocopida and Myodocopida, were recognized in the four studied faunas. The Podocopida took up the dominant place by the average percentage of 75%. The Palaeocopida held an average percentage of 20.3% and Myodocopida only 4.7%. 16 of 43 genera have been reported from the Triassic strata in other localities by previsous studies (Tab.5-2-B). In specific level, neither one of the 128 species survived into the Triassic. Three species were compared to Early Anisian elements from Romania (*Bairdia* cf. *szaszi*, *Bairdia* aff. *mirautaae* and *Polycope* aff. *baudi*). Similar to the shallow water faunas, the Mesozoic forms of Bairdiidae (heavily shelled and strongly ornamented) are also found here, such as *Mirabairdia comisa* Chen, 1982 also found in the Late Permian of Jiangsu and Guangxi (Heshan, Yishan) and *Petasobairdia bicornuta* Chen, 1982 widely reported from the Changhsingian strata of South China, including the Meishan Section, and regarded as a Changhsingian species (Chen & Shi, 1982; Shi & Chen, 1987; Hao, 1992a, 1994, 1996; Yi, 2004). Except the *Petasobairdia* spp., other Mesozoic forms had a single occurrence or a very short stratigraphical distribution in the studied faunas. In addition, some of the common species have long stratigraphic repartition from the Late Devonian- Carboniferous (Mississippian) to the Late Permian (Tab.3-2-C). In brief, the discovered faunas are still dominated by typical Paleozoic species but accompanied with some Mesozoic forms. Thus the same as the shallow water faunas, the character of "mix" is also present in the deep water faunas.

However, the Paleozoic elements in the mixed faunas here are different from those in shallow water faunas. In the discovered shallow water faunas, the Paleozoic forms were dominated by the nearshore-neritic Palaeocopids (e.g. *Kirkbya, Amphissites*). But in the deep water faunas here, the

Paleozoic elements are composed of the same paleopsychrospheric species as those in the Late Devonian deep-water strata of Poland, France, Germany and Massif Rhenish and the Wuchiapingian deep-water strata of of Italy and Indonesia (Gründel, 1961, 1962; Gründel & Kozur, 1975; Olempska, 1981, 1997; Bless, 1987; Becker, 1990; Lethiers & Feist, 1991; Kozur, 1991a, b; Blumenstengel, 1993, 1994; Crasquin-Soleau *et al.,* 2008). As described in chapter 4, the paleopsychrospheric species discovered from the latest Ordovician to the Middle Triassic and had a so slow evolution that there was not evident change between the Devonian and latest Permian species. The different compositions of the deep water and shallow water assemblages implies that the ostracod faunas yielded from different environments would vary in response during the crisis and thus displayed different “extinction” modes.

Diversity and abundance in general

In the studied faunas, the diversity and abundance per bed/sub-bed were generally low (Fig.3-1-A, B, C, D). There were some diverse and abundant* horizons, such as 03DP3-14 and 03DP5-17 of the Dongpan Section, LQ16 of the Liuqiao Section and SW13-12 of the Shaiwa Section. In these beds, both the diversity and abundance reached a prominent peak value and declined rapidly to the low value upwards. From the diversity curve, except the “peak” horizons, no evident decreasing trend was observed along the whole section. However, the disappearance of ostracods from below the PTB to the very early Triassic did demonstrate the decline of ostracods during the boundary interval. In the Dongpan Section, the samples from the bed 03DP10 to 03DP14 were processed but no ostracod was found. Only several sponge spicules and pyritized small bivalves and gastropods were yielded in the basal of Triassic. In the Chaohu Section, the strata near the Permian-Triassic boundary had very high content of mudstones. Nothing was found in the latest Permian strata above the bed CH3-2 (only one fragment) and the basal of Triassic strata. This may indicate the catastrophic environment, began since the Late Permian, still continued in the early Early Triassic of the Dongpan and Chaohu Sections.

Miniaturization?

As mentioned above, the discovered ostracod faunas are dominated by small, thin-shelled individuals with length between 0.2mm-0.5mm, except some Kirkbyoidea and ornamented Bairdioidea larger than 0.6mm (<1.1mm). The change in individual size was not observed along the sections studied here. As mentioned above, there are 19 common species between the studied sections and other occurrences. Some of the common species were reported from the Late Devonian-Carboniferous strata. Was there the “miniaturization” in these long-ranging species? For finding out the answer, the measurements of the 19 common species in this study were compared with the previous data (Tab.5-2-A).

From the data listed in Tab.5-2-A, the long-range species have smaller size than the specimens in the Late Devonian-Early Carboniferous (? *Libumella athabascensis* Green, 1963, *Microcheilinella* cf. *elatus* (Lethiers, 1978) *sensu* Lethiers, 1981, *Microcheilinella aculeata* Buschmina, 1975, *Healdiopsis*

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* Only compared to the other horizons in studied sections, these beds yielded more abundant and diverse faunas.

thuringensis thuringensis (Gründel, 1961), *Waldeckella* ? *sphaerula* (Gründel, 1961) *sensu* Becker, 1999). But the Late Carboniferous individuals of *Pseudobythocypris concava* (Cooper, 1941) and *Discoidella xingyangensis* Zhang, 1987 were not larger than the latest Permian ones found here. The *Pseudobythocypris concava* (Cooper, 1941) specimens even have larger size than their ancient congeners. Thus along the geological time, no unified change can be concluded from the present data. Most of the common species ranging in the Permian have a comparable size with individuals from other localities of shallow and deep environments. The specimen of *Roundyella* ? *oblonga* Wang, 1978 is larger than the Guizhou ones. The specimens of *Cyathus caperata* (Guan, 1978) *sensu* Shi & Chen 1987, ? *Bairdia anbeedi* Belousova, 1965, *Bairdia* sp.1 *sensu* Gründel & Kozur, 1975, *Bairdia altiarcus* Chen 1958, *Mirabairdia comisa* Chen, 1982 and *Fabalicypris parva* Wang, 1978 have a common size-variation interval or comparable measurements with the previous reported specimens. The exception is the specimens of *Bairdia* ? sp. 6 *sensu* Bless, 1987 which have evidently smaller size than the Early and Middle Permian individuals. But it is noticeable that the Middle Permian specimens from Sicily (Crasquin-Soleau *et al.,* 2008) had a median size between the Early Permian individuals of Indonesia (Bless, 1987) and the specimens here. All the three localities were deep water environments which are characterized by the strong stability. Thus I consider the variation in size as the differences between instars and adults rather than the miniaturization. In the species *Bairdia altiarcus* Chen 1958, the similar phenomenon can be observed: the Late Permian specimens from the shallow water environment of South China (Chen, 1958) were larger than the Middle Permian specimens discovered in deep water strata of Sicily (Crasquin-Soleau *et al.,* 2008). So it is more reasonable to regard the small individuls as the instars. The presence of different sizes in one species reflects the ontogenic lineage among different occurrences.

Thus, even though the specimens here are small in general, compared with the contemporary specimens from different environments or to the very ancient specimens, there is not general miniaturization occurring. The no-miniaturization was also observed in the reported neritic ostracod faunas in Turkey (Crasquin-Soleau *et al.*, 2002). In addition, the coexistence of instars and adults supports the preservation *in situ* of the studied faunas.

5. 2. 2 Concrete discussion on Dongpan and Liuqiao faunas

Of the studied faunas, the Dongpan and Liuqiao Sections have the clearest stratigraphical relationship and were situated in the same geological settings. The Liuqiao Section, underlying the Dongpan Section with a gap of about 5m, was deposited in the Late Changhsingian earlier than the Dongpan Section. Thus, the two sections are here regarded as a whole, constituted of the Liuqiao Section in the lower part and the Dongpan Section above, for finding out whether or not the “extinction” has occurred in the deep water faunas here. The stratigraphical distributions of genera and species in the joint section are respectively illustrated (Fig.5-2-A, B)

Tab.5-2-A Comparison of measurements for the common species between this work and previous studies

Common species	**In this work (length/height) (µm)**	**general measurements in previous studies (mm)**	**detailed measurements in previous studies (length/height) (mm)**
Roundyella ? *suboblanga* Wang, 1978	653/360	0.44/0.24	0.44/0.24(Guizhou,Late Perm.)
Cyathus caperata (Guan, 1978) *sensu* Shi & Chen 1987	353/240	0.325-0.63/0.2-0.38	0.40-0.63/0.25-0.38(Zhejiang,Late Perm.); 0.325-0.375/0.2-0.27(Hunan,Early Perm.)
? *Libumella athabascensis* Green, 1963	217-261/166-196	0.89-1.56/0.59-1.03	0.89-1.56/0.59-1.03(Canada,Early Carb.)
Bairdia altiarcus Chen 1958	415/262	0.54-1.63/0.34-1.00	0.9-1.28/0.51-0.77(Jiangsu,Early Perm.); *0.54/0.34 (Sicily, Middle Perm.); 0.86-1.63/0.52-1.00(Guangxi,Late Perm.)
? *Bairdia anbeedei* Belousova, 1965	874/549	0.54-0.97/0.23-0.56	0.54-0.97/0.23-0.56(Iran, Late Perm.); *0.625/0.33(Hungary,Middle Perm.)
Bairdia sp.1 *sensu* Gründel & Kozur, 1975	908/551	*0.83-1.02/0.6-0.64	*0.83-1.02/0.6-0.64(Indonesia,Early Perm.)
Bairdia ? sp. 6 *sensu* Bless, 1987	311-565/142-226	*0.725-1.59/0.275-0.55	*1.59/0.55 (Indonesia,Early Perm.); *0.725/0.275(Sicily, Middle Perm.)
Bairdia cf.*austriaca* (Kollmann, 1963) *sensu* Gründel & Kozur, 1975	786/400	*0.96-1.09/0.49-0.57	*0.96-1.09/0.49-0.57(Indonesia,Early Perm.)
Mirabairdia comisa Chen, 1982	694-705/360-365	0.77-0.98/0.42-0.56	0.98/0.56(Jiangsu,Late Perm.); 0.77/0.42(Guangxi,Late Perm.)
Petasobairdia bicornuta Chen, 1982	541/335	0.73-1.0/0.37-0.6	0.8-1.0/0.48-0.6(Jiangsu&Hubei, Late Perm.); 0.84-0.92/0.552-0.56(Zhejiang,Late Perm.); 0.73/0.37(Guizhou,Late Perm.)
Fabalicypris glennensis (Harlton, 1927) *sensu* Yi, 1993	1076/441	1.14/0.45	1.14/0.45(Fujian,Early Perm.)
Fabalicypris parva Wang, 1978	416-729/190-326	*0.56-0.82/0.24-0.34	0.68-0.82/0.32-0.34(Guizhou,Late Perm.); *0.56/0.24(Hungary,Late Perm.)
Bohemina (*Pokornina*) ? sp.1 *sensu* Gründel & Kozur, 1975	178-207/100-129	pencil sketch in original plate	pencil sketch in original plate
Microcheilinella cf. *elatus* (Lethiers, 1978) *sensu* Lethiers,1981	274-311/174-200	0.36/0.24	0.36/0.24 (Canada,Late Dev.)
Microcheilinella aculeata Buschmina, 1975	457/186	0.750/0.425	0.750/0.425(Russia,Early Carb.)
Pseudobythocypris concava (Cooper, 1941)	457-578/229-289	0.46/0.23	0.46/0.23(Illinois,Early Carb.)
Healdiopsis thuringensis thuringensis (Gründel, 1961)	350/229	0.41-1.44/0.23-0.95	0.41-1.44/0.23-0.95(Germany,Late Dev.-Carb.)
Waldeckella ? *sphaerula* (Gründel, 1961) sensu Becker, 1999	212-243/312-329	*0.389/0.57	*0.389/0.57(Rhenish Massif;Late Dev.)
Discoidella xingyangensis Zhang, 1987	348-356/322-333	0.38-0.5/0.34-0.43	0.38/0.34 (Henan,Carb.); *0.5/0.43(Fujian,Late Perm.)

Remarks: The measurements with * mean the data were not provided in the original references and measured here according to the published plates.

Tab.5-2-B List of all the genera recognized in this study with marked if survived during the end-Permian events

Genera	**DP**	**LQ**	**SW**	**CH**	**Disappear or survive?**	**Reference**
Tribolbina Latham, 1932		*				
Kirkbya Jones, 1859	*	*				
Aurikirkbya Sohn, 1950	*	*				
Nodokirkbya Kozur, 1991	*					
Tubulikirkbya Kozur, 1985a		*				
Kellettina Swartz, 1936	*				disappear	Sohn,1954
Roundyella Bradfield, 1935		*			disappear	
Permokegelites Becker & Wang, 1992		*				
Cyathus Roth & Skinner, 1930			*		disappear	
Macronotella Ulrich, 1894	*				disappear	
Libumella Rozhdestvenskaya, 1959	*				disappear	
Permoyoungiella Kozur, 1985a	*					
Paraparchites Ulrich & Bassler, 1906	*				survive	Sohn, 1963; Yi, 1992; [*]Forel, 2007
Bairdia McCoy, 1844	*	*	*	*	survive	
Abrobairdia Chen, 1982		*			survive	
Lobobairdia Kollmann, 1963		*			survive	
Mirabairdia Kollmann, 1963		*			survive	
Petasobairdia Chen, 1982	*	*	*		survive	
Pustulobairdia Sohn, 1960		*	*			
Spinobairdia Morris & Hill, 1952	*					
Bairdiacypris Bradfield, 1935	*		*	*	survive	[*]Forel, 2007
Bythocypris Brady 1880			*		survive	Sohn, 1963
Fabalicypris Cooper, 1946	*	*		*	survive	Hao,1992a; Wang & Wang, 1997
Acratia Delo 1930			*		survive	Yi, 1992; Hao, 1994
Cooperuna Gründel, 1962	*					
Monoceratina Roth, 1928	*				survive	Sohn,1963, 1970; Wei, 1981; Zheng, 1976,1988; Kristan-Tollmann, 1983
Bohemina Snajdr, 1951	*		*			
Paraberounella Blumenstengel, 1965	*	*			survive	Crasquin-Soleau & Gradinaru, 1996
Rectonaria Gründel, 1961	*					
Denticupachydomella n.gen.		*				
Microcheilinella Geis, 1933	*		*		survive	
Spinomicrocheilinella Kozur, 1985a	*	*	*			
Pseudobythocypris Shaver, 1958	*	*	*	*	survive	Sohn, 1987
Healdia Roundy, 1926	*	*			survive	Sohn, 1963; Crasquin-Soleau & Gradinaru, 1996
Healdiopsis Gründel, 1962	*					
Marginohealdia Blumenstengel, 1965			*			
Waylandella Coryell & Billings, 1932			*			
Triplacera Gründel, 1961			*			
Cavellina Coryell, 1928	*				survive	CIGMR, 1983
Absina Gründel, 1962	*	*				
Waldeckella Rabien, 1954	*					
Polycope Sars, 1866	*	*		*	survive	Crasquin-Soleau & Gradinaru, 1996; Kolar_Jurkovsek,1988/89
Discoidella Croneis & Gale, 1938	*	*				

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[*] Forel M-B. Les ostracodes margueurs des modifications paléoenvironmentales lors des événements de la limite Permien-Trias en Chine du Sud: [mémoire de maîtrise]. Université Bordeaux 1: Bordeaux. 2007. (in French with english abstract).

Dongpan and Liuqiao faunas - generic level

The stratigraphical distribution of all genera (37 genera) in the joint section is showed as Fig.5-2-A. From this figure, three horizons are prominently special, i.e. the bed LQ16, the top to 03DP5 to bottom of 03DP6 and the bed 03DP10.

In the bed LQ16, the Mesozoic forms of bairdiids *Lobobairdia, Mirabairdia, Petasobairdia, Abrobairdia* and other genera surviving into the Triassic (*Fabalicypris, Healdia*) appeared at one time. This bed is the only occurrence of the genus *Lobobairdia* in studied sections. *Abrobairdia* and *Mirabairdia* disappeared until the bed LQ22. In addition, it is noticeable that the bed LQ16 had highest diversity and abundance in the Liuqiao Section. The abundant occurrence of bairdiids implies the normal environment in this horizon. Thus it can be inferred that this bed is cofessedly below the major episode horizon of the mass extinction (suppose the mass extinction existed).

The second special horizon, the top of 03DP5 to bottom of 03DP6, experienced a rapid decline in diversity. A quarter of the total genera, including three palaeocopid genera (*Kirkbya, Libumella, Permoyoungiella*), disappeared above this horizon in the Dongpan Section. It seems well accordant to the data in other ways. The first crisis of radiolarians occurred in the bottom of 03DP6 (Feng *et al.,* 2007b). In addition, the paleoenvironmental analysis shows the presence of the regression and possible anoxia (dysoxia) in this bed. The studies on sedimentology, mineralogy and geochemistry indicated the occurrence of strong volcanic activities. And the TOC also suggested the mass burial of organisms by its largest positive excursion (Zhang, 2006; Zhang *et al.*, 2007a, b). All studies highlighted this "event horizon". However, for ostracods, it is too early to draw a conclusion on extinction because the genera disppeared in the Dongpan Section have been reported from the Triassic strata. *Paraberounella* has been found in the Early Anisian of Romania (Crasquin-Soleau & Gradinaru, 1996). *Monoceratina* and *Bairdia* was widely discovered from the Triassic strata and even still exists at present (references see Tab.5-2-B). *Bairdiacypris* was also very common Triassic species. This means that these genera, disappeared in the studied sections, still survived into the post-Permian in fact. Consequently, the extinction in the top of 03DP5 to the bottom of 03DP6 belongs to the apparent extinction rather than the real extinction for ostracods. And the apparent extinction was well accordant to the paleoenvironmental change.

In the bed 03DP10, it appears the last occurrence of all genera surviving after the apparent extinction horizon in the Dongpan fauna. *Macronotella*, the only palaeocopids surviving the "extinction" but has not been found in the Triassic, could be the relict. *Fabalicypris, Cavellina*, *Microcheilinella* and *Pseudobythocypris* have been reported from the Triassic strata (Tab.5-2-B). Thus the disappearance of all taxa in 03DP10 of the Dongpan Section was also apparent extinction. In addition, it should be noted that the surviving genera are mostly deposit-feeders. Their sudden disappearance in 03DP10 may indicate the enhancement of anoxia/dysoxia, which could have continued until the early Early Triassic suggested by the presence of the pyritized bivalves and gastropds in the Dongpan Section.

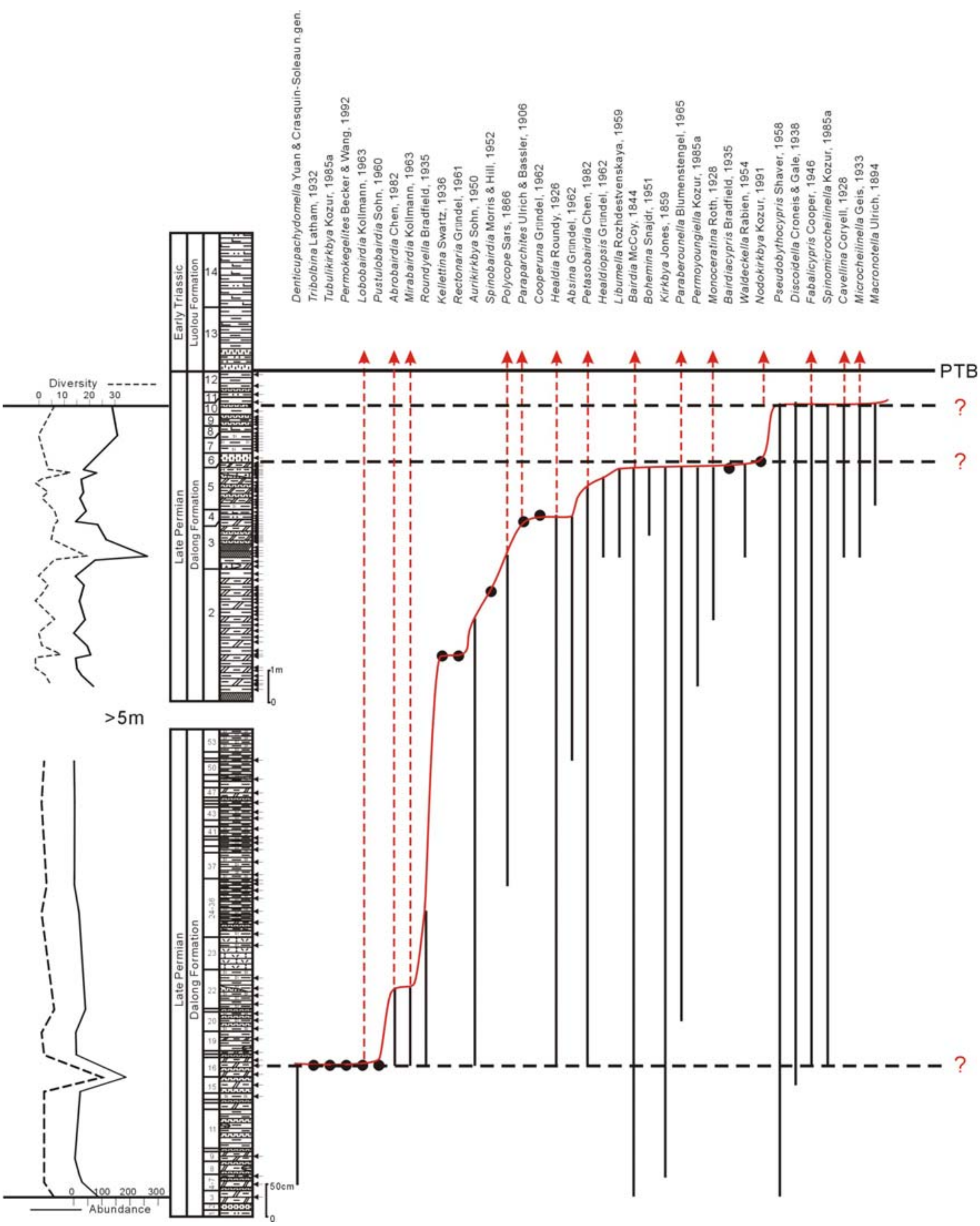

Fig.5-2-A Stratigraphical distribution of ostracod genera in the Dongpan and Liuqiao Sections

(the black dasheds mark the three special horizons, i.e. LQ16, top of 03DP5-bottom of 03DP6 and 03DP10 from the bottom up; the red dasheds indicate the genera which have been reported from the Triassic strata in previous studies)

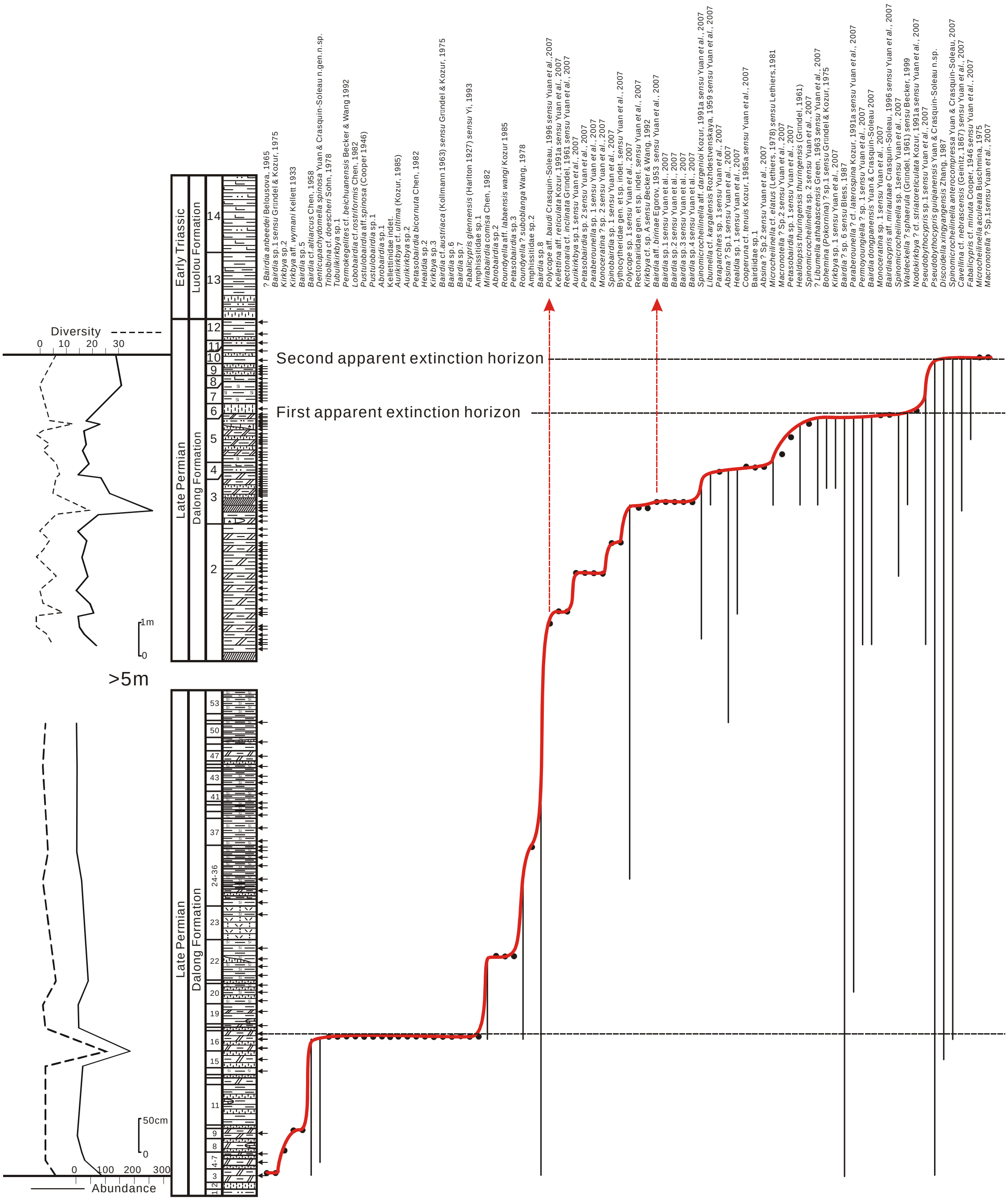

Fig.5-2-B Stratigraphical distribution of ostracod species in the Dongpan and Liuqiao Sections (the black dasheds marks the two apparent extinction horizons proposed in this work; the red dasheds indicate the species compared to the Triassic elements).

Dongpan and Liuqiao faunas – specific level

The stratigraphical distribution in specific level (82 species) displays both accordance and difference with generic distribution (Fig.5-2-B).

Of course, the mentioned three special horizons were also well reflected in specific change. In the bed LQ16, 21 species appeared for the first time in the Liuqiao fauna. In this horizon, the fauna was dominated by the bairdiids including both smooth and ornamented shelled species. The present data are insufficient to determine this horizon as the first occurrence for the Mesozoic forms in ths studied faunas. However, their abundant yielding undoubtedly implies the normal marine environment.

Above this horizon, the environments appeared worsening stepwisely. In the bed LQ22, only the species, which continued to the apparent extinction horizons, were yielded. Several samples from the 5m gap strata between the Dongpan and Liuqiao Sections were also picked. Only the long-ranging species in the studied faunas, such as *Spinomicrocheilinella anteropressa* and *Bairdia dongpanensis*, were found. In the top of 03DP5 to bottom of 03DP6, most of species disappeared and only six species survived this “apparent extinction horizon”. Thus the“apparent extinction” of ostracod faunas existed in both generic and specific levels. Here this event horizon is considered as the **First (major) apparent extinction horizon**. The survived 6 species finally disappeared in the bed 03DP10, which is regared as the **Second apparent extinction horizon** for ostracods.

However, compared to the generic distribution, it appears more phases of “extinction” took place in specific level than in the generic level. There are other two evident “extinction” horizons, the lower 03DP3 and 03DP4. If we correlate with the paleoenvironmental analysis of the previous chapter, these two “extinction” events seem more “apparent”. As mentioned above, in the lower part of 03DP3, there was an influx of turbid current. The sudden increase of many neritic species could be explained by transported through turbid current from the shallower environments. Fig. 5-2-B shows that all the extincted species in the lower 03DP3 were neritic inhabitants. Thus it can be inferred that the environment then was not proper for those species, which disappeared rapidly after being transported by the turbid current. So the “extinction” in lower 03DP3 was actually the reflection of local events. The extincted taxa were not the original members. Consequently, the lower 03DP3 is here excluded from the apparent extinction horizon. The “extinction” in 03DP4 is probably associated with the oxygen deficiency, which is suggested above by the analyses on ostracods, foraminifera and trace elements. Above this horizon, still more than 20 species survived. Thus the extinction in this horizon was not general. It is presumable that the dynoxia did not destroy the whole ostracod faunas. The regression (bottom of 03DP6) finally inflicted on the ostracod faunas and caused the First apparent extinction.

5. 2. 3 Comparison and Discussion

Interestingly, if we compared the Dongpan & Liuqiao faunas with the Meishan and Chaohu faunas, the ordinal “extinction” in the different faunas can be concluded.

Comparison with Meishan fauna

If we follow Jin *et al.* (2000), the ostracod "extinction" in the Meishan Section occurred at the bottom of the bed 25. In the Dongpan Section, the First and Major apparent extinction took place at the bottom of 03DP6, which is corresponding to the boundary of 24d and 24e in the Meishan Section (Feng *et al.,* 2007; Zhang *et al.,* 2007a, b) (Fig.1-2 & Fig.5-3-B). This means the ostracod "extinction" happened earlier in the Dongpan Section than in the Meishan Section. This phenomenon was also observed in the radiolarian extinction: the first crisis in radiolarian faunas occurred at the bottom of 03DP6 (Feng *et al.* 2007), which is earlier than the major extinction in the Meishan Section. In addition, the extinction in radiolarian faunas had a "paleoecological rule". The deep water indicator Albaillellaria disappeared at first, and then the shallower representive Latentifistularia, and finally Entactinaria and Spumellaria. This implies that the extinction could earliest take place in the deep environment and gradually spread to the shallow environment. In fact, the "successive phenomenon" was proposed by some researchers. Isozaki (1997) held the opinion that the anoxia had begun in the deep water area since the Middle Permain but spread to the shallow water until the late Late Permian. All of these indicate that the deep water seems affected foremost so that the inhabitants thereinto suffered from the crisis earliest. Then the catastrophe spread upwards and resulted in the extinction in the shallow water environments. The extinction observed in ostracods and radiolarians implies that the organisms with different lifestyles (benthic, pelagic) did not escape the drastic crisis.

Note that both the major "extinction" horizon in the Dongpan and Meishan Sections are underlied the volcanic claystone layer. Thus it seems the volcanic activity played an important role in the "extinction", but not all volcanic activity could induce the "extinction". In the studied interval of the Dongpan Section, 21 claystone layers with volcanic origins were yielded. But the claystone layers were thicker and more frequently yielded in the two "extinction" horizons, which may indicate the strong and frequent volcanic activities. Thus the volcanic activity was not always the definitive factor in the "extinction", only the strong and/or frequently multi-phased ones took an important place. In addition, in the Dongpan Section, the First apparent horizon is accordant to the regression event, whereas the major "extinction" in the Meishan Section took place in the shelf-margin sequence tract above the second-order sequence boundary (regression event) (Zhang *et al.*, 1996; He *et al.,* 2007). This implies that the "extinction" in different environments was resulted from variable origins, which further reveals the complexity of the extinction.

Comparison between Chaohu, Meishan & Dongpan faunas

The comparison with the Chaohu Section shows another interesting phenomenon. In the Chaohu Section, ostracods were mainly yielded below the bed 5 (accordant to the bed labelled in figure and different from the sample number, see Fig.3-1-D & Fig.5-2-C). Above the bed 5, only several ostracod fragments were discovered in the bed 8. In the samples collected from bed 9 to bed 13, neither one fragment was found. Based on the present data, it is insufficient to delimit the ostracod "extinction" horizon in the Chaohu Section, but the bed 5 can be regarded as an "event horizon" for ostracod fauna

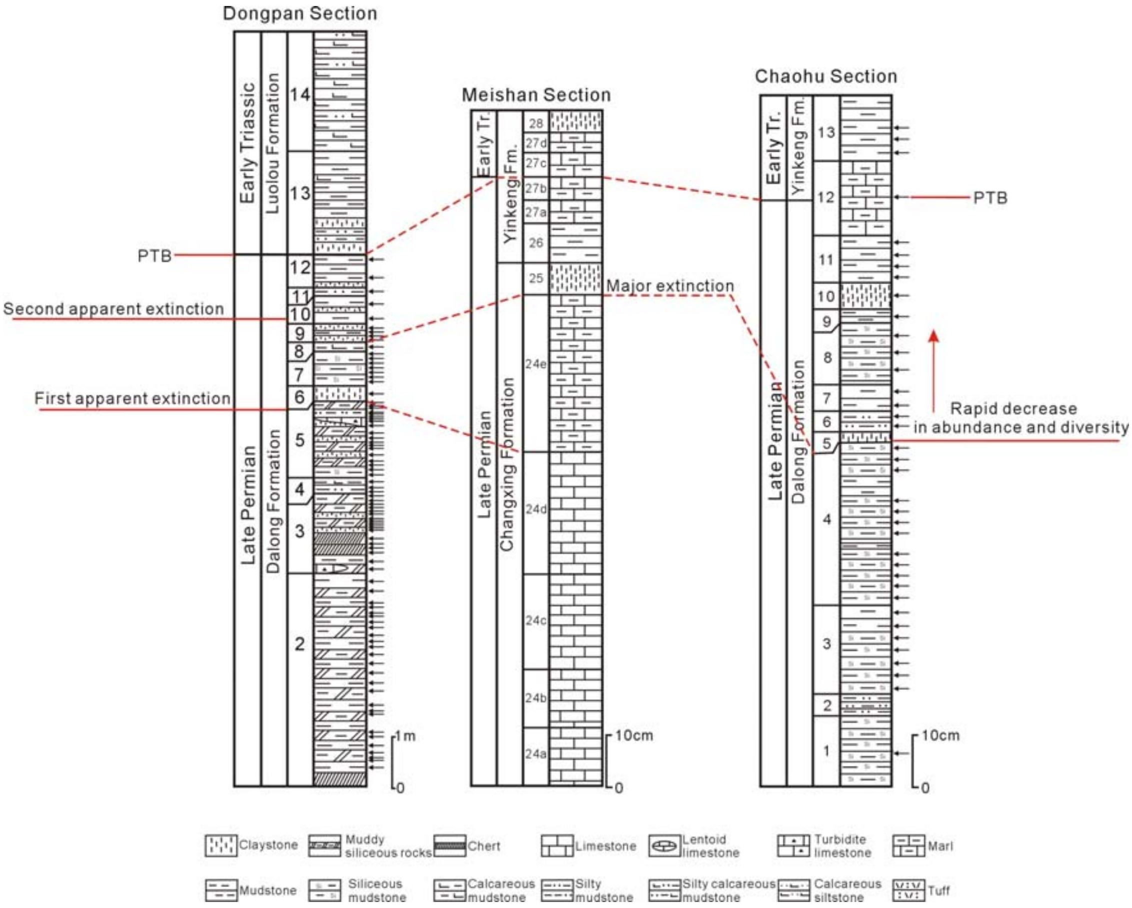

Fig.5-2-C Comparison of the extinction horizon between the Dongpan, Meishan and Chaohu Sections.

due to the rapid decrease both in diversity and abundance. According to the stratigraphical correlation, the bottom of bed 5 is corresponding to the bottom of bed 25 in the Meishan Section. Thus the ostracod “event horizon” in the Chaohu Section was comparable to the major extinction horizon in the Meishan Sections but delayed than the First apparent extinction horizon in the Dongpan Section (Fig.5-2-C). As mentioned above, the Chaohu fauna is dominated by bairdiids. The absence of paleopsychrospheric species implies a shallower environment than the Dongpan Section. But the bairdiids had very thin and elongated shells which may still indicate a relatively deep environment. The radiolarians yielded in the Chaohu Section also suggested that the Chaohu Section was deposited in the paleobathymetry between the Dongpan and Meishan Sections. The comparison between the Dongpan and Meishan Sections implies that the extinction took place earlier in the deep water environments. Then here the delay of the “event” in the Chaohu Section strengthens this proposition. In addition, the synchronous occurrence between the Chaohu and Meishan Sections seems indicating another character of the “extinction”. Maybe this synchronousness implies that the Chaohu Section was deposited in a very similar environment to the Meishan Section. However, the paleogeographical locality and geological settings can not be ignored. The Chaohu and Meishan Section were situated in the Lower Yangtze Region during the Late Permian. Although the former was deposited in basin environment and the latter in upper part of slope, the similarity in ostracod "extinction" suggests that the paleogeographical locality played an important role in influencing the extinction process. This further displays the complexity of the mass extinction induced by various factors.

Discussion

In general, the discussion and comparison above provide some informations on the "extinction" of deep water ostracod faunas during the latest Permian.

(1) The deep water faunas included typical Paleozoic and some Mesozoic forms and thus were presented as mixed faunas.

(2) The comparison of 19 common species with other localities indicates that no miniaturization occurred in the deep water ostracod faunas during the "extinction". Some specimens found in this work were larger than their ancestors. The smaller individuals are here considered as the instars according to the reason mentioned above. Thus the coexistence of instars and adults strengenthen the *in situ* preservation of the studied faunas.

(3) Two "extinction" horizons were proposed for the Dongpan & Liuqiao joint Section. The First apparent extinction horizon is at the top of 03DP5 to the bottom of 03DP6. In this horizon, the first crisis of radiolarians, the largest positive excursion of TOC, regression, volcanic activities and possible dysoxia/anoxia occurred at one time, which greatly highlighted this "event horizon". The Second apparent extinction horizon is located at the bed 03DP10. Above this horizon, all ostracod taxa disappeared.

(4) The two apparent extinction horizons were well reflected both in the generic and specific distributions. However, the specific distribution displayed more detailed information upon the influence of some paleoenvironmental changes (anoxia, influx of turbid current, etc.). Although in this work the specific distribution is well accordant to the generic one after eliminating the influence by the local events, it also reveals that it is indispensable to point out in which level when the "extinction" is mentioned.

(5) In the studied faunas, except few peak values, no evident decreasing trend was observed in diversity and abundance during the "extinction". The abundance curve even showed a small positive excursion above the First apparent extinction horizon. Thus it seems that the ostracod faunas were not affected in abundance as much as in the diversity, although both decreased to zero above the Second apparent extinction horizon. Anyhow, it is strict to clarify the response of faunas in diversity or abundance. Take this work for example, the two apparent extinction events proposed for the Dongpan Section, were reflected in diversity other than in abundance.

(6) The comparison of "extinction" horizon between the Dongpan and Meishan Sections indicate the diachronism of the "extinction" in different environments. The "extinction" might have begun foremost in the deep water area and then spread into the shallow water area. This indicates the concrete extinction process greatly varies for faunas from different paleoenvironments. In addition,

the comparison between Chaohu, Dongpan and Meishan Sections, on the one side the difference between the former two strengthened the paleoenvironmental influence; on the other side, the similarity between the Chaohu and Meishan Sections implies the extinction process was also restricted by the paleogeography.

Chapter 6 Conclusions and Perspectives

§ 6.1 Conclusions

In this work, four sections, the Dongpan Section, the Liuqiao Section, the Shaiwa Section and the Chaohu Section, were selected for thorough studies on deep water ostracod taxonomy, paleoecology and "extinction" process. This is the first systematic study on ostracods from the latest Permian deep water strata worldwide. The acquired cognition during this work will be summarized as follows.

1. General visage of the latest Permian deep-water faunas

In general, the faunas are abundant and diverse although there are many barren horizons (especially in the Shaiwa Section). There are some heavily shelled and strongly ornamented representatives, but the ostracod faunas are dominated by small and thin-shelled individuals. Many specimens are in very poor preservation and did not provide information for identifying.

In total, 43 genera and 128 species have been identified. 2 new species *Bairdia dongpanensis* and *Spinomicrocheilinella anterocompressa* were described and one new genera *Denticupachydomella* n.gen. and 2 new species *Pseudobythocypris guiqianensis* n.sp. and *Denticupachydomella spinosa* n.sp. are proposed. Majority of the ostracod species are endemic although 19 common species were reported from the Late Devonian-Late Permian strata of Europe, North America and Southeast Asia. The ostracod faunas, including Palaeocopida, Podocopida & Myodocopida, are dominated by typical Paleozoic species accompanying with several Mesozoic forms (e.g. *Abrobairdia*, *Lobobairdia*) and thus appeared as mixed faunas.

2. Paleobathymetric evaluation

The studied faunas mix neritic and paleopsychrospheric species. The discussion on the term "paleopsychrospheric" is reviewed. This proposition of Kozur (1991b) to replace "Thüringian" by "paleopsychrospheric" is adopted here. The ostracods with the following characters, archaic, smooth/delicately ornamented, thin-shelled and/or having one to four spines, can be considered as the paleopsychrospheric ostracods. The reasons of adopting this term are also demonstrated in the text. According to the definition, in the studied faunas, 38 species are regarded to be paleopsychrospheric. They belong to the spinose Bairdiidae, Bythocytheridae, Tricorninidae, Berounellinidae, Rectonariidae, Pachydomellidae, Healdiidae, Quasillitidae, Polycopidae[*], *Discoidella*[*] and the two undetermined podocopid species.

The paleobathymetry is generally interpreted according to the families/superfamilies with the paleoecological significance. Then the triangular model, proposed by Lethiers & Raymond (1991), is adopted for tracing the paleobathymetric variation along each studied section and between studied sections. The beds/sub-beds yielding more than 3 species and 15 individuals are considered as the valid statistic horizon. The statistics by 14 sub-beds in the Dongpan Section indicated the frequent variations of the paleobathymetry. The few/barren beds valid for statistics in the Shaiwa, Liuqiao and Chaohu Sections were insufficient to trace the paleobathymetric variations along the section. But the comparison between sections displays, among the studied faunas, the Dongpan fauna was yielded in the deepest habitats from the outer shelf to bathyal stage, the Shaiwa fauna took the second place and indicated a inner shelf to upper slope environment, then the Chaohu fauna dominated by thin-shelled and elongated bairdiids may represente the open-marine environments, and the last, the Liuqiao fauna indicated the shallowest normal marine environments by the presence of heavily shelled and strongly ornamented bairdiids and other typical neritic species.

The paleobathymetric analyses by different methods were compared. The interpretation based on ostracod was well supported by other evidences (radiolarians, sedimentology, mineralogy and geochemistry). The comparison implies the necessity of integration with other evidence when the triangular model is applied. Some local events may influence the original fauna and thus distort the meaning of the assemblage.

3. Oxygen-level reconstruction

The oxygen level is reconstructed according to the alimentation mode of the benthic ostracods. This is the first time to apply the FF% (percentage of the filter-feeders) model in the deep-water fauna composed of both the neritic and paleopsychrospheric species. The paleopsychrospheric species found here were considered as filter-feeders or deposit-feeders according to the shell morphology. The statistics are carried out for beds/sub-beds with more than 2 species and 10 individuals. The general oxic conditions can be inferred from the present statistics. In the Dongpan Section, 19 bed/sub-beds were analysed the proportion of filter-feeders. The bed 03DP4, yielding 62.5% filter-feeders, was the unique dysoxic horizon according to the relationship between FF% and oxygen level proposed by Lethiers & Whatley (1994). This interpretation appeared accordant with the results by trace elements and foraminifera. Thus the application of FF% model is reliable. But it should be mentioned that the oxygen level reconstruction in deep water environments seems still very difficult, because not all

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[*] The myodocopids found here are usually present with the paleopsychrospheric species, but their own paleobathymetric significance is ambiguous.

evidence from different methods support the same horizons. More work is needed in oxygen level reconstructing.

4. Proposed deep water ostracod "extinction" horizons

Some hotspots related to the extinction event were evolved in this work. As the contemporary shallow water ostracod faunas, the "mixed" phenomenon was also reflected by the latest Permian deep water ostracod faunas, which were dominated by typical Paleozoic species accompanying with Mesozoic forms. But the deep water faunas differed from their shallow contemporary by including the long-ranging paleopsychrospheric species, reported from the Late Devonian-Early Carboniferous strata. The difference in composition may result in various "extinction" process. The change of diversity and abundance in studied sections did not show continuous decline upwards along the studied interval. But below the Permian-Triassic boundary, the diversity and abundance showed sudden decline because no ostracod was found from the topmost of Upper Permian and lowermost Triassic. The discussion on miniaturization was also carried out. In the studied faunas, the change in individual size was not observed along the section. The comparison of the 19 common species between the studied faunas and previous occurrences also did not display the miniaturization. Some individuals found in this study were larger than their ancestors. Thus no general miniaturization occurred in the latest Permian deep water ostracods. The smaller individuals than the ancient ones are considered as the instars (detailed discussion see 5.2.1).

The concrete discussion on ostracod "extinction" was involved in the Dongpan and Liuqiao joint section. According to the specific and generic distribution, two apparent extinction horizons were proposed for the Dongpan and Liuqiao faunas. The First/Major apparent extinction horizon was located at the top of 03DP5 to the bottom of 03DP6. Above this horizon only 6 species survived. The Second apparent extinction horizon was in 03DP10, above which all ostracod taxa disappeared in the Dongpan Section. The First apparent extinction horizon is corresponding to the first crisis of radiolarians, the regression, the strong volcanic activities and possible anoxia/dysoxia. And the TOC curve showed the largest excursion in this horizon. All studies highlighted this "event horizon".

5. Diachronism of extinction along with paleoenvironment and paleogeography

The comparison of the "extinction" horizon, between the Dongpan and Meishan Sections, indicated that the "extinction" took place earlier in the Dongpan section (Major extinction horizon of the Meishan Section following Jin *et al.* (2000); stratigraphical correlation between the Dongpan and Meishan Sections according to Feng *et al.* (2007) and Zhang *et al.* (2007a, b)). The Chaohu fauna, yielded in the deep water environments (although shallower than the Dongpan Section), declined rapidly in diversity and abundance at the corresponding horizon of the Meishan Major extinction. Then it can be inferred not only the paleoenvironment but also the paleogeography played an important role in the "extinction" process of the ostracod faunas.

The delay of "extinction" in the Meishan Section may indicate that the deep water area was earlier affected by the catastrophic events, such as the anoxia. The reason resulting in the similarities and differences by the paleogeography is still pendent. However, without doubt, the variety of "extinction" between the different paleoenvironments and paleogeographical localities, indicates the necessity of the research on deep water ostracods, comparing the shallow water contemporaries with relatively abundant data (although systematic collation and revision are necessary).

§ 6.2 Perspectives

This work has opened up the study and acquired the primary understanding on Late Permian deep water ostracod faunas in South China. However, more additional work is needed for comprehensively cognizing the Late Permian deep water ostracods and further draw a general conclusion on Late Permian ostracods from different paleoenvironments and regions. Reflecting upon this study, the following perspectives could be carried out in the future work.

1. Systematic collation and revision for previous data

In this work, all the comparisons of the species between this dissertation and previous studies are built on the assumption that the identification in previous studies are correct. In fact, during the identification, there are sorts of subjective and objective factors. The assignation of some specimens, especially some in very poor preservation, is in disagreement, which greatly distorts the objectivity of the comparison. Thus the systematic collation and revision is imperative.

In addition, the precise stratigraphical correlations are another difficulty in the present work. Take the Meishan Section for example, the ostracod study in Shi & Chen (1987) was sampled according to the stratigraphical division by Zhao *et al.* (1981) which is different from the accepted system at present. Thus it seems difficult to confirm the ostracod occurrences and further influences the comparison between the faunas. Consequently, the stratigraphical correlation of previous sections should be scheduled in the ostracod studies. It is also suggested that the future ostracod studies had better be carried out along with the stratigraphical studies.

2. Extend the studies in stratigraphical interval, different paleoenvironments and paleogeographical localities

As mentioned in the preface, there are two main problems restricting the Late Permian ostracod study. This dissertation has been attempted in the first problem, i.e. the study on deep water ostracod faunas. The second problem is the studied interval. In the previous studies, the too short studied interval made it difficult to trace the ostracod extinction and recovery in the Permian-Triassic events. Crasquin-Soleau *et al.* (2007) proposed the extinction and recovery process of shallow water ostracods. It seems the ostracods have begun the extinction from the Wuchiapingian and the recovery continued until the early Anisian. But this proposition was based on synthesizing the data scattered in different regions and geological times. The systematic ostracod study is necessary in the sections with complete interval spanning from the Wuchiapingian to the Anisian.

This dissertation highlights the differences of ostracod faunas between different paleoenvironments and paleogeographical localities. But the present data are still far from the comprehensive understanding. For example, in this study, the studied sections were located in the Yunnan-Guizhou-Guangxi basin and Lower Yangtze basin, between which the Middle Yangtze regions were not investigated. The "lack" of data in paleogeography makes it insufficient to summarize the whole characters of Late Permian ostracod faunas.

3. Seek more extracting methods

The samples in this study are commonly siliceous and muddy. No ostracod was obtained from the mudstones although some methods were attempted. The effective method needs seeking in the future work.

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Appendices

Appendix 1: Index of figures and tables

Remarks: There are 36 figures and 24 tables in this thesis. All figures cited or modified from other literatures have been indicated the derivation. Figures without illustration are from our own research.

Fig. 2-1-2-B: transverse section and marginal structure of ostracod carapace (modified from Scott, 1961; Harding, 1965; Pokorny, 1978)

Fig. 2-1-3-A: measurements of a *Bairdia* carapace.

Fig. 2-1-3-B: morphological features of the lateral surface ((a) *Bairdia* sp.4 *sensu* Yuan & Crasquin-Soleau from Dongpan section, right lateral view of valve; (b) Kellettinidae indet. from Liuqiao section, in right lateral view of valve).
Nomenclature referred to Scott (1961). MA: mid-anterior; MP: mid-posterior; M: median; MD: mid-dorsal; AD: anterodorsal; PD: posterodorsal; MV: mid-ventral; AV: anteroventral; PV: posteroventral; AM: anteromedian; PM: posteromedian; DM: dorsomedian; VM: ventromedian.

Fig. 2-1-3-C: examples of carapace overlap ((a) *Bairdia dongpanensis* Yuan & Crasquin-Soleau, 2007 from Dongpan section, LV>RV, right lateral view of carapace; (b) *Cyathus ceparata* (Guan 1978) from Tieqiao section. RV>LV, left lateral view of carapace; (c) from Tieqiao section. LV>RV, dorsal view of carapace; (d) *Fabalicypris* cf. *minuta* Cooper, 1946 *sensu* Yuan *et al.* (2007), LV>RV, ventral view of carapace). Scale bar is 100µm.

Fig. 2-1-3-D: sketch of preplete (a), amplete (b) and postplete (c) carapace.

Fig. 2-1-3-E: cardinal angles of *Permoyoungiella* ?sp.1 *sensu* Yuan *et al.* (2007), right lateral view of valve. Scale bas is 100µm.

Fig. 2-1-3-F: sketch showing common ornamentation for ostracod shell. (modified after Scott, 1961)

Fig. 2-1-3-G: some examples of ornamentations. All specimens from this work ((a) *Aurikirkbya* cf. *ultima* (Kozur, 1985), right lateral view of valve; (b) *Permokegelites* cf. *beichuanensis* Becker & Wang, 1992 *sensu* Yuan & Crasquin-Soleau 2007 , right lateral view of valve; (c) left lateral view of carapace; (d) right lateral view of carapace; (e) *Paraberounella* ?cf. *laterospina* Kozur, 1991 *sensu* Yuan *et al.* 2007, left lateral view of valve; (f) *Spinomicrocheilinella anterocompressa* Yuan & Crasquin-Soleau, 2007, right lateral view of carapace; (g) *Petasobairdia bicornuta* Chen, 1982, left lateral view of valve; (h) *Macronotella* ? sp.1 *sensu* Yuan *et al.* 2007, left lateral view of carapace; (i) ?*Libumella athabascensis* Green, 1963 *sensu* Yuan *et al*. 2007, right lateral view of valve; (j) *Denticupachydomella spinosa* n.gen.n.sp., left lateral view of valve; (k) *Hollinella* sp., right lateral view of valve; (l) *Monoceratina* sp.1 *sensu* Yuan *et al*. 2007, right lateral view of valve. Scale bas is 100µm.

Fig. 2-1-3-H: sketch of lobes and sulci for palaeocopids.

Fig. 2-1-4-A: measurements for ostracod with different outlines. The red dashed indicates the hinge line.

Fig. 2-1-4-B: comparison of measurements Lb and Lh.
Lb: maximum length parallel to hinge line; Lh: maximum length parallel to basal line; Ha: vertical distance between anterior extremity and basal line; Lp: vertical distance between posterior extremity and basal line; angle h&b: the angle between hinge line and basal line.

Fig. 2-2 shows the complete procedures of hot-acetolysis.
A: sample crushing; B: sample dehydration in heater; C: sample acidization; D: acid recycling and residua rinsing with a battery of three sieves; E: residua dehydration; F: hand picking and sorting under a binocular stereoscope; G: stubs prepared for scanning.

Fig. 3-1-A Ostracod distribution in the Dongpan Section.

Fig. 3-1-B Ostracod distribution in the Liuqiao Section.

Fig. 3-1-C Ostracod distribution in the Shaiwa Section.

Fig. 3-1-D Ostracod distribution in the Chaohu Section.

Fig.4-1 Sketch map showing the marine zonation (after Yin *et al.*, 1995, Fig.1-4).

Fig.4-2-A Diagram showing the triangular model proposed by Lethiers & Raymond (1991) (after Lethiers & Raymond, 1991).

Fig.4-2-B Proportions of paleopsychrospheric, bairdiid and other neritic species by sub-bed (14 valid horizons according to the statistics standard of triangular model) along the Dongpan Section.

Fig.4-2-C Projecting based on the Dongpan ostracod compositions by sub-bed (14 valid horizons according to the statistics standard of triangular model) in the triangular diagram.

Fig.4-2-D Projecting according to the Shaiwa (2 valid horizons) and Liuqiao (3 valid horizons) ostracod composition in the triangular diagram.

Fig.4-3-A Comparison of oxygen-level reconstruction based on different methods (grey zones indicate the interval of oxygen deficiency; curves of V/Cr and Ce modified from He *et al.,* 2007; foraminifer and trace fossils data from group work).

Fig.4-3-B The percentage of filter-feeding ostracod species and approximately calculated oxygen levels in relationship to paleoenvironments and individual abundance proposed by Lethiers & Whatley (1994).

Fig.4-3-C Diagram showing changes in the percentage of filter-feeders in the Dongpan Section (19 valid sub-beds) (the data of oxygen level according to Lethiers & Whatley, 1994).

Fig.4-3-D Comparison of oxygen-level reconstruction interpreted by ostracods and other analyses (grey zones indicate the interval of oxygen deficiency; the data of oxygen level in the column of ostracod according to Lethiers & Whatley, 1994).

Fig.5-2-A Stratigraphical distribution of ostracod genera in the Dongpan and Liuqiao Sections (the black dasheds mark the three special horizons, i.e. LQ16, top of 03DP5-bottom of 03DP6 and 03DP10 from the bottom up; the red dasheds indicate the genera which have been reported from the Triassic strata in previous studies).

Fig.5-2-B Stratigraphical distribution of ostracod species in the Dongpan and Liuqiao Sections (the black dasheds marks the two apparent extinction horizons proposed in this work; the red dasheds indicate the species compared to the Triassic elements).

Fig.5-2-C Comparison of the extinction horizon between the Dongpan, Meishan and Chaohu Sections.

Tab.1-1 Geographic location and studied strata of the other investigated sections in this work

Tab. 2-1-3-A Some common ornamentations of ostracods

Tab. 2-1-4-A Common criteria for distinguishing the anterior and posterior of ostracods

Tab. 2-1-4-B Common criteria for distinguishing the dorsal and ventral of ostracods

Tab. 2-1-5-A Milestones of ostradological development in the early times (before 1961)

Tab. 2-1-5-B Classification adopted in this work (mainly modified after Moore, 1961)

Tab. 2-1-5-C Common criteria for ostracod identification in different levels

Tab. 2-2-A Date sheet used during ostracod picking

Tab. 2-2-B Data sheet used during ostracod scanning

Appendix 2: Alphabetic index of identified species in this dissertation

Appendix 3: Published paper

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Latest Permian deep-water ostracods from southwestern Guangxi, South China

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ABSTRACT – A very diverse ostracod fauna was discovered in the latest Permian strata of the Dongpan section, southwestern Guangxi, South China. Fifty-one species belonging to twenty-eight genera were identified and described, including two new species (*Bairdia dongpanensis* n. sp. and *Spinomicrocheilinella anterocompressa* n. sp). This type of assemblage, with nineteen palaeopsychrospheric species and four pelagic species, is the first world-wide deep-water ostracod fauna reported from the latest Permian strata and the first one recorded in the Permian of China. The palaeoenvironmental analysis allows one to propose an evaluation of the bathymetry variation along the Dongpan section. *J. Micropalaeontol.* **26**(2): 169–191, October 2007.

KEYWORDS: *Ostracods, Late Permian, deep water, Guangxi, South China*

INTRODUCTION

Knowledge of Late Permian shallow-water ostracods of South China is increasing following the studies of Wang (1978), Chen & Shi (1982), Shi & Chen (1987, 2002), Yi (1992, 1993, 2004), Hao (1992, 1993, 1994) and Crasquin-Soleau & Kershaw (2005). Comprehensive information on taxonomy, biostratigraphy and palaeoenvironment has been proposed. Permian non-marine ostracods are unknown in South China; however, Guan (1985), Yang (2001) and Pang & Jin (2003) reported some forms in North China. No ostracod assemblages were reported from the Late Permian deep-water strata in China. The only world-wide data available on Permian deep-water ostracods are works by Gründel & Kozur (1975) and Bless (1987) in Timor (Indonesia) and Kozur (1991a, b) and Crasquin-Soleau *et al.* (in press) in Sicily (Italy).

A diverse ostracod fauna was discovered in the latest Permian strata of the Dongpan Section, southwestern Guangxi, South China. A multidisciplinary research project was initiated on this section in 2002. A well-preserved and abundant fauna, including radiolarians, foraminifera, bivalves, ammonoids, brachiopods and skeletal porifera, was recovered and has been studied by the research group (Feng *et al.*, 2004, 2006a, b, in press; He *et al.*, 2005; Jin *et al.*, 2007). All ostracods studied here come from residues used for radiolarian extraction. This is the first deep-water ostracod fauna reported from the Carboniferous-Permian strata in China. This paper presents the ostracod fauna and discusses its palaeoenvironmental setting and palaeobiogeographical relationships.

GEOGRAPHICAL AND GEOLOGICAL SETTING

The Dongpan Section (22°16.196′ N, 107°41.505′ E) is located approximately 5 km southwest of Dongpan Village, Liuqiao Town, Fusui County, southwestern Guangxi, South China (Fig. 1).

During the Late Permian, the studied area was situated in the southeastern part of the Damingshan Platform under open-marine conditions comprising platform and rift basin deposits. The Dongpan Section displays a continuous Upper Permian (Dalong Formation) to Lower Triassic (Luolou Formation) sedimentary sequence (Fig. 2) (BGMRGZAR, 2001). The Dalong Formation, as exposed, is 11.2 m thick and subdivided into 12 beds. The age of this formation, determined by the associated radiolarians (*Neoalbaillella optima* Zone in Beds 2–6 (Yao *et al.*, 2001)) and ammonoids (*Huananoceras* cf. *perornatum* Chao & Liang, *Laibinoceras* cf. *compressum* Yang (Yang *et al.*, 1987), *Qianjiangoceras* sp. at the top of the Bed 12), is Late Changhsingian (Feng *et al.*, 2004, 2006a, b; He *et al.*, 2005; Jin *et al.*, 2007). The Triassic Luolou Formation conformably overlies the Dalong Formation and is represented by interbedded mudstones and thin claystones. An Early Triassic age was provided by the Triassic ammonoids *Ophiceras* sp., *Ophiceras tingi* Tien and the bivalve *Claraia dieneri* Nakazawa from the base of the Bed 13 (He *et al.*, 2005).

METHODOLOGY

Sixty-seven samples were collected for radiolarians from Bed 2 to Bed 10 of the Dalong Formation. Fifty samples were located in mudstones, siliceous mudstones, muddy siliceous rocks and bedded siliceous rocks and yielded ostracods. Consequently, the ostracods were retrieved after dilute hydrofluoric acid (HF) (2% to 5%) processing, which is a special method for extracting radiolarians from cherts (Pessagno & Newport, 1972). After 12 hours of desegregation, the deposits in the solution were transferred into another container filled with water to reduce acidity. Every 12 hours, the process was repeated until enough deposit was collected and the liquid reached neutral values (a period of two weeks generally). Thereafter, the residues were washed through a 0.054 mm sieve and dried. Some 1664 specimens were obtained and 360 specimens were photographed using a scanning electronic microscope (SEM). The ostracods recovered were silicified, consequently some specimens which were preserved in original calcite were destroyed during processing, but it is impossible to consider another extraction method due to the mixed composition of the sediments (Crasquin-Soleau *et al.*, 2005).

SYSTEMATIC DESCRIPTIONS

Fifty-one species, including two new ones, belonging to twenty-eight genera were recognized (Fig. 2). In addition, many

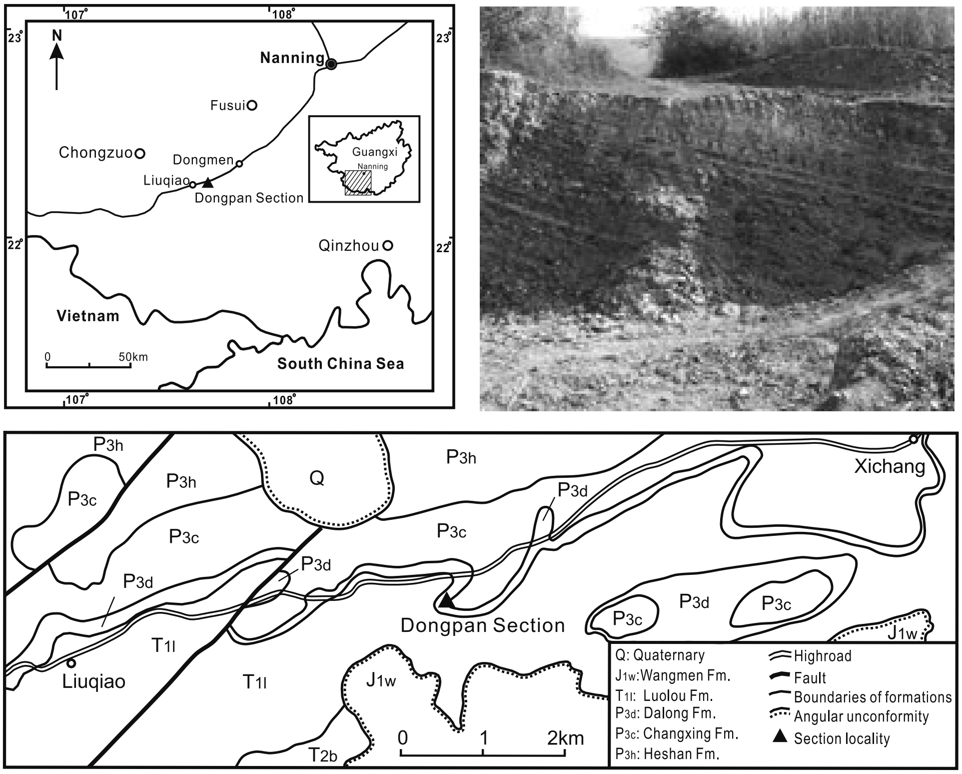

Fig. 1. Geographical and geological setting of Dongpan Section (after Feng *et al*., 2006*a*).

specimens could not be identified due to the poor preservation of the silicified material. The taxonomic classification of Moore (1961) was used in association with schemes proposed by Gründel (1961, 1962), Blumenstengel (1965), Gründel & Kozur (1975), Kozur (1985, 1991a), Lethiers & Feist (1991) and Becker (1999) for additional new taxa. All specimens figured in this paper are deposited in the palaeontological collections of the Museum of the China University of Geosciences (Wuhan, People's Republic of China) with numbers X0301-101 to X0301-182.

Abbreviations: LV, left valve; RV, right valve; DB, dorsal border; VB, ventral border; AB, anterior border; PB, posterior border; ADB, anterior dorsal border; PDB, posterior dorsal border; AVB, anterior ventral border; PVB, posterior ventral border; L, length; H, height; H/L, ratio of height/length; S2, median sulcus.

Order **Palaeocopida** Henningsmoen, 1953
Suborder **Beyrichicopina** Scott, 1961
Superfamily **Kirkbyoidea** Ulrich & Bassler, 1906
Family **Kirkbyidae** Ulrich & Bassler, 1906
Genus *Kirkbya* Jones, 1859

Type species. *Dithyrocaris permiana* Jones, 1850.

Kirkbya cf. sp. A *sensu* Becker & Wang, 1992
(Pl. 1, fig. 1)

1992 *Kirkbya* sp. A; Becker & Wang: 19, pl. 4, figs 5–6.

Material. One right valve.

Dimensions. L=0.32 mm, H=0.17 mm (with the shoulder), H/L=0.54.

Occurrence. Latest Permian, South China (Guangxi).

Remarks. This specimen is similar in outline and in possessing the peculiar central swelling to *Kirkbya* sp. A *sensu* Becker & Wang, 1992 from the Early Permian of Jiangsu, South China. However, our specimen has a higher central swelling and lacks an outer carina.

Kirkbya sp. 1
(Pl. 1, figs 4–6)

Material. Two left valves and one right valve.

Dimensions. L=0.39–0.58 mm, H=0.20–0.30 mm, H/L=0.51–0.52.

Occurrence. Beds 03DP3 and 03DP5, latest Permian, South China (Guangxi).

Remarks. The AB of our specimens resembles *Parvikirkbya transita raricostata* Kozur, 1985 and *Parvikirkbya laevis* Kozur,

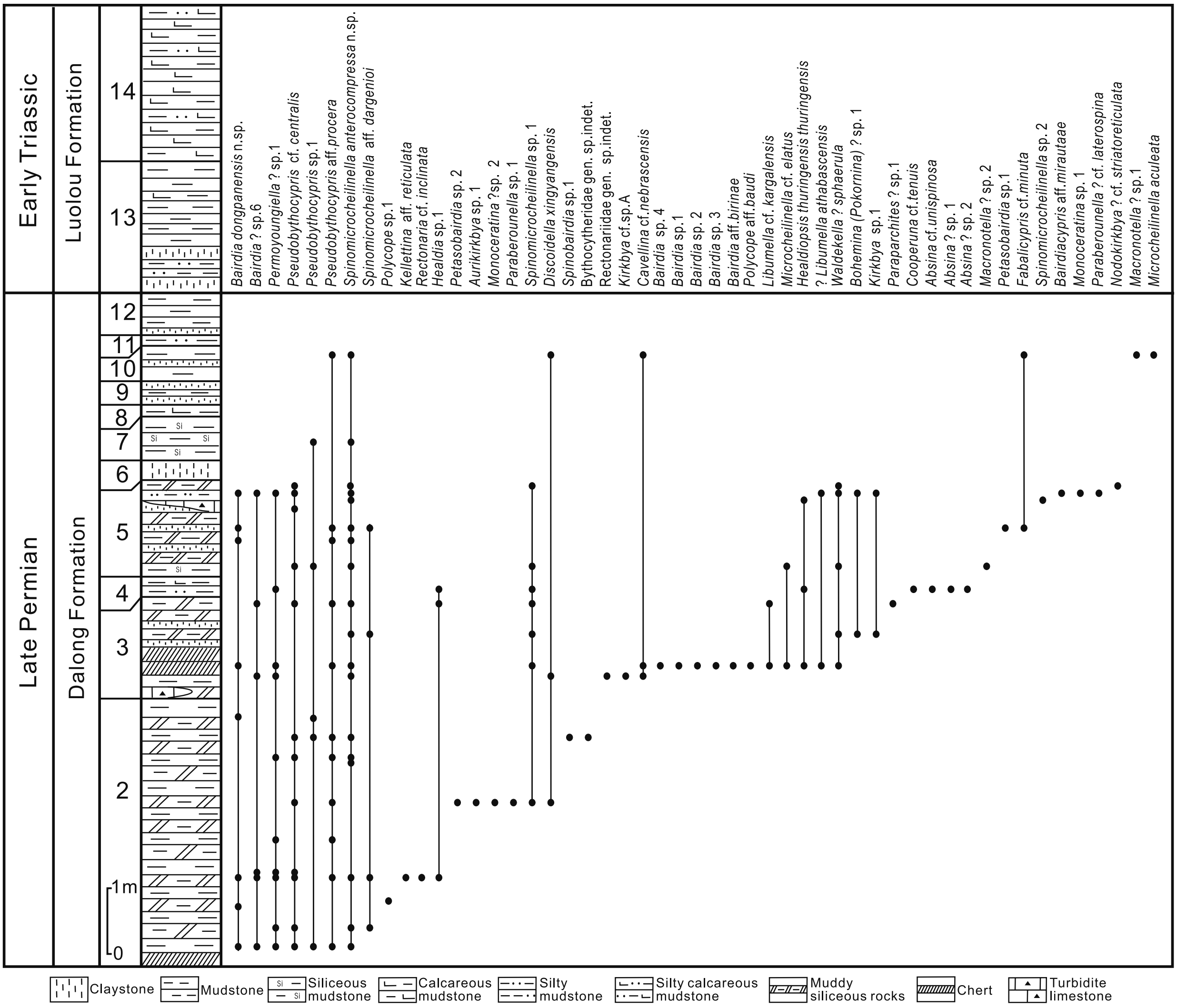

Fig. 2. Stratigraphic distribution of ostracods identified in this paper.

1985 from the Late Permian (Abadehian) of Hungary, but differs in having more distinct cardinal angles, a more rounded VB, a sub-rectangular outline and by the peculiar marginal ridges. According to the presence of a typical kirkbyan pit, they are attributed to the genus *Kirkbya*.

Genus *Aurikirkbya* Sohn, 1950

Type species. *Aurikirkbya wordensis* (Hamilton, 1942).

Aurikirkbya sp. 1
(Pl. 1, fig. 2)

Material. One damaged valve.

Occurrence. Bed 03DP2, latest Permian, South China (Guangxi).

Remarks. It is attributed to the genus *Aurikirkbya* Sohn, 1950 as it has a centrally connected lobe. The poor preservation does not allow a more precise identification.

Genus *Nodokirkbya* Kozur, 1991

Type species. *Nodokirkbya striatoreticulata* Kozur, 1991

Nodokirkbya ? cf. *striatoreticulata* Kozur, 1991
(Pl. 1, fig. 3)

1991a *Nodokirkbya striatoreticulata* Kozur: 11, pl. 1, figs 15, 19.

Material. One right valve.

Dimensions. L=0.25 mm, H=0.17 mm, H/L=0.70.

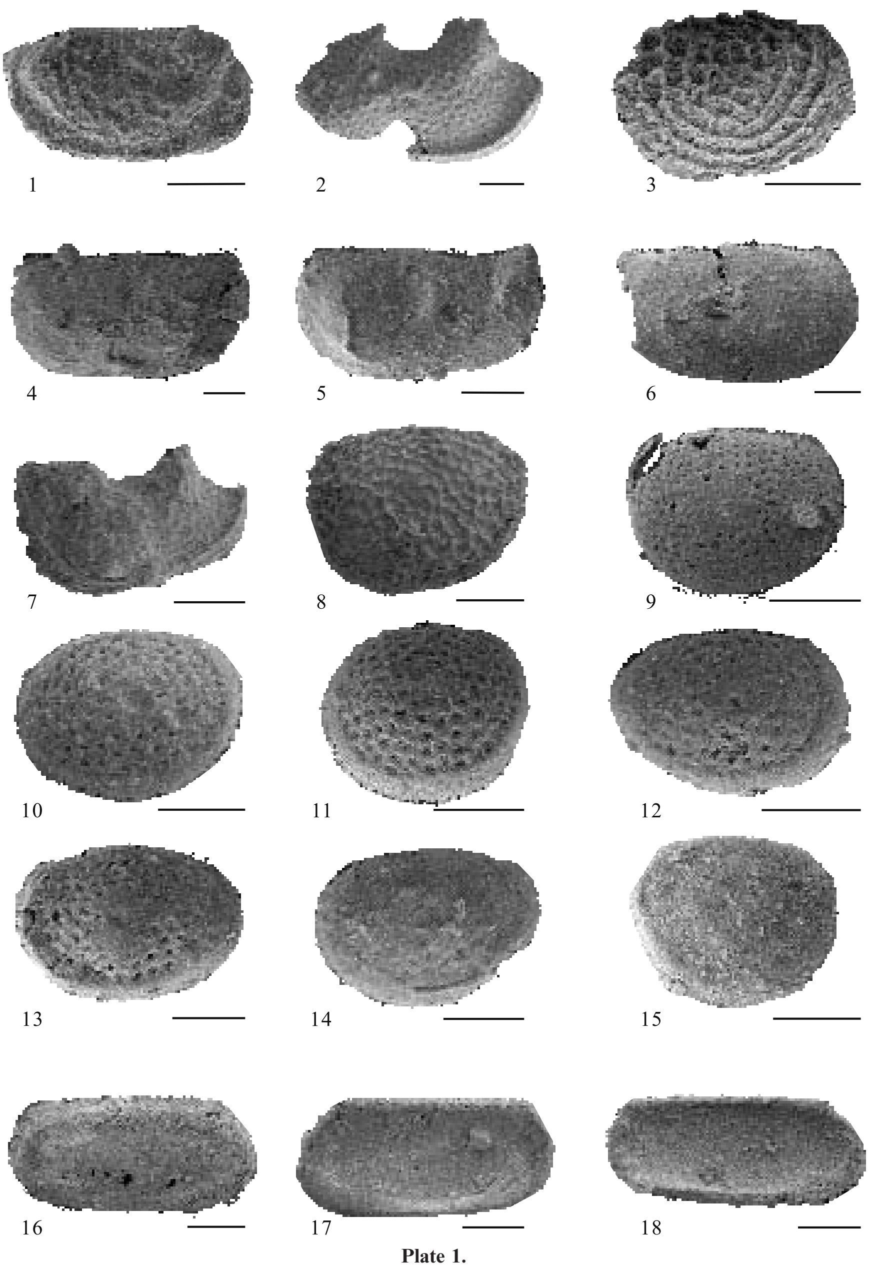

Plate 1.

Explanation of Plate 1. fig. 1. *Kirkbya* cf. sp. A *sensu* Becker & Wang, 1992: sample 03DP3-16, right view of right valve, collection number X0301-107. **fig. 2.** *Aurikirkbya* sp. 1: 03DP2-12, lateral view of incomplete valve, collection number X0301-108. **fig. 3.** *Nodokirkbya* ? cf. *striatoreticulata* Kozur, 1991: 03DP5-19, right view of right valve, collection number X0301-109. **figs 4–6.** *Kirkbya* sp. 1: **4,** 03DP3-7, left view of left valve, collection number X0301-110; **5,** 03DP5-17, left view of left valve, collection number X0301-111; **6,** 03DP5-17, right view of right valve, collection number X0301-112. **fig. 7.** *Kellettina* aff. *reticulata* Kozur, 1991: 03DP2-19, left view of left valve, collection number X0301-113. **fig. 8.** *Macronotella* ? sp. 1: 03DP10-1, left view of carapace, collection number X0301-114. **fig. 9.** *Macronotella* ? sp. 2: 03DP5-2, left view of left valve, collection number X0301-115. **figs 10–12.** ? *Libumella athabascensis* Green, 1963: **10,** 03DP5-17, left view of left valve, collection number X0301-116; **11,** 03DP3-14, left view of left valve, collection number X0301-117; **12,** 03DP5-17, right valve of right valve, collection number X0301-118. **figs 13–14.** *Libumella* cf. *kargalensis* Rozhdestvenskaya, 1959: **13,** 03DP3-14, left view of left valve, collection number X0301-119; **14,** 03DP3-1, right view of right valve, collection number X0301-120. **fig. 15.** *Paraparchites* sp. 1: 03DP3-1, right view of right valve, collection number X0301-121. **figs 16–18.** *Permoyoungiella* ? sp. 1: **16,** 03DP4, right view of right valve, collection number X0301-122; **17,** 03DP2-16, inner view of right valve, collection number X0301-123; **18,** 03DP2-23, inner view of left valve, collection number X0301-124. Scale bar is 100 μm.

Occurrence. Bed 03DP5, latest Permian, South China (Guangxi).

Remarks. The peculiar ornamentation is very similar to *Nodokirkbya striatoreticulata* Kozur, 1991a from Late Permian deep-water sediments of Western Sicily. However, our specimen lacks the generic characteristic of *Nodokirkbya* (posterodorsal conical node). Poor preservation, excluding the ornamentation, does not provide enough generic and specific characteristics for identification. Therefore, it is assigned tentatively to *N.*? *striatoreticulata* due to similar ornamentation.

Family **Kellettinidae** Sohn, 1954
Genus *Kellettina* Swartz, 1936

Type species. *Ulrichia robusta* Kellett, 1933.

Kellettina aff. *reticulata* Kozur, 1991a
(Pl. 1, fig. 7)

1991a *Kellettina reticulata* Kozur: 12, pl. 1, fig. 14.

Material. One incomplete left valve (?).

Dimensions. L=0.33 mm (?).

Occurrence. Bed 03DP2, latest Permian, South China (Guangxi).

Remarks. Due to poor preservation, it is difficult to orientate the valve. The two large subdorsal nodes and the whole-length reticulation suggest that this specimen strongly resembles *Kellettina reticulata* Kozur, 1991a. However, our specimen differs from *K. reticulata* by the presence of a distinct adventral ridge.

Superfamily **Oepikelloidea** Jaanusson, 1957
Family **Aparchitidae** Jones, 1901
Genus *Macronotella* Ulrich, 1894

Type species. *Macronotella scofieldi* Ulrich, 1894.

Macronotella ? sp. 1
(Pl. 1, fig. 8)

Material. One carapace.

Dimensions. L=0.32 mm, H=0.25 mm, H/L=0.79.

Occurrence. Bed 03DP10, latest Permian, South China (Guangxi).

Remarks. According to the semicircular outline and smooth central spot, it is assigned to the genus *Macronotella* Ulrich, 1894; further assignation is not possible as the ventral ridge is missing and the carapace is higher.

Macronotella ? sp. 2
(Pl. 1, fig. 9)

Material. One left valve.

Dimensions. L=0.24 mm, H=0.17 mm, H/L=0.72.

Occurrence. Bed 03DP5, latest Permian, South China (Guangxi).

Remarks. Our specimen resembles *Macronotella ulrichi* Ruedemann, 1901 from the Middle Ordovician of New York by the swollen valve, the pitted surface and the smooth spot. But it is distinguished from the latter by its thin shell, straighter DB and absence of the broad depressed border. Similarly, as for *Macronotella* ? sp.1, the generic attribution is uncertain.

Genus *Libumella* Rozhdestvenskaya, 1959

Type species. *Libumella discoides* Rozhdestvenskaya, 1959.

? *Libumella athabascensis* Green, 1963
(Pl. 1, figs 10–12)

1963 *Libumella athabascensis* Green: 120, pl. 7, figs 1–9.

Material. Two left valves and one right valve.

Dimensions. L=0.22–0.26 mm, H=0.17–0.20 mm, H/L=0.75–0.87.

Occurrence. Early Mississippian?–latest Permian, Canada (Alberta) ? and South China (Guangxi)

Remarks. Our specimens are assigned tentatively to *Libumella athabascensis* Green, 1963 in having the central smooth spot, the subovate lateral view, the coarse reticulation and the marginal ridge. However, our specimens have a more evenly rounded AB and acutely rounded PB.

Libumella cf. *kargalensis* Rozhdestvenskaya, 1959
(Pl. 1, figs 13–14)

1959 *Libumella kargalensis* Rozhdestvenskaya: 135, pl. 3, figs 3a–c.

Material. One left valve and one right valve.

Dimensions. L=0.27–0.31 mm, H=0.19–0.21 mm, H/L=0.69–0.71.

Occurrence. Bed 03DP3, latest Permian, South China (Guangxi).

Remarks. The specimens resemble *Libumella kargalensis* Rozhdestvenskaya, 1959 from the Middle Devonian of Bashkiria, eastern European Russia in having an ovate outline, rounded median DB, marginal ridge, pitted lateral surface and central spot. However, our specimens are not so swollen and do not present the oval-shaped depression in the hinge line.

Superfamily **Youngielloidea** Kellett, 1933
Family **Youngiellidae** Kellett, 1933
Genus *Permoyoungiella* Kozur, 1985

Type species. *Permoyoungiella bogschi* Kozur, 1985.

Permoyoungiella ? sp. 1
(Pl. 1, figs 16–18)

Material. Twenty valves and one carapace.

Dimensions. L=0.41–0.42 mm, H=0.18–0.19 mm, H/L=0.43–0.46.

Occurrence. Beds 03DP2–03DP5, latest Permian, South China (Guangxi).

Remarks. In outline, our specimens could be attributed to the genus *Permoyoungiella* Kozur, 1985 from the Late Permian (Abadehian) of Hungary, but do not have the long ridges along anterior and anteroventral borders, which is characteristic for diagnosis of this genus.

Suborder **Kloedenellocopina** Scott, 1961
Superfamily **Paraparchitoidea** Scott, 1959
Family **Paraparchitidae** Scott, 1959
Genus *Paraparchites* Ulrich & Bassler, 1906

Type species. *Paraparchites humerosus* Ulrich & Bassler, 1906.

Paraparchites sp. 1
(Pl. 1, fig. 15)

Material. One right valve.

Dimensions. L=0.24 mm, H=0.19 mm, H/L=0.81.

Occurrence. Bed 03DP3, latest Permian, South China (Guangxi).

Remarks. This specimen resembles *Paraparchites subrotunda* (Ulrich, 1891) from the Middle Devonian of Indiana in shape. However, it lacks the flat marginal rim. Without knowing the valve overlap type, it is difficult to identify the precise species.

Order **Podocopida** Müller, 1894
Suborder **Podocopina** Sars, 1866
Superfamily **Bairdioidea** Sars, 1888
Family **Bairdiidae** Sars, 1888
Genus *Bairdia* McCoy, 1844

Type species. *Bairdia curtus* McCoy, 1844.

Bairdia aff. *birinae* Egorov, 1953
(Pl. 2, fig. 2)

1953 *Bairdia birinae* Egorov: 25, pl. 12, figs 3–4.

Material. One left valve.

Dimensions. L=0.41 mm, H=0.19 mm, H/L=0.47.

Occurrence. Bed 03DP3, latest Permian, South China (Guangxi).

Remarks. Our specimen is similar to *Bairdia birinae* Egorov, 1953 from the Frasnian (Late Devonian) of the northeastern part of European Russia with its elongate and medially bent carapace, but poor preservation of the single valve makes it impossible to see the valve overlap type.

Bairdia ? sp. 6 *sensu* Bless, 1987
(Pl. 2, figs 4–6)

1987 *Bairdia* ? sp. 6 Bless: 9, fig. 6C.
In press *Bairdia* ? sp. 6 *sensu* Bless; Crasquin-Soleau *et al.*: pl. 2, fig. 16.

Material. One left valve and five right valves.

Dimensions. LV: L=0.57 mm, H=0.23 mm, H/L=0.4; RV: L=0.31–0.54 mm, H=0.14–0.22 mm, H/L=0.34–0.46.

Occurrence. Permian, Indonesia (Timor), Italy (Sicily) and South China (Guangxi).

Bairdia dongpanensis Yuan & Crasquin-Soleau n. sp.
(Pl. 2, figs 7–12)

Derivation. The species is named after the type locality, Dongpan Section, southwestern Guangxi, South China.

Diagnosis. A species of genus *Bairdia* with the posterior border of left valve terminated by a spine and a knee-like posterodorsal margin of right valve.

Holotype. A complete carapace (Pl. 2, fig. 7) from Bed 03DP3, collection number X0301-101.

Paratypes. A complete carapace (Pl. 2, fig. 10) from Bed 03DP2, collection number X0301-102; a left valve (Pl. 2, fig. 8) from Bed 03DP3, collection number X0301-103.

Material. Six complete carapaces and nine valves.

Description. Carapace with typical bairdiid shape, surface smooth.

RV: irregularly hexagonal in lateral view; median DB straight, ADB and PDB sharply inclined, the former more gently; VB slightly concave, AVB bent outward, PVB slightly raised; AB rounded and forward, slightly flattened; PB tapered and slightly upward to form an upturned marginal rim, which is flattened and situated near ventral margin; postero-dorsal part knee-like.

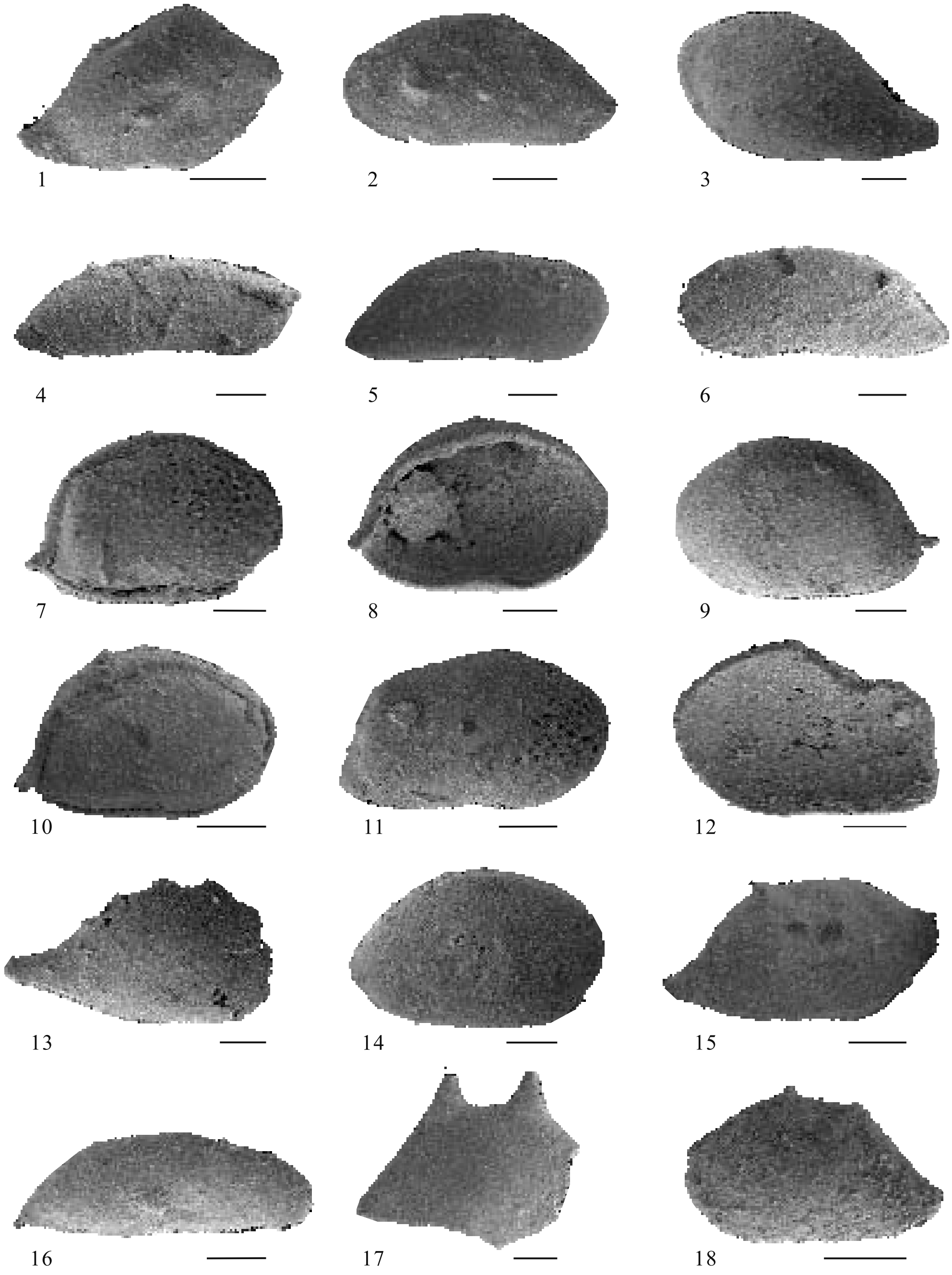

Plate 2.

Explanation of Plate 2. Fig. 1. *Bairdia* sp. 4: 03DP3-14, right view of right valve, collection number X0301-125. **fig. 2.** *Bairdia* aff. *birinae* Egorov, 1953: 03DP3-14, left view of left valve, collection number X0301-126. **fig. 3.** *Bairdia* sp. 3: 03DP3-14, left view of left valve, collection number X0301-127. **figs 4–6.** *Bairdia* ? sp. 6 *sensu* Bless, 1987: **4,** 03DP2-18, right view of right valve, collection number X0301-128; **5,** 03DP5-17, right view of right valve, collection number X0301-129; **6,** 03DP3-1, left view of left valve, collection number X0301-130. **figs 7–12.** *Bairdia dongpanensis* n. sp.: **7,** 03DP3-14, right view of carapace, holotype, collection number X0301-101; **8,** 03DP3-14, inner view of left valve, paratype, collection number X0301-103; **9,** 03DP3-14, left view of left valve; **10,** 03DP2-25, right view of carapace, paratype, collection number X0301-102; **11,** 03DP3-14, right view of right valve, collection number X0301-131; **12,** 03DP3-14, inner view of right valve, collection number X0301-132. **fig. 13.** *Bairdia* sp. 1: 03DP3-14, right view of right valve, collection number X0301-133. **fig. 14.** *Bairdia* sp. 2: 03DP3-14, right view of right valve, collection number X0301-134. **fig. 15.** *Spinobairdia* sp.1: 03DP2-4, right view of right valve, collection number X0301-135. **fig. 16.** *Cooperuna* cf. *tenuis* Kozur, 1985: 03DP4, right view of right valve, collection number X0301-136. **fig. 17.** *Petasobairdia* sp. 1: 03DP5, right view of incomplete right valve, collection number X0301-137. **fig. 18.** *Petasobairdia* sp. 2: 03DP2-12, left view of left valve, collection number X0301-138. Scale bar is 100 µm.

LV: DB gently convex, gradually extending to anterior and posterior borders; VB sub-straight; AB broadly rounded, with greatest extension above or at the mid-height; PB sharply acuminate, terminating in a spine below mid-height; maximum height median; hinge line slightly inclined posteriorly; overlapping the RV all around the carapace, maximum overlap at DB, PB and VB, slight at AB. Internal features are unknown.

Dimensions. Holotype: L=0.45 mm, H=0.33 mm, H/L=0.72; paratypes: L=0.34–0.45 mm, H=0.25–0.31 mm, H/L=0.65–0.75.

Occurrence. Beds 03DP2–03DP5, latest Permian, South China (Guangxi).

Remarks. Our specimens are very distinctive in having a posterior spine in the left valve and a knee-like postero-dorsal region and in the hexagonal outline of the right valve. *B. dongpanensis* n. sp. is similar to *Cryptobairdia submanifesta* Zhang, 1987 from the Late Carboniferous of Henan, North China (Zhang & Liang, 1987) with its posterior spine and carapace shape. Our specimens differ in the knee-like postero-dorsal part in the right valve and more raised extremity of PB. In addition, our specimens are comparable to *Cryptobairdia berniciana* Robinson, 1978 from the Early Carboniferous of England; however, our specimens differ in specific characteristics. From the view of single valves, the RVs have a strong resemblance to *Bairdia hexagona* Polenova, 1952 from the Middle Devonian of Russia, but our specimens differ in having a shorter and higher shell, a more rounded outline of the left valve and by the stronger overlap. LVs resemble *Bairdia wabashensis* Scott & Borger, 1941 from the Late Carboniferous of southeastern Illinois. Typically, our specimens are distinguished by a sub-straight VB, a lower extremity of PB and a shorter posterior spine.

Bairdia sp. 1
(Pl. 2, fig. 13)

Material. One incomplete right valve.

Occurrence. Bed 03DP3, latest Permian, South China (Guangxi).

Bairdia sp. 2
(Pl. 2, fig. 14)

Material. One right valve.

Dimensions. L=0.49 mm, H=0.30 mm, H/L=0.6.

Occurrence. Bed 03DP3, latest Permian, South China (Guangxi).

Remarks. The slightly raised posterior margin presents the characteristics of the genus *Bairdia*. It has a similar shape to *Bairdia hooverae* Kellett, 1934 from the Pennsylvanian of Kansas. *B. hooverae* is characterized by its extreme inflation and very broad and flat VB while our specimen has a lower posterior and not so characteristic ventral margin. The valve overlap type is unknown.

Bairdia sp. 3
(Pl. 2, fig. 3)

Material. Two left valves.

Dimensions. (one valve measured) L=0.60 mm, H=0.32 mm, H/L=0.55.

Occurrence. Bed 03DP3, latest Permian, South China (Guangxi).

Remarks. These specimens resemble *Bairdia* cf. *austriaca* (Kollmann, 1963) *sensu* Gründel & Kozur, 1975 from the Early Permian of Timor. Compared with the latter, our specimens have a more rounded and higher anterior extremity, longer and lower posterior extremity and more convex AVB.

Bairdia sp. 4
(Pl. 2, fig. 1)

Material. One right valve.

Description. Typically bairdiid shape in lateral view; DB straight and steeply inclined posteriorly (making an angle of about 30° with the VB), ADB slightly concave, angle between DB and ADB about 120°, PDB concave, angle between DB and PDB about 150°; VB sub-straight and slightly concave in median part, AVB outward bent and then curved to make the anterior beak, PVB slightly extending to posterior beak; AB and PB form upturned marginal rim, anterior beak blunt and having a very small curvature radius, with maximum convexity above mid-height, posterior beak acute, low and obliquely upward; maximum height about anterior third length of valve; DB swollen and forms a dorsal plane, VB and PB flattened; surface smooth.

Dimensions. L=0.35 mm, H=0.21 mm, H/L=0.62.

Occurrence. Bed 03DP3, latest Permian, South China (Guangxi).

Remarks. By the outline, our specimen may belong to the genus *Sinabairdia* Becker & Wang, 1992 from the Late Permian of Sichuan, China. However, *Sinabairdia* is characterized by its distinct, subcentrally located carapace protuberance, while our specimen has an almost uniformly swollen dorsum. The specimen has shorter and steeper ADB and longer AVB. The anterior point of DB is ahead of the anterior point of VB. The H/L here is greater than *Sinabairdia*. The only known species *Sinabairdia nodosa* Becker & Wang, 1992 has a short spine on the dorsal surface at anterior end of dorsal margin. These features make our specimen a different and perhaps a new species; however, to date, there is insufficient material (only one right valve) to establish a new species.

Genus *Petasobairdia* Chen, 1982

Type species. *Petasobairdia bicornuta* Chen, 1982.

Petasobairdia sp. 1
(Pl. 2, fig. 17)

Material. Fragment of one right valve.

Occurrence. Bed 03DP5, latest Permian, South China (Guangxi).

Remarks. *Petasobairdia bicornuta* Chen, 1982 from the Late Permian shallow-water strata of Nanjing (Chen & Shi, 1982), Zhejiang (Shi & Chen, 1987), Guizhou (Hao, 1992) and Guangxi (Shi & Chen, 2002) is closed to our specimen. Due to the incomplete preservation, it is difficult to confirm this attribution, so it is placed in the genus *Petasobairdia* based on its two peculiar dorsal horns.

Petasobairdia sp. 2
(Pl. 2, fig. 18)

Material. One left valve.

Dimensions. L=0.31 mm, H=0.18 mm, H/L=0.59.

Occurrence. Bed 03DP2, latest Permian, South China (Guangxi).

Remarks. This specimen is assigned to the genus *Petasobairdia* Chen, 1982 (Chen & Shi, 1982), according to the bairdiid outline, dorsal knobs and slightly compressed ventral margin. The high AB and small knobs make it different from any other *Petasobairdia* species.

Genus *Spinobairdia* Morris & Hill, 1952

Type species. *Spinobairdia kellettae* Morris & Hill, 1952.

Spinobairdia sp. 1
(Pl. 2, fig. 15)

Material. One right valve.

Dimensions. L=0.46 mm, H=0.23 mm, H/L=0.5.

Occurrence. Bed 03DP2, latest Permian, South China (Guangxi).

Remarks. Due to the bairdiid shape, the presence of the lateral spine and the short hinge line, the specimen is assigned to the genus *Spinobairdia*.

Genus *Bairdiacypris* Bradfield, 1935

Type species. *Bairdiacypris deloi* Bradfield, 1935.

Bairdiacypris aff. *mirautaae* Crasquin-Soleau, 1996
(Pl. 3, fig. 4)

1996 *Bairdiacypris mirautaae* Crasquin-Soleau; Crasquin-Soleau & Gradinaru: 82, pl. 4, figs 9–12.

Material. One left valve.

Dimensions. L=0.33 mm, H=0.11 mm, H/L=0.34.

Occurrence. Bed 03DP5, latest Permian, South China (Guangxi).

Remarks. This specimen strongly resembles *Bairdiacypris mirautaae* Crasquin-Soleau, 1996 from the Early Anisian (Middle Triassic) of Romania (Crasquin-Soleau & Gradinaru, 1996) but it has a more inclined and straighter ADB.

Genus *Fabalicypris* Cooper, 1946

Type species. *Fabalicypris wileyensis* Cooper, 1946.

Fabalicypris cf. *minuta* Cooper, 1946
(Pl. 3, figs 1–3)

1946 *Fabalicypris minuta* Cooper: 60, pl. 5, figs 31–32.

Material. Seventeen complete carapaces and one left valve.

Dimensions. L=0.42–0.51 mm, H=0.19–0.23 mm, H/L=0.45–0.49, W/L=2.7.

Occurrence. Beds 03DP5 and 03DP10, latest Permian, South China (Guangxi).

Remarks. Our specimens differ from *Fabalicypris minuta* Cooper, 1946 from the Early Carboniferous of Illinois in having a smaller carapace, a more rounded PB and narrower AB.

Family **Acratiidae** Gründel, 1962
Subfamily **Acratiinae** Gründel, 1962
Genus *Cooperuna* Gründel, 1962

Type species. *Acratia* (*Cooperuna*) *cooperi* Gründel, 1962.

Cooperuna cf. *tenuis* Kozur, 1985
(Pl. 2, fig. 16)

1985 *Cooperuna tenuis* Kozur: 108, pl. 20, fig. 7.

Material. One right valve.

Dimensions. L=0.50 mm, H=0.18 mm, H/L=0.36.

Occurrence. Bed 03DP4, latest Permian, South China (Guangxi).

Remarks. Due to bad preservation, the AB does not display the anterior beak of *C. tenuis*.

Superfamily **Cytheroidea** Baird, 1850
Family **Bythocytheridae** Sars, 1926

Bythocytheridae gen. et sp. indet.
(Pl. 3, fig. 6)

Material. One right valve.

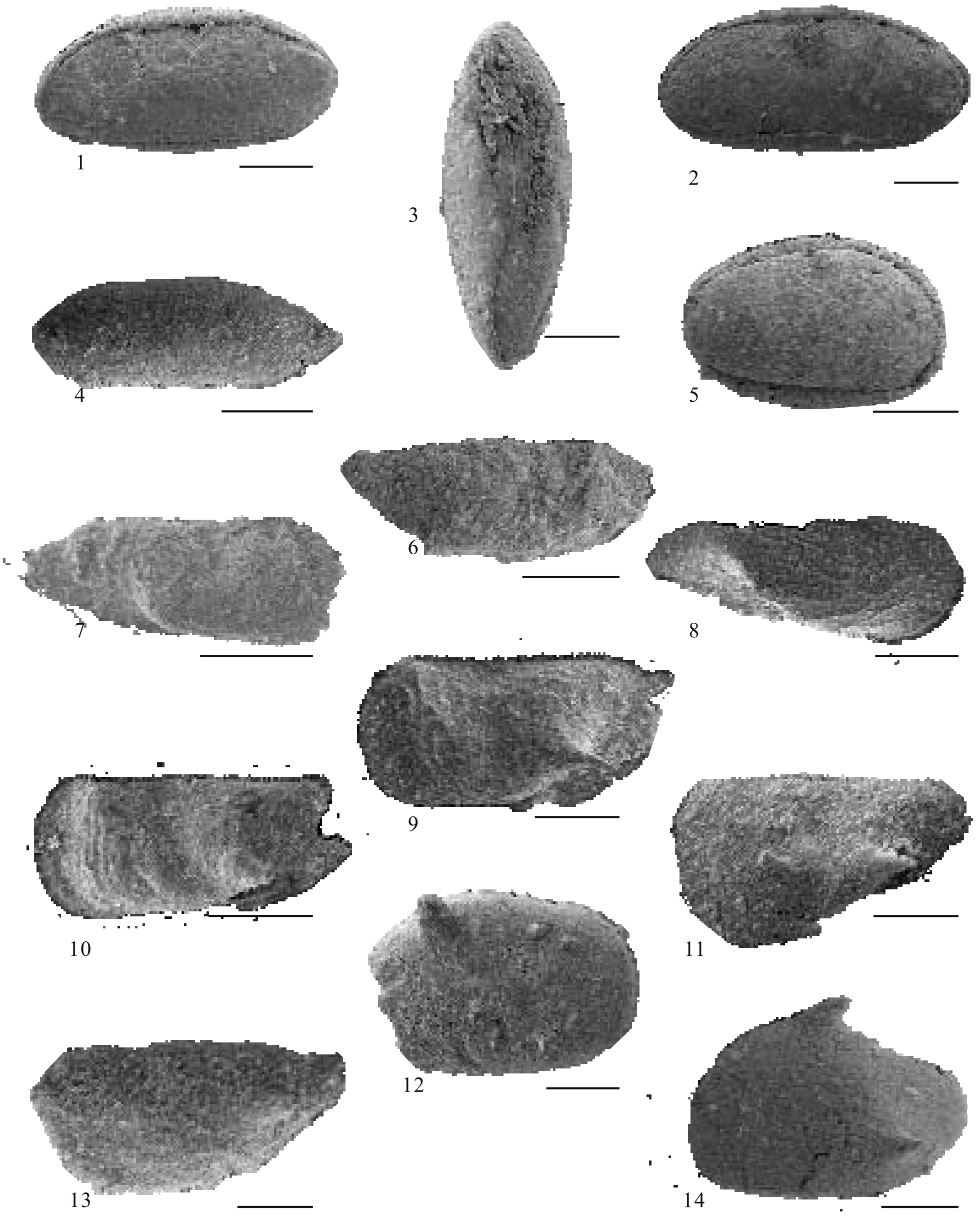

Plate 3.

Explanation of Plate 3. figs 1–3. *Fabalicypris* cf. *minuta* Cooper, 1946, 03DP10-1: **1, 2,** right views of carapaces, collection number X0301-139 and 140; **3,** ventral view of carapace, collection number X0301-141. **fig. 4.** *Bairdiacypris* aff. *mirautaae* Crasquin-Soleau, 1996: 03DP5-17, left view of left valve, collection number X0301-142. **fig. 5.** *Microcheilinella* cf. *elatus* (Lethiers, 1978) *sensu* Lethiers, 1981: 03DP3-14, right view of carapace, collection number X0301-143. **fig. 6.** Bythocytheridae gen. et sp. indet.: 03DP2-4, right view of incomplete right valve, collection number X0301-144. **fig. 7.** *Monoceratina* ? sp. 2: 03DP2-12, right view of right valve, collection number X0301-145. **fig. 8.** *Monoceratina* sp. 1: 03DP5-17, right view of right valve, collection number X0301-146. **figs 9–10.** *Paraberounella* ? cf. *laterospina* Kozur, 1991: **9,** 03DP5-17, left view of left valve, collection number X0301-147; **10,** 03DP5, left view of left valve, collection number X0301-148. **fig. 11.** *Bohemina* (*Pokornina*) ? sp. 1 *sensu* Gründel & Kozur, 1975: 03DP5-17, left view of left valve, collection number X0301-149. **fig. 12.** Rectonariidae gen. et sp. indet.: 03DP3-16, right view of right valve, collection number X0301-150. **fig. 13.** *Paraberounella* sp. 1: 03DP2-12, left view of left valve, collection number X0301-151. **fig. 14.** *Rectonaria* cf. *inclinata* Gründel, 1961: 03DP2-19, left view of left valve, collection number X0301-152. Scale bar is 100 μm, except figs 11 and 13, where it is 50 μm.

Dimensions. L=0.29 mm, H=0.12 μm, H/L=0.40.

Occurrence. Bed 03DP2, latest Permian, South China (Guangxi).

Remarks. According to the presence of both caudal process and S2, this specimen is assigned to the family Bythocytheridae Sars, 1926 (*in* Moore, 1961), but poor preservation precludes the identification of the genus and species.

Genus *Monoceratina* Roth, 1928

Type species. *Monoceratina ventrale* Roth, 1928.

Monoceratina sp. 1
(Pl. 3, fig. 8)

Material. One incomplete right valve.

Dimensions. L=0.37 mm, H=0.14 mm, H/L=0.39.

Occurrence. Bed 03DP5, latest Permian, South China (Guangxi).

Remarks. Based on the adventral horn-like spine, this specimen is assigned to the genus *Monoceratina* Roth, 1928.

Monoceratina ? sp. 2
(Pl. 3, fig. 7)

Material. One right valve.

Dimensions. L=0.31 mm, H=0.12 mm, H/L=0.38.

Occurrence. Bed 03DP2, latest Permian, South China (Guangxi).

Remarks. This specimen is assigned to *Monoceratina* Roth, 1928 with doubt (hinge type unknown) based on the prolonged caudal process, short S2 and the adventral spine.

Family **Tricornidae** Blumenstengel, 1965
Genus *Bohemina* Snajdr, 1951

Bohemina (*Pokornina*) ? sp. 1 *sensu* Gründel & Kozur, 1975
(Pl. 3, fig. 11)

1975 *Bohemina* (*Pokornina*) ? sp. 1 Gründel & Kozur: 41, pl. 1, fig. 10.

Material. One right valve and one left valve.

Dimensions. L=0.18–0.21 mm, H=0.10–0.13 mm, H/L/=0.56–0.62.

Occurrence. Early to latest Permian, Indonesia (Timor) and beds 03DP3 and 03DP5, South China (Guangxi).

Remarks. Due to the triangular outline and the obliquely outward and downward spine, our specimens are assigned to *Bohemina* (*Pokornina*) ? sp. 1 *sensu* Gründel & Kozur, 1975.

Family **Berounellidae** Sohn & Berdan, 1960
Genus *Paraberounella* Blumenstengel, 1965

Type species. *Paraberounella lobella* Blumenstengel, 1965.

Paraberounella ? cf. *laterospina* Kozur, 1991a
(Pl. 3, figs 9–10)

1991a *Paraberounella* ? *laterospina* Kozur: 8, pl. 1, figs 12, 29.

In press *Paraberounella* ? *laterospina* Kozur; Crasquin-Soleau *et al.*: pl. 5, fig. 15

Material. Two left valves.

Dimensions. L=0.30(?)–0.37 mm, H=0.13–0.17 mm, H/L= 0.43(?)–0.46.

Occurrence. Bed 03DP5, latest Permian, South China (Guangxi).

Remarks. According to the position and the narrow base of the spine, our specimens are comparable to *Paraberounella* ? *laterospina* Kozur, 1991 but have a more delicate spine and ornamentation.

Paraberounella sp. 1
(Pl. 3, fig. 13)

Material. One incomplete left valve.

Dimensions. L=0.20 mm, H=0.10 mm, H/L=0.5.

Occurrence. Bed 03DP2, latest Permian, South China (Guangxi).

Remarks. The specimen is assigned to *Paraberounella* species, based on the position and narrow base of the spine.

Superfamily **Bairdiocypridoidea** Shaver, 1961
Family **Rectonariidae** Gründel, 1962

Rectonariidae gen. et sp. indet.
(Pl. 3, fig. 12)

Material. One right valve.

Dimensions. L>0.30 mm, H=0.21 mm, H/L<0.71.

Occurrence. Bed 03DP3, latest Permian, South China (Guangxi).

Genus *Rectonaria* Gründel, 1961

Type species. *Rectonaria muelleri* Gründel, 1961.

Rectonaria cf. *inclinata* Gründel, 1961
(Pl. 3, fig. 14)

1961 *Rectonaria inclinata* Gründel: 115–116, pl. 9, fig. 6; pl. 10, figs 1–2.

Material. One left valve.

Dimensions. L=0.36 mm, H=0.26 mm (with the dorsal spine), H=0.24 mm (without the spine), H/L=0.72/0.66.

Occurrence. Bed 03DP2, latest Permian, South China (Guangxi).

Remarks. *Rectonaria inclinata* was first identified by Gründel (1961) from the Early Carboniferous of Thuringia (Germany). Subsequent specimens were found from Late Devonian–Early Carboniferous strata of Algeria (Becker, 1987), China (Guangxi; Wang, 1988), France (Montagne Noire; Lethiers & Feist, 1991), Germany (Thuringia; Blumenstengel, 1965, 1979, 1993; Bartzsch & Weyer, 1979, 1985, 1986; Bartzsch *et al.*, 1995), north Spain (Cantabrian Mountains; Becker, 1981), Poland (Holy Cross Mountains; Olempska, 1997) and Rhenish Massif (North Sauerland; Becker *et al.*, 1993; Becker, 1999). Compared to *Rectonaria inclinata*, our specimen has shorter spines and a more oblique anterior extremity. Furthermore, in our specimen, the dorsal spine is closer to the DB and the posteroventral spine is more anterior.

Family **Pachydomellidae** Berdan & Sohn, 1961
Genus *Microcheilinella* Geis, 1933

Type species. *Microcheilus distortus* Geis, 1932.

Microcheilinella cf. *elatus* (Lethiers, 1978) *sensu* Lethiers, 1981
(Pl. 3, fig. 5)

1981 *Newsomites* cf. *elatus* Lethiers, 1978; Lethiers: 72, pl. 14, figs 136a, c.

Material. Two carapaces.

Dimensions. L=0.27–0.31 mm, H=0.17–0.20 mm, H/L=0.64.

Occurrence. Late Devonian–latest Permian, NW Canada and South China (Guangxi).

Remarks. In our opinion, it appears doubtful to assign the specimens, including the ones in Lethiers (1981), to the genus *Newsomites*, which is distinguished by its bairdian shape, the expanded dorsum and no valve overlap along hinge line. All these characters are absent here. The specimens are attributed to *Microcheilinella*.

Microcheilinella aculeata Buschmina, 1975
(Pl. 4, fig. 16)

1975 *Microcheilinella aculeata* Buschmina: 44, pl. 2, fig. 11.
1981 *Microcheilinella aculeata* Buschmina; Olempska: 45, pl. 7, figs 2a–c.
1988 *Microcheilinella aculeata* Buschmina; Wang: 280, pl. 2, figs 20–22.
1997 *Microcheilinella aculeata* Buschmina; Olempska: 318, pl. 17, figs C–E.

Material. One carapace.

Dimensions. L=0.46 mm (with the spine), H=0.19 mm, H/L=0.41.

Occurrence. Early Carboniferous–latest Permian, Russia (Kolyma Massif), Poland (Holy Cross Mountains) and South China (Guangxi).

Remarks. This specimen is attributed to *Microcheilinella aculeata* Buschmina, 1975 from the Early Carboniferous of Russia (Buschmina, 1975), South China (Wang, 1988) and Poland (Olempska, 1981, 1997) by the elongate carapace, posterior spine and the valve overlap type.

Genus *Spinomicrocheilinella* Kozur, 1985

Type species. *Spinomicrocheilinella spinosa* Kozur, 1985.

Spinomicrocheilinella anterocompressa Yuan & Crasquin-Soleau n. sp.
(Pl. 4, figs 1–3)

Derivation. From the Latin *antero*=anterior and *compressus*=compressed.

Diagnosis. A species of genus *Spinomicrocheilinella* with a flattened anterior border and a strong, obliquely inclined backward posteroventral spine in the right valve.

Holotype. One complete carapace (Pl. 4, fig. 3) from Bed 03DP2, collection number X0301-104.

Paratypes. One right valve (Pl. 4, fig. 1) from Bed 03DP2, collection number X0301-105; one right valve (Pl. 4, fig. 2) from Bed 03DP2, collection number X0301-106.

Material. Fifty-two carapaces and fifty-four valves.

Description. Carapace elliptical in lateral view; DB evenly arched in left valve and inclined posteriorly in right valve; VB convex in left valve and sub-straight in right valve; AB rounded and forms a downwards and slightly flattened swing with the maximum convexity below mid-height; PB narrowly rounded and in right valve ended by a posteroventral, strong and obliquely inclined backward spine; LV strongly overlaps RV all around and has an offset in the AVB, maximum overlap along PVB and minimum overlap along AVB; maximum length below mid-height, maximum height about mid-length in left valve and anterior third of the length in right valve; surface smooth; internal features unknown.

Dimensions. (Length with the spine) Holotype: L=0.30 mm, H=0.15 mm, H/L=0.50; paratypes: L=0.26–0.34 mm, H=0.13–0.20 mm, H/L=0.49–0.58.

Occurrence. Beds 03DP2, 03DP3, 03DP5, 03DP7 and 03DP10, latest Permian, South China (Guangxi).

Remarks. Our specimens strongly resemble the juveniles of the shallow-water species *Spinomicrocheilinella praespinosa* Kozur, 1985 from the Abadehian (Late Permian) of Hungary in outline, but differ by a slightly compressed AB and in having a spine only in the right valve. Similarly, compared to *Spinomicrocheilinella dargenioi* Kozur, 1991a from the Late Permian deep-water sediments of Western Sicily, our specimens are distinguished by having a spine only in the right valve, with its maximum height about mid-length in the left valve and in the

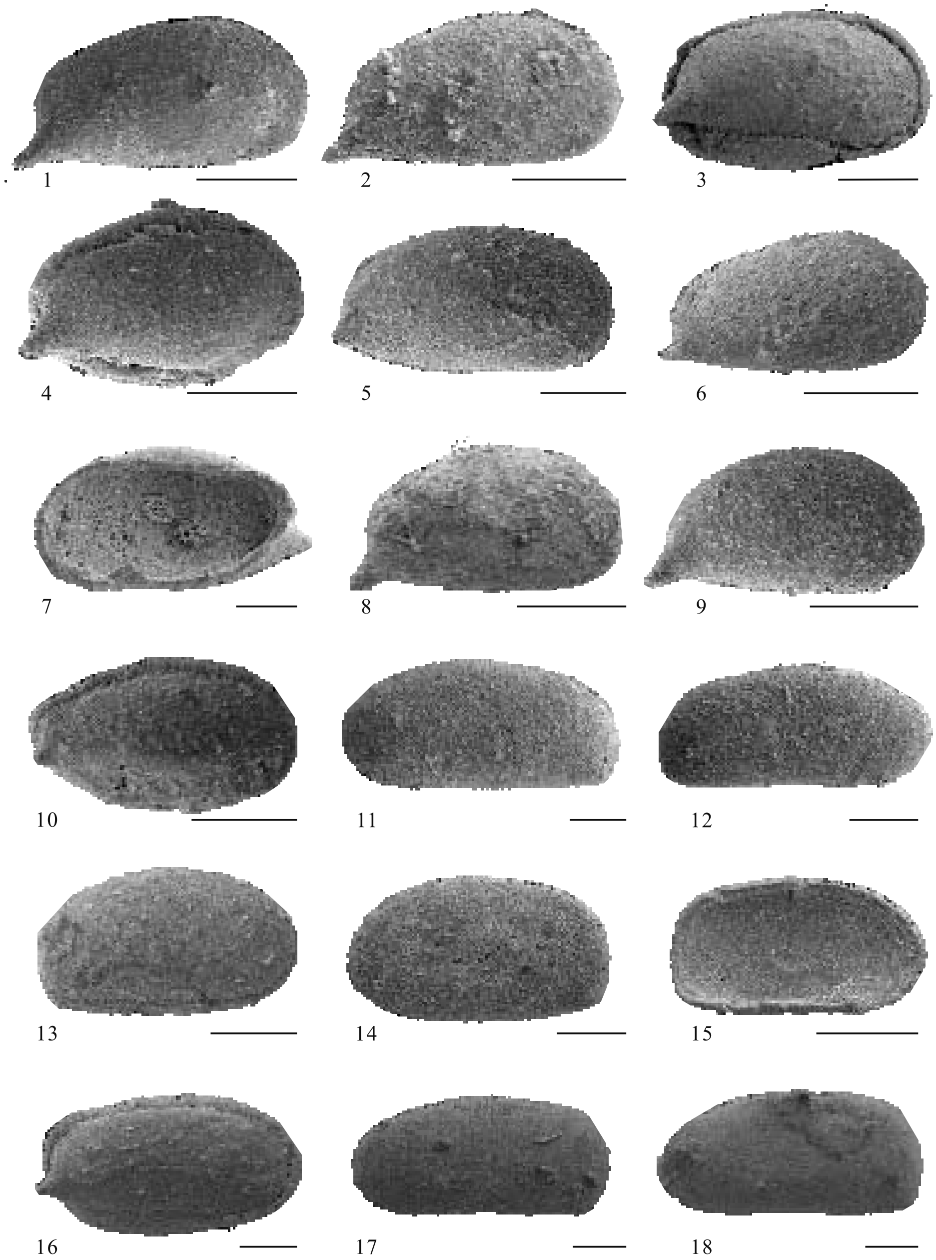

Plate 4.

Explanation of Plate 4. figs 1–3. *Spinomicrocheilinella anterocompressa* n. sp.: **1,** 03DP2-19, right view of right valve, paratype, collection number X0301-105; **2,** 03DP2-19, right view of right valve, paratype, collection number X0301-106; **3,** 03DP2-23, right view of carapace, holotype, collection number X0301-104. **figs 4–7.** *Spinomicrocheilinella* aff. *dargenioi* Kozur, 1991: **4,** 03DP3-7, right view of carapace, collection number X0301-153; **5,** 03 DP3-7, right view of right valve, collection number X0301-154; **6,** 03DP2-19, right view of right valve, collection number X0301-155; **7,** 03DP2-23, inner view of right valve, collection number X0301-156. **figs 8–9.** *Spinomicrocheilinella* sp. 1: **8,** 03DP3-7, right view of right valve, collection number X0301-157; **9,** 03DP4, right view of right valve, collection number X0301-159. **fig. 10.** *Spinomicrocheilinella* sp. 2: 03DP5-12, right view of carapace, collection number X0301-160. **figs 11–12.** *Pseudobythocypris* aff. *procera* (Coryell & Billings, 1932): **11,** 03DP3-1, left view of left valve, collection number X0301-160; **12,** 03DP3-1, right view of right valve, collection number X0301-161. **figs 13–15.** *Pseudobythocypris* cf. *centralis* (Coryell & Billings, 1932): **13,** 03DP2, right view of carapace, collection number X0301-162; **14, 15,** 03DP2-23, left and inner views of left valves, collection number respectively X0301-163 and X03101-164. **fig. 16.** *Microcheilinella aculeata* Buschmina, 1975: 03DP10-1, right view of carapace, collection number X0301-165. **figs 17–18.** *Pseudobythocypris* sp. 1: **17,** 03DP2-4, left view of left valve, collection number X0301-166; **18,** 03DP5, left view of left valve, collection number X0301-167. Scale bar is 100 μm.

anterior third of the length in the right valve, anterior downward swing and in being not so tumid. In addition, our specimens have strong similarities with *Microcheilinella postspinosa* Chen, 1958 from the Chihsia Formation of Nanjing, China. However, our specimens have a more inclined DB, a longer and obliquely backward pointing spine and its maximum length is developed below mid-height.

Spinomicrocheilinella aff. *dargenioi* Kozur, 1991
(Pl. 4, figs 4–7)

1991a *Spinomicrocheilinella dargenioi* Kozur: 5, pl. 1, figs 11, 17.

Material. Three complete carapaces and ten valves.

Dimensions. (Length with the spine) Single valves: L=0.33–0.45 mm, H=0.16–0.22 mm, H/L=0.47–0.56; juvenile valve: L=0.23 mm, H=0.12 mm, H/L=0.50; juvenile carapace: L=0.26 mm, H=0.16 mm, H/L=0.60.

Occurrence. Beds 03DP2, 03DP3 and 03DP5, latest Permian, South China (Guangxi).

Remarks. Our specimens are similar to *Spinomicrocheilinella dargenioi* Kozur, 1991 from Upper Permian deep-water sediments of Western Sicily in the outline of carapace and in having a postero-ventral spine. The specimens were assigned as the *affinis* species as nothing is known about the left valve of an adult carapace. Comparing juveniles with adult carapaces from both Kozur (1991a) and our specimens, it was found that the latter have more elongate carapaces than the former. Furthermore, the juvenile carapace has a straight and inclined posterior DB in left valve with their maximum convexity of DB developed ahead of mid-length. The adult carapace has a convex DB with the maximum convexity of DB about mid-length. The specimens are different from *Spinomicrocheilinella anterocompressa* n. sp. (see above) by their shorter and higher posteroventral spine, a more broadly rounded AB with maximum convexity about mid-length, with no flattened anterior wing and slightly convex VB.

Spinomicrocheilinella sp. 1
(Pl. 4, figs 8–9)

Material. Seven valves.

Dimensions. L=0.25–0.26 mm (length with the spine), H=0.13–0.14 mm, H/L=0.52–0.56.

Occurrence. Beds 03DP2–03DP5, latest Permian, South China (Guangxi).

Remarks. Our specimens resemble instars of *Spinomicrocheilinella dargenioi* Kozur 1991 from Upper Permian deep-water sediments of Western Sicily. However, when compared to *S. dargenioi*, our specimens have a more evenly rounded DB, lower maximum extremity of AB and longer posteroventral spine.

Spinomicrocheilinella sp. 2
(Pl. 4, fig. 10)

Material. One carapace.

Dimensions. L=0.25 mm, H=0.15 mm, H/L=0.60

Occurrence. Bed 03DP5, latest Permian, South China (Guangxi).

Remarks. This specimen is distinguished with other *Spinomicrocheilinella* species by its rather elongate carapace and an acutely rounded PB.

Family **Bairdiocyprididae** Shaver, 1961
Genus *Pseudobythocypris* Shaver, 1958

Type species. *Bythocypris pediformis* Knight, 1928.

Pseudobythocypris aff. *procera* (Coryell & Billings, 1932)
(Pl. 4, figs 11–12)

1932 *Bythocypris procera* Coryell & Billings: 174, pl. 17, fig. 12.

Material. Six valves and three carapaces.

Dimensions. L=0.31–0.50 mm, H=0.17–0.24 mm, H/L=0.46–0.55.

Occurrence. Beds 03DP2, 03DP3, 03DP5 and 03DP10, latest Permian, South China (Guangxi).

Remarks. Our specimens resemble *Bythocypris procera* Coryell & Billings, 1932 from the Pennsylvanian of Texas in having their maximum height located anterior of mid-length and a posterior height less than the maximum height. However, our specimens differ from the latter in straighter PDB.

Pseudobythocypris cf. *centralis* (Coryell & Billings, 1932)
(Pl. 4, figs 13–15)

1932 *Bythocypris centralis* Coryell & Billings: 174, pl. 17, fig. 11.

Material. Seven valves and two carapaces.

Dimensions. (one carapace measured) L=0.30 mm, H=0.17 mm, H/L=0.57.

Occurrence. Beds 03DP2, 03DP3 and 03DP5, latest Permian, South China (Guangxi).

Remarks. Due to the posteroventral angle, they were assigned to the genus *Pseudobythocypris* Shaver, 1958; our specimens are similar to *Bythocypris centralis* Coryell & Billings, 1932 from the Pennsylvanian of Texas in having maximum height about mid-length.

Pseudobythocypris sp. 1
(Pl. 4, figs 17–18)

Material. Five valves.

Dimensions. L=0.39–0.49 mm, H=0.20–0.22 mm, H/L=0.45–0.54.

Occurrence. Beds 03DP2, 03DP5 and 03DP7, latest Permian, South China (Guangxi).

Remarks. These specimens differ from *P.* cf. *centralis* (Coryell & Billings, 1932) and *P.* aff. *procera* (Coryell & Billings, 1932) described above, in the rather high and blunt PB, a lower AB and its indistinct posterior slope.

Suborder **Metacopina** Sylvester-Bradley, 1961
Superfamily **Healdioidea** Hartlon, 1933
Family **Healdiidae** Harlton, 1933
Genus *Healdia* Roundy, 1926

Type species. *Healdia simplex* Roundy, 1926.

Healdia sp. 1
(Pl. 5, fig. 1)

Material. Four valves.

Dimensions. (one valve measured) L=0.56 mm (with the spine)/ 0.46 mm (without the spine), H=0.25 mm, H/L=0.44/0.53.

Occurrence. Beds 03DP2–03DP4, latest Permian, South China (Guangxi).

Remarks. In outline, our specimens are similar to *Healdia ratra* Gründel, 1961 from the Early Carboniferous of Central Germany. However, our specimens have slightly tumid and more broadly rounded AB and have stronger spines. The appearances of the spines (strong and protruding from PDB and PVB) make our specimens similar to some *Timorhealdia* species, e.g. *Timorhealdia nitidula* (Blumenstengel, 1979). However, here, the generic characters (anterodorsal spine and the shallow groove near the AB) are missing. In addition, our specimens have a crescent shape between the bases of the two spines.

Genus *Healdiopsis* Gründel, 1962

Type species. *Healdia thuringensis* Gründel, 1961.

Healdiopsis thuringensis thuringensis (Gründel, 1961)
(Pl. 5, fig. 2)

1961 *Healdia thuringensis* Gründel: 99, pl. 4, figs 3–5; pl. 14, fig. 4.
1962 *Healdiopsis thuringensis thuringensis* (Gründel, 1961); Gründel: 76, tables 2–4.
1981 *Healdiopsis thuringensis* (Gründel, 1961); Olempska: 42, pl. 5, fig. 4, table 2.
1986 *Healdia thuringensis* Gründel; Bartzsch & Weyer: pl. 3, fig. 19.
1990 *Healdia thuringensis* Gründel; Becker: 35, pl. 1, fig. 4.
1990 *Healdia thuringensis* Gründel; Becker & Bless: 428, figs 2–5.
1991 *Healdiopsis thuringensis thuringensis* (Gründel, 1961); Lethiers & Feist: 80, pl. 3, fig. 6.
1993 *Healdia thuringensis* Gründel; Becker *et al.*: 25, pl. 5, figs 1–9; pl. 6, figs 1–11.
1993 *Healdiopsis thuringensis thuringensis* Gründel, 1961; Blumenstengel: pl. 2, fig. 16.
1994 *Healdia thuringensis* Gründel, 1961; Blumenstengel: table 1.
1995 *Healdia thuringensis* Gründel; Becker & Blumenstengel: 69–71, figs 2–5, 4–4.
1997 *Healdia thuringensis* Gründel; Olempska: 316, figs 8D–F.

Material. Five valves.

Dimensions. (one valve measured) L=0.35 mm (with the spine)/ 0.33m (without the spine), H=0.23 mm, H/L=0.66/0.70.

Occurrence. Late Devonian–latest Permian, France (Montagne Noire), Poland (Holy Cross Mountain), Rhenish Massif (North Sauerland), Germany (Thuringia) and beds 03DP3, 03DP4, 03DP5, South China (Guangxi).

Family **Cavellinidae** Egorov, 1950
Genus *Cavellina* Coryell, 1928

Type species. *Cavellina puchella* Coryell, 1928.

Cavellina cf. *nebrascensis* (Geinitz, 1867)
(Pl. 5, fig. 3)

1990 *Cavellina nebrascensis* (Geinitz, 1867); Kohn & Dewey: pl. 2, fig. 2.

Material. Two carapaces and one valve.

Dimensions. (one carapace measured) L=0.33 mm, H=0.19 mm, H/L=0.59.

Occurrence. Beds 03DP3 and 03DP10, latest Permian, South China (Guangxi).

Remarks. Our specimens strongly resemble *Cavellina nebrascensis* (Geintze, 1867) in Kohn & Dewey (1990) from the Early Permian of south-central New Mexico, but have a more developed ventral overlap and a more truncated AB than *C. nebrascensis*.

Superfamily **Thlipsuroidea** Ulrich, 1894
Family **Quasillitidae** Coryell & Malkin, 1936
Genus *Absina* Gründel, 1962

Type species. *Absina ectina* Gründel, 1962.

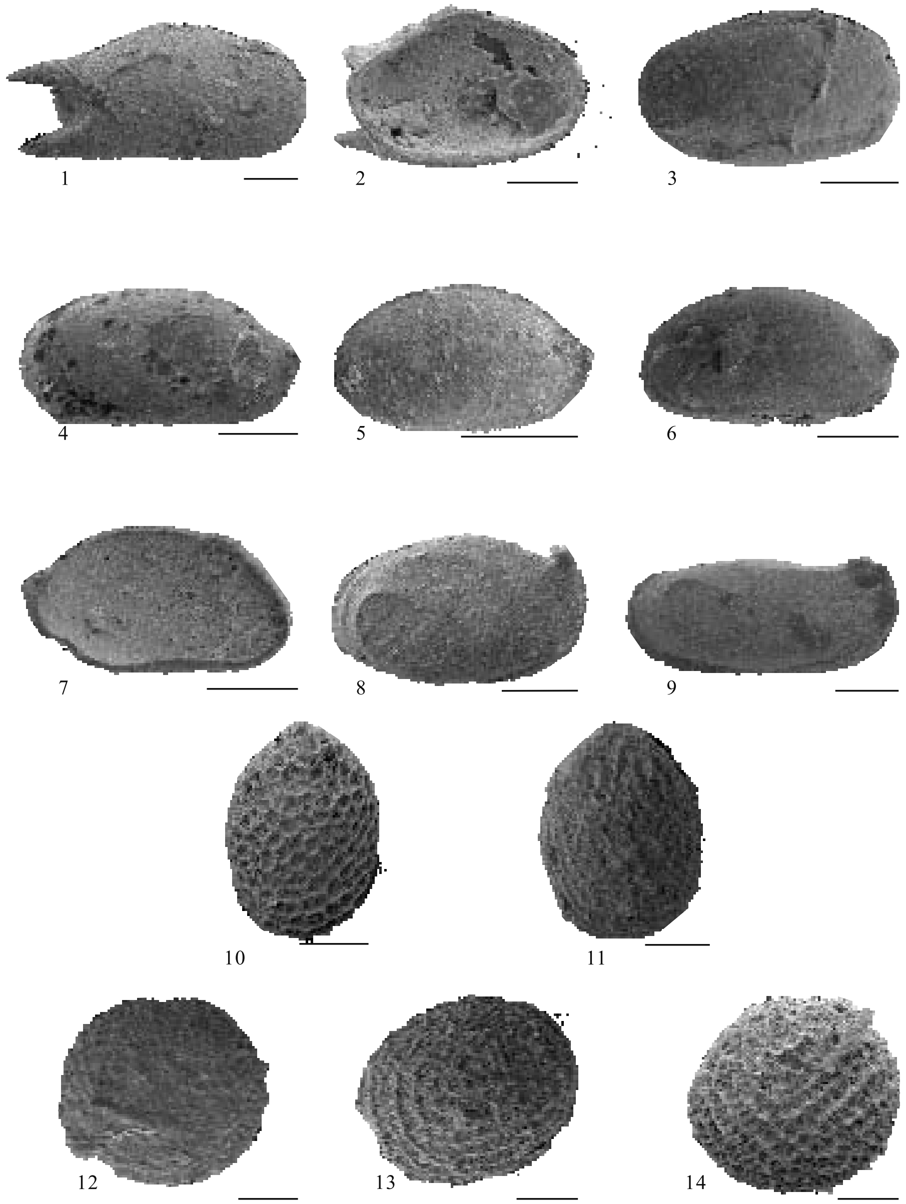

Plate 5.

Explanation of Plate 5. fig. 1. *Healdia* sp. 1: 03DP4, right view of right valve, collection number X0301-168. **fig. 2.** *Healdiopsis thuringensis thuringensis* (Gründel, 1961): 03DP4, inner view of left valve, collection number X0301-169. **fig. 3.** *Cavellina* cf. *nebrascensis* (Geintze, 1867): 03DP10-1, left view of carapace, collection number X0301-170. **figs 4–7.** *Absina* cf. *unispinosa* (Gründel, 1961) *sensu* Becker, 1999: **4, 5,** 03DP4, right views of right valves, collection numbers respectively X0301-171 and X0301-172; **6,** 03DP4, right view of right valve, collection number X0301-173; **7,** 03DP4, inner view of right valve, collection number X0301-174. **fig. 8.** *Absina* ? sp. 1: 03DP4, right view of right valve, collection number X0301-175. **fig. 9.** *Absina* ? sp. 2: 03DP4, right view of right valve, collection number X0301-176. **figs 10–11.** *Waldeckella* ? *sphaerula* (Gründel, 1961) *sensu* Becker, 1999: **10,** 03DP5-19, right view of right valve; 11, 03DP3-14, collection number X0301-177. **11,** sample 03DP3-14, right view of right valve, collection number X0301-178. **fig. 12.** *Polycope* sp. 1: 03DP2-20, right view of right valve, collection number X0301-179. **fig. 13.** *Polycope* aff. *baudi* Crasquin-Soleau, 1996: 03DP3-14, left view of left valve, collection number X0301-180. **fig. 14.** *Discoidella xingyangensis* Zhang, 1987: 03DP2-12, left view of left valve, collection number X0301-181. Scale bar is 100 µm.

Remarks. The genus *Absina* was established by Gründel in 1962 with the type species and *Cypridina* ? *unispinosa* Gründel, 1961. In two papers (Gründel, 1961, 1962), DB and VB are reversed so that the anterior beak was bent downward and considered as the myodocopid rostriform; consequently, the genus was assigned to the order Myodocopida. In 1979, Blumenstengel reversed the ventral and dorsal orientation of *Absina* (*Heterma*) *unispinosa*. Becker (1999), describing this genus in detail, gives it the present systematic position and this paper follows him.

Absina cf. *unispinosa* (Gründel, 1961)
(Pl. 5, figs 4–7)

1961 *Cypridina* ? *unispinosa* Gründel: 118–119, pl. 11, figs 1–2; pl. 14, fig. 5.

Material. Three right valves.

Dimensions. L=0.22–0.31 mm, H=0.13–0.17 mm, H/L=0.53–0.59.

Occurrence. Bed 03DP4, latest Permian, South China (Guangxi).

Remarks. Compared with *Absina unispinosa*, our specimens have the similar anterior upward restriform but differ in the absence of the postero-ventral spine.

Absina ? sp. 1
(Pl. 5, fig. 8)

Material. Three valves.

Description. Valve shape ovate in lateral view; DB strongly arched, ADB and PDB straight; VB slightly convex; AB broadly rounded and distinctly flattened, terminated in an acuminate, upward-directed beak; PB rounded with maximum convexity below mid-height; a ridge beginning from the posterodorsal part follows the outline of PB and ends at the posteroventral part, anterior of the ridge, a sickle-shaped ridge occurs on the posterior part in which the widest part of the carapace occurs, upper arm of sickle-shaped ridge shorter than the lower one; maximum height anterior of mid-length; surface smooth.

Dimensions. (one valve measured) L=0.34 mm, H=0.20 mm, H/L=0.60.

Occurrence. Bed 03DP4, latest Permian, South China (Guangxi).

Remarks. Based on the anterior beak-like feature, our specimens are questionably assigned to the genus *Absina* Gründel, 1962. However, the ovate outline and posterior sickle-shaped ridge give a healdiid appearance. Perhaps our specimens belong to a new genus, but at present, there is insufficient material to establish whether this is the case.

Absina ? sp. 2
(Pl. 5, fig. 9)

Material. One right valve.

Description. Carapace elongate and sub-quadrangular in lateral view; DB slightly bowed and the dorsal part of the carapace is oblate, slightly concave and extending to the anterior and posterior borders; VB sub-parallel to dorsal margin and slightly curved; AB rounded and flattened, with upper part terminated in a swing, which extends beyond DB; PB regularly rounded and flattened, with a small curvature radius, and maximum convexity about mid-height; sickle-shaped ridge occurs on posterior half of shell, the C-shaped ridge has shorter upper arm, which roughly follows the outline of the posterior and ventro-posterior borders; maximum length about mid-height, maximum height about mid-length; surface smooth.

Dimensions. L=0.42 mm, H=0.16 mm, H/L=0.39.

Occurrence. Bed 03DP4, latest Permian, South China (Guangxi).

Remarks. Our specimen resembles *Absina ventrorostrata* Gründel, 1962 through the anterior swing and elongate valve, but differs from the latter by the posterior C-shaped ridge, the arched DB and the flattening of dorsal part of the carapace. Our specimen may have affinities with *Absina* ? sp. 1. However, this specimen can be distinguished from *Absina* ? sp.1 by the more elongated outline, dorsal plan and broader AB.

Order **Myodocopida** Sars, 1866
Suborder **Myodocopina** Sars, 1866
Superfamily **Entomozoidea** Pribyl, 1951
Family **Entomozoidae** Pribyl, 1951
Genus *Waldeckella* Rabien, 1954

Type species. *Bertillonella subcircularis* Stewart & Hendrix, 1945.

Waldeckella ? *sphaerula* (Gründel, 1961) *sensu* Becker, 1999
(Pl. 5, figs 10–11)

1999 *Waldeckella* ? *sphaerula* (Gründel, 1961); Becker: 83, pl. 14, figs 1–6; pl. 16, fig. 7; pl. 17, fig. 16.

Material. Six valves.

Dimensions. L=0.21–0.24 mm, H=0.31–0.33 mm, H/L=1.35–1.47.

Occurrence. Late Devonian–latest Permian, Rhenish Massif (North Sauerland) and bed 03DP3-5, South China (Guangxi).

Remarks. Based on their outline and similar ornamentation, these specimens are assigned to *Waldeckella*? *sphaerula* (Gründel, 1961) *sensu* Becker, 1999 from the Devonian–Carboniferous of North Sauerland (Rheinisches Schiefergebirge).

Suborder **Cladocopina** Sars, 1866
Family **Polycopidae** Sars, 1866
Genus *Polycope* Sars, 1866

Type species. *Polycope orbicularis* Sars, 1866.

Polycope aff. *baudi* Crasquin-Soleau, 1996
(Pl. 5, fig. 13)

1996 *Polycope baudi* Crasquin-Soleau; Crasquin-Soleau & Gradinaru: 73, pl. 1, figs 1–3.

Material. Two valves.

Dimensions. (one valve measured) L=0.36 mm, H=0.29 mm, H/L=0.80.

Occurrence. Bed 03DP3, latest Permian, South China (Guangxi).

Remarks. Our specimens are similar to *Polycope baudi* Crasquin-Soleau, 1996 from the Anisian (Middle Triassic) of Romania (Crasquin-Soleau & Gradinaru, 1996) based on the circular outline and concentric ridges, but are distinguished by inclined valve axis, more forward AB and lower maximum convexity of AB.

Polycope sp. 1
(Pl. 5, fig. 12)

Material. One right valve.

Dimensions. L=0.36 mm, H=0.36 mm, H/L=1.

Occurrence. Bed 03DP2, latest Permian, South China (Guangxi).

Remarks. The circular outline and reticulated shell make our specimen similar to *Nodopolycope binodosa* Kozur, 1985 from the Late Permian (Abadehian) of Hungary, but our specimen lacks the two knobs near the DB. When compared to other *Polycope* species, our specimen is distinguished by its maximum length below mid-height.

Family Uncertain
Genus *Discoidella* Croneis & Gale, 1938

Type species. *Discoidella simplex* Croneis & Gale, 1938.

Discoidella xingyangensis Zhang, 1987
(Pl. 5, fig. 14)

1987 *Discoidella xingyangensis* Zhang; Zhang & Liang: 307, pl. 3, fig. 5.
2004 *Discoidella xingyangensis* Zhang; Yi: pl. 1, fig. 12.

Material. Four valves.

Dimensions. (one valve measured) L=0.35 mm, H=.32 mm, H/L=0.93.

Occurrence. Late Carboniferous–latest Permian, China (Henan, Guangxi (beds 03DP2, 03DP3, 03DP11) and Fujian).

Remarks. Our specimens are assigned to *Discoidella xingyangensis* Zhang, 1987 from the Late Carboniferous of Henan, North China based on the sub-circular lateral outline, straight DB and the reticulation which is arranged in a V-shape towards the DB and concentrically towards the VB. Compared with the holotype, our specimens have a more forward AB.

Palaeopsychrospheric species	*Absina* cf. *unispinosa* (Gründel, 1961) *Absina* ? sp. 1 *Absina* ? sp. 2 *Bohemina* (*Pokornina*) ? sp. 1 *sensu* Gründel & Kozur, 1975 Bythocytheridae gen. sp. indet. *Cooperuna* cf. *tenuis* Kozur, 1985 *Healdia* sp. 1 *Healdiopsis thuringensis thuringensis* (Gründel, 1961) *Monoceratina* sp. 1 *Monoceratina* ? sp. 2 *Paraberounella* ? cf. *laterospina* Kozur, 1991a *Paraberounella* sp. 1 Rectonariidae gen. sp. indet. *Rectonaria* cf. *inclinata* Gründel, 1961 *Spinobairdia* sp. 1 *Spinomicrocheilinella* aff. *dargenioi* Kozur, 1991a *Spinomicrocheilinella anterocompressa* n. sp. *Spinomicrocheilinella* sp. 1 *Spinomicrocheilinella* sp. 2
Pelagic/swimming species	*Discoidella xingyangensis* Zhang, 1987 *Polycope* aff. *baudi* Crasquin-Soleau, 1996 *Polycope* sp. 1 *Waldeckella* ? *sphaerula* (Gründel, 1961) *sensu* Becker, 1999

Table 1. Palaeopsychrospheric and pelagic species from the Dongpan Section.

PALAEOENVIRONMENTAL ANALYSIS

Nineteen species in this study are considered as palaeopsychrospheric elements, four species are pelagic and all the others are neritic (Table 1). The palaeopsychrospheric ostracods (previously described as 'Thuringian ecotype' by Bandel & Becker (1975)), indices of deep water environments, differ from contemporary neritic forms by their thin tests and/or the presence of very well-developed spines. During the Late Devonian–Dinantian interval, such forms are associated with bathyal facies, in low energy cold water, and probably with low oxygen content (Lethiers & Crasquin, 1987; Crasquin-Soleau *et al.*, 1989; Lethiers & Feist, 1991). Similar faunas were described in the Early Permian of Timor (Gründel & Kozur, 1975; Bless, 1987), in the Middle Permian of Sicily (Kozur, 1991*a*; Crasquin-Soleau *et al.*, in press), as well as in the Early and Middle? Triassic of the Alps (Kozur, 1972) and of Romania (Crasquin-Soleau & Gradinaru, 1996). The term 'palaeopsychrospheric' was proposed by Kozur (1972) to indicate this special kind of assemblage present in the whole Late Palaeozoic–earliest Mesozoic interval. This term was chosen to point out the morphological analogy with the assemblages present in the modern psychrosphere, occurring from the Eocene to Present. The modern psychrosphere is defined as the lower cold level of the modern ocean, as opposed to the thermosphere, the less dense and warmer upper level (more than 10 °C) (Benson &

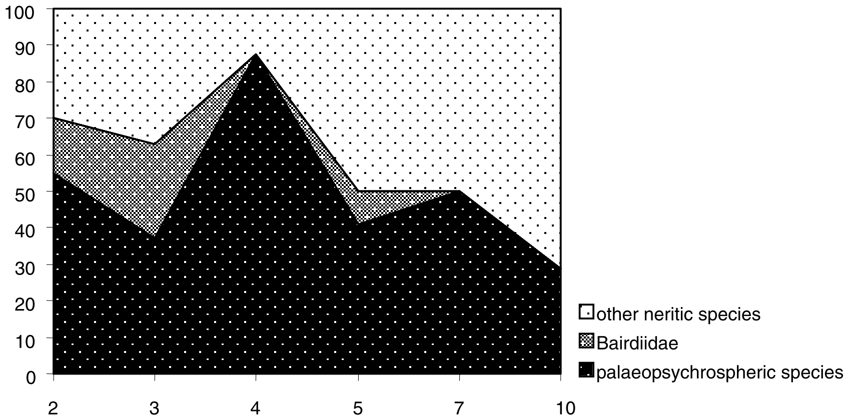

Fig. 3. Ostracod composition in each bed of the Dongpan Section. In abscissa: percentage of species; in ordinate: sample numbers.

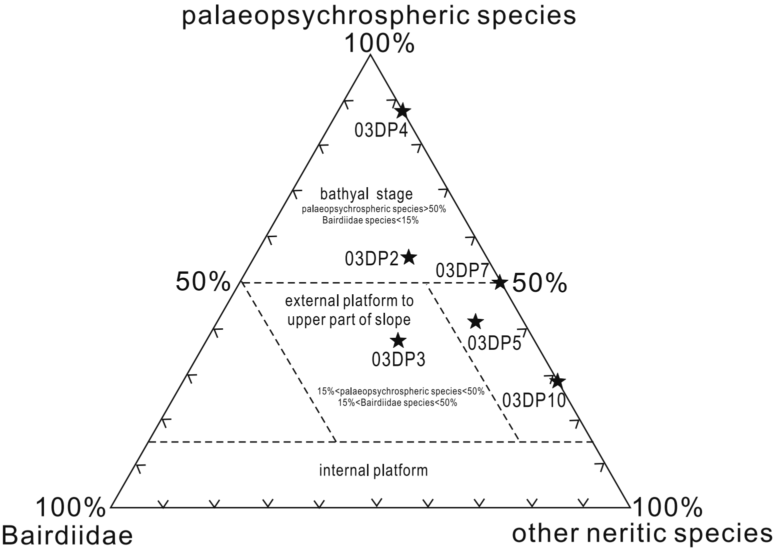

Fig. 4. Triangular diagram of ostracod composition, bed by bed (based on Lethiers & Raymond, 1991).

Sylvester-Bradley, 1971; Benson, 1972, 1975). This fauna is restricted to deep-water environments, from 500 m to 5000 m deep, in connection with a global ocean supplied with cold water by ice caps. Becker (2000) suggested that the palaeopsychrospheric ecotype is more indicative of low-energy conditions than of water depth. The authors agree with the opinion of low-energy conditions; however, the bathymetric evaluations based on palaeopsychrospheric ostracods have been supported by the associated facies and fauna (see radiolarian results below).

The neritic forms present in the Dongpan Section are typical of tropical warm water and could be split into two palaeoecological 'groups': the Bairdiidae, which are open-marine platform inhabitants, and 'other neritic' species, which belong to a shallower environment. Following the Lethiers & Raymond (1991) model, a percentage of palaeopsychrospheric ostracods higher than 50% is indicative of a slope to bathyal environment.

This model was applied to evaluate the bathymetry. Ostracod composition was calculated from Bed 2 to Bed 10-1 by bed at species level (Fig. 3) and represented on a triangular diagram (Fig. 4). Bed 2 and Bed 4, with percentages of palaeopsychrospheric species of 55% and 87.5%, respectively, are probably bathyal. Bed 3, with 37% palaeopsychrospheric species and 26% Bairdiidae, could indicate an external platform limited to the upper part of the continental slope. Beds 5, 7 and 10-1, containing lower than 50% palaeopsychrospheric species and 15% Bairdiidae, may indicate a much shallower environment than Bed 3. Consequently, a possible bathymetric variation is shallowing from Bed 2 to Bed 3, deepening from Bed 3 to Bed 4 and then shallowing.

Environmental changes are also indicated by accompanying radiolarians, foraminifera and brachiopods. According to Meng (pers. comm. unpublished PhD thesis), radiolarians represented by a few *Albaillellaria* species and rich *Latentifistularia* were recorded from Bed 2 to Bed 5. *Albaillellaria* begin to appear in the open-marine environment with a water depth range of 200–500m and are used to indicate bathyal and abyssal conditions (Kozur, 1993). *Latentifistularia* usually live in the external platform to

The common species	Age	Location	Living pattern
? *Libumella athabascensis* Green, 1963	Early Carboniferous	Western Canada	neritic
Microcheilinella cf. *elatus* (Lethiers, 1978) *sensu* Lethiers, 1981	Late Devonian	Western Canada	neritic
Microcheilinella aculeata Buschmina, 1975	Early Carboniferous	Russia, Poland	in neritic ecotype in original description
Bairdia ? sp. 6 *sensu* Bless, 1987	Early and Middle Permian	Timor and Sicily	in palaeopsychrospheric ecotype in original description
Bohemina (*Pokornina*) ? sp. 1 *sensu* Gründel & Kozur, 1975	Early Permian	Timor	palaeopsychrospheric
Healdiopsis thuringensis thuringensis (Gründel, 1961)	Late Devonian–Early Carboniferous	France, Germany, Poland and Rhenish Massif	palaeopsychrospheric
Waldeckella ? *sphaerula* (Gründel, 1961) *sensu* Becker, 1999	Late Devonian	Rhenish massif	pelagic
Discoidella xingyangensis Zhang, 1987	Late Carboniferous–Late Permian	China	pelagic

Table 2. Age and occurrence of common species described in previous studies.

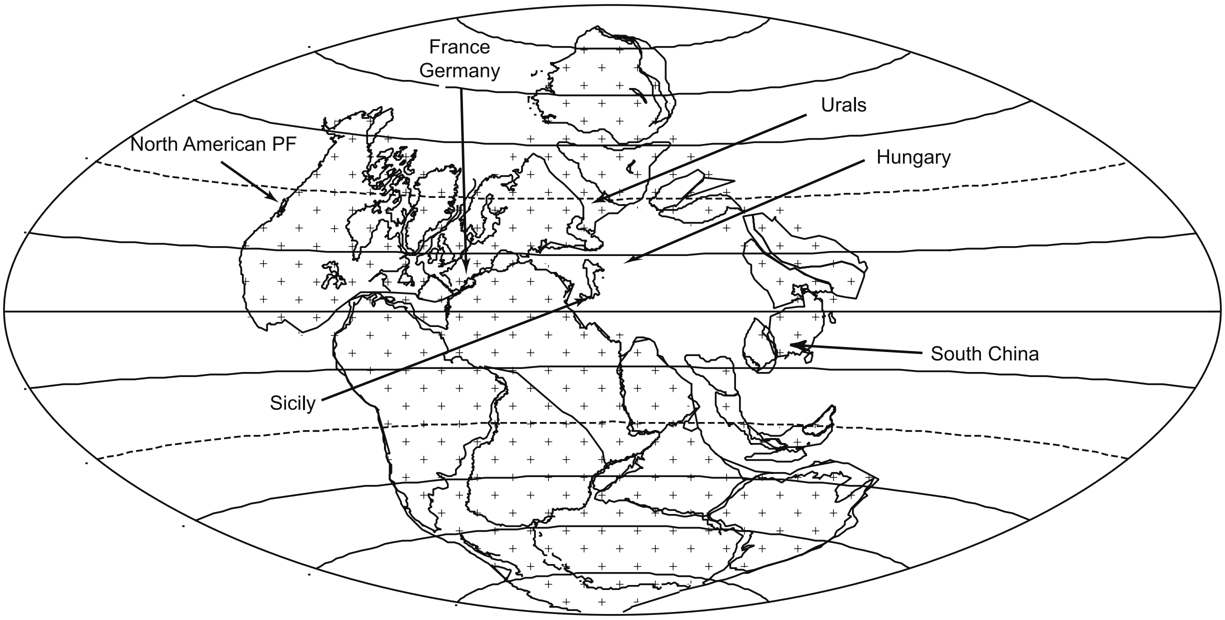

Fig. 5. Wordian palaeogeographical map – Pangaea B reconstruction (modified after Crasquin-Soleau *et al.*, 2001). PF: platform.

bathyal environments (Fang & Feng, 1996). Therefore, this assemblage, when associated with small benthic foraminiferids and benthic brachiopods with thin shells, suggests an upper bathyal environment. *Albaillellaria* disappear beyond Bed 6 (Jin *et al.*, 2007). Bed 7 yielded a few *Latentifistularia* and thus belongs to the external platform environment. Bed 8–Bed 10, containing more Entactinidae than Copicyntrinae, was assigned to the external platform with the water depth shallower than Bed 7.

PALAEOBIOGEOGRAPHICAL RELATIONSHIPS

Although the majority of the ostracod fauna is endemic, eight of the species discovered in the Dongpan Section were described and/or recognized in other areas (Table 2). The comparison shows that the species, which are common in south-west Guangxi, appeared earlier in the other areas (from Late Devonian to Middle Permian) (Fig. 5). For the neritic species, the migration ways are limited to the shallow-marine platforms in warm water environments. During the Late Permian, the Pangaea Supercontinent was formed and migrations were impossible through the western part of Pangaea (no marine connection) and could not take place through northern or southern routes due to temperature barriers. It means that the migrations from western American platform of ?*Libumella athabascensis* Green, 1963 and *Microcheilinella* cf. *elatus* (Lethiers, 1978) *sensu* Lethiers, 1981 took place before the final stage of the formation of Pangaea. In the same way, *Microcheilinella aculeata* Buschmina, 1975 could have followed the continental margins of Pangaea from the Urals and Poland southwards during the Late Carboniferous and Early Permian. The migration of palaeopsychrospheric species is less restricted. Indeed, the migration ways are located in the deep water, within the bathymetric tolerance of the species. Crasquin-Soleau *et al.* (in press) showed that palaeopsychrospheric species could have migrated from Indonesia to Sicily from the Early to Middle Permian. This paper shows that an eastwards direction of migration is also possible from Indonesia to South China. The eastward migration could have begun earlier (from the Late Devonian of France, Germany, Poland and Rhenish Massif) to explain the migration of *Healdiopsis thuringensis thuringensis*. More investigations in South China and particularly in earlier time periods are essential to understand the exact migration routes.

CONCLUSIONS

This is the first Late Permian deep-water ostracod fauna reported in China and the first latest Permian world-wide. The mixed neritic and palaeopsychrospheric fauna is used to analyse the bathymetry along the Dongpan Section. Even though the Dongpan fauna is mainly endemic, some palaeobiogeographical links can be recognized. The westwards migration of fauna from Indonesia to Western Tethys during the Early and Middle Permian (Crasquin-Soleau *et al*., in press) seems to coincide with an eastward migration from Indonesia to South China. The slow evolution rate in the palaeopsychrospheric ecotype is emphasized by the discovery of very long-ranging species.

The Dongpan ostracods provide important evidence for our knowledge of the history of the palaeopsychrospheric ecotype. This study fills the gap of data between the Middle Permian (Kozur, 1991a, b; Crasquin-Soleau *et al*., in press) and the base of the Middle Triassic ostracod fauna (Crasquin-Soleau & Gradinaru, 1996).

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Plate & Plate Captions

All specimens figured here are from this work. The origin and depository of specimens are listed in the following table.

SECTION	COLLECTION NUMBER	DEPOSITORY
Dongpan Section (DP)	X0301-101 to X0301-182	Geological Museum of China University of Geosciences, Wuhan, the People's Republic of China
Liuqiao Section (LQ)	X0301-183 to X0301-227	
Shaiwa Section (SW)	X0301-228 to X0301-279	
Chaohu Section (CH)	X0301-280 to X0301-311	
Xichang Section (XC)	X0301-312 and X0301-313	
Tieqiao Section (TQ)	P6M2347 and P6M2348	Laboratory of Micropaleontology, University Pierre & Marie Curie, Paris, France

Plate 1

Scale bar is 300µm except in figs 2, 5, 12, 16 where it is 100µm.

Fig.1 *Tribolbina* cf. *doescheri* Sohn, 1978. External view of right valve. Collection number X0301-189.

Fig.2 *Kirkbya* cf. sp. A *sensu* Becker & Wang, 1992. External view of right valve. Collection number X0301-107.

Fig.3 *Kirkbya* aff. *wymani* Kellett, 1933. External view of right valve. Collection number X0301-190.

Figs 4-6 *Kirkbya* sp. 1 *sensu* Yuan *et al.*, 2007. 4, 5. external view of left valves; **6.** external view of right valve. Collection numbers X0301-110, X0301-111and X0301-112.

Fig.7 *Kirkbya* sp.2. External view of left valve. Collection number X0301-191.

Fig.8 *Kirkbya* sp.3. External view of right valve. Collection number X0301-192.

Fig.9 *Aurikirkbya* cf. *ultima* (Kozur, 1985a). External view of right valve. Collection number X0301-193.

Fig.10 *Aurikirkbya* sp.1 *sensu* Yuan *et al.*, 2007. External view of incomplete valve. Collection number X0301-108.

Fig.11 *Aurikirkbya* sp.2. External view of left valve. Collection number X0301-194.

Fig.12 *Nodokirkbya* ? cf. *striatoreticulata* Kozur, 1991a *sensu* Yuan *et al.*, 2007. External view of right valve. Collection number X0301-109.

Fig.13 *Tubulikirkbya* sp.1. External view of left valve. Collection number X0301-195.

Fig.14 Amphissitidae sp.1. External view of right valve. Collection number X0301-196.

Fig.15 Amphissitidae sp.2. External view of right valve. Collection number X0301-197.

Fig.16 *Kellettina* aff. *reticulata* Kozur, 1991a *sensu* Yuan *et al.*, 2007. External view of left valve. Collection number X0301-113.

Figs 17, 18 Kellettinidae indet.1. 17. external view of left valve. Collection number X0301-198; **18.** external view of right valve.. Collection number X0301-199.

Plate 1

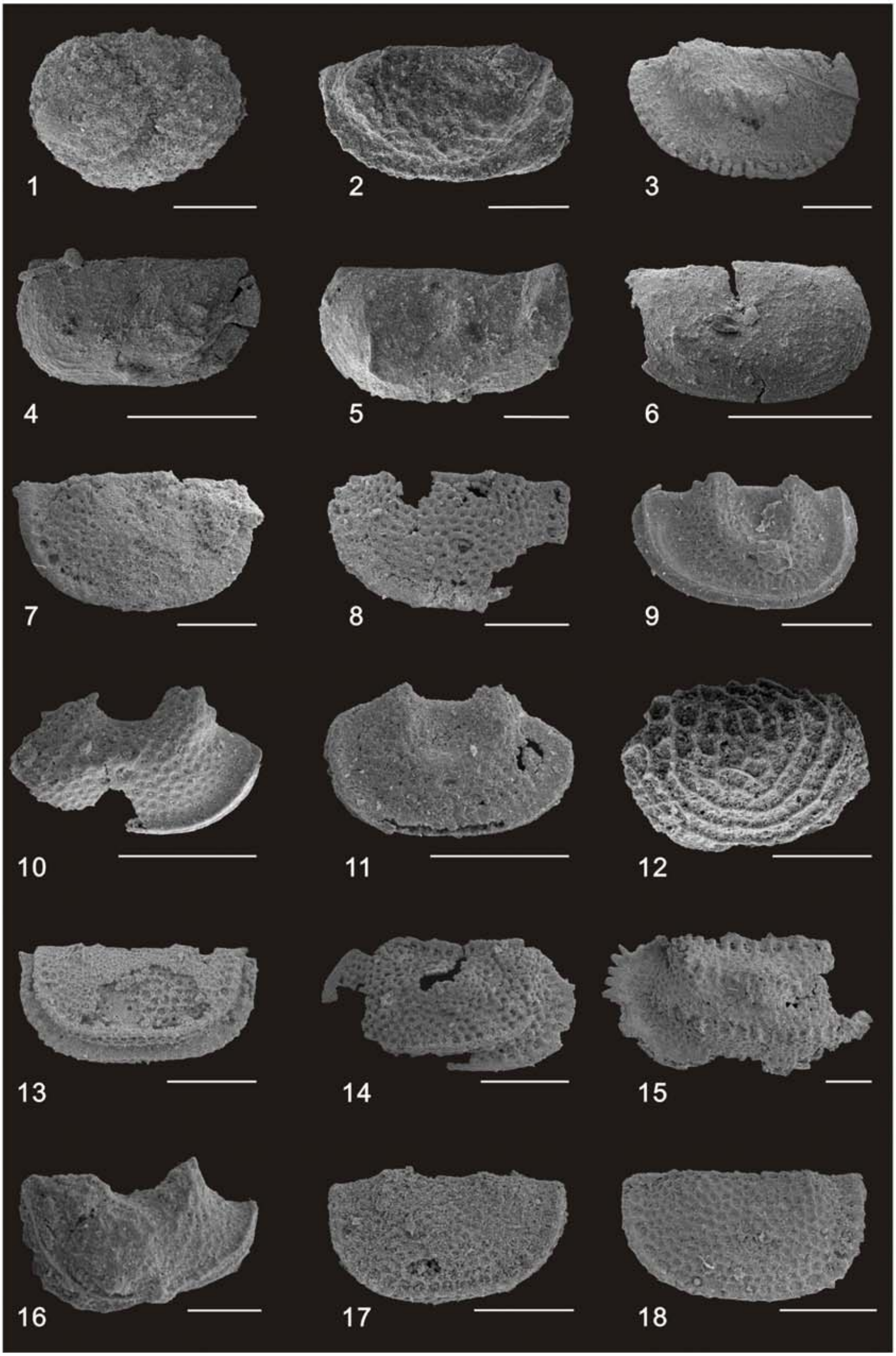


Plate 2

Scale bar is 100μm.

Fig.1 ***Roundyella* ? *suboblanga* Wang, 1978.** External view of right valve. Collection number X0301-200.

Fig.2 ***Roundyella* aff. *labaensis wangi* Kozur, 1985a.** External view of right valve. Collection number X0301-201.

Fig.3 ***Permokegelites* cf. *beichuanensis* Becker & Wang, 1992.** External view of right valve. Collection number X0301-202.

Figs 4-6 ***Cyathus caperata* (Guan, 1978). 4.** external view of right valve. Collection number X0301-234; **5.** right lateral view of carapace. Collection number P6M2347; **6.** left lateral view of carapace. Collection number P6M2348.

Fig.7 ***Macronotella* ? sp.1 *sensu* Yuan *et al.*, 2007.** Left lateral view of carapace. Collection number X0301-114.

Fig.8 ***Macronotella* ? sp.2 *sensu* Yuan *et al.*, 2007.** External view of left valve. Collection number X0301-115.

Fig.9 ***Paraparchites* sp. 1 *sensu* Yuan *et al.*, 2007.** External view of right valve. Collection number X0301-121.

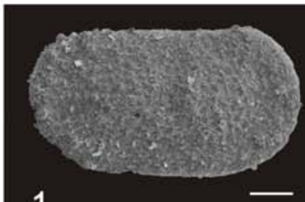
Figs 10-12 ? *Libumella athabascensis* Green, 1963 *sensu* Yuan *et al.*, 2007. 10. external view of left valve. Collection number X0301-116; **11.** external view of left valve. Collection number X0301-117; **12.** external view of right valve. Collection number X0301-118.

Figs 13, 14 ***Libumella* cf. *kargalensis* Rozhdestvenskaya, 1959 *sensu* Yuan *et al.*, 2007. 13.** external view of left valve. Collection number X0301-119; **14.** external view of right valve. Collection number X0301-120.

Fig.15 Palaeocopida indet. External view of right valve. Collection number X0301-235.

Figs 16-18 ***Permoyoungiella* ? sp. 1 *sensu* Yuan *et al.*, 2007. 16.** external view of right valve. Collection number X0301-122; **17.** inner view of right valve. Collection number X0301-123; **18.** inner view of left valve. Collection number X0301-124.

Plate 2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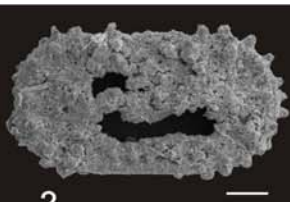
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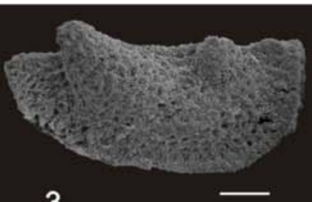
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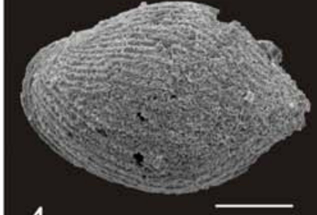
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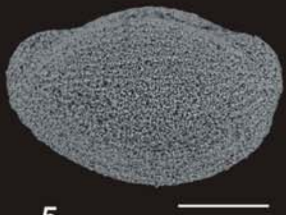
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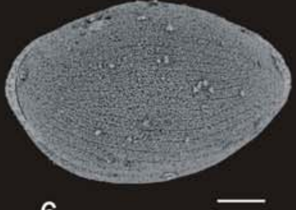
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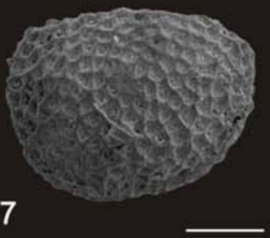
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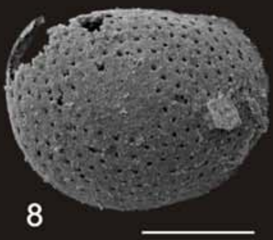
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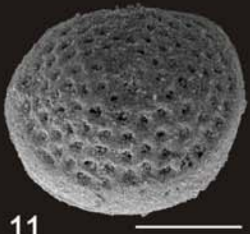
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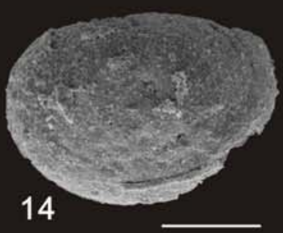
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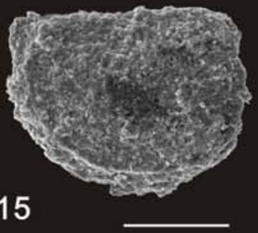
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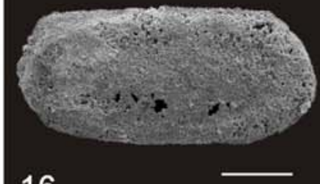
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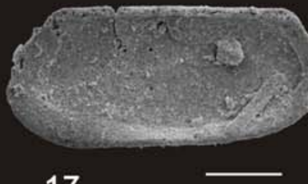
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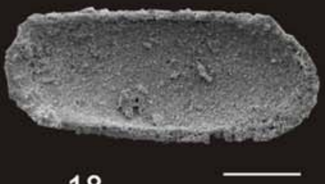
18

Plate 3

Scale bar is 100µm.

Fig.1 ***Bairdia altiarcus*** **Chen, 1958.** External view of right valve. Collection number X0301-236.

Fig.2 ***Bairdia*** **cf.*altiarcus*** **Chen, 1958.** Right lateral view of carapace. Collection number X0301-203.

Fig.3 ? ***Bairdia anbeedei*** **Belousova, 1965.** External view of left valve. Collection number X0301-204.

Figs 4-9 ***Bairdia dongpanensis*** **Yuan & Crasquin-Soleau, 2007. 4.** right lateral view of carapace, holotype, collection number X0301-101; **5.** inner view of left valve, paratype, collection number X0301-103; **6.** external view of left valve. Collection number X0301-182; **7.** right lateral view of carapace, paratype, collection number X0301-102; **8.** external view of right valve. Collection number X0301-131; **9.** inner view of right valve. Collection number X0301-276.

Figs 10-12 ***Bairdia*** **? sp. 6** ***sensu*** **Bless, 1987. 10.** external view of right valve. Collection number X0301-128; **11.** external view of right valve. Collection number X0301-129; **12.** external view of left valve. Collection number X0301-130.

Fig.13 ***Bairdia*** **cf.** ***szaszi*** **Crasquin-Soleau & Gradinaru, 1996.** External view of right valve. Collection number X0301-280.

Fig.14 ***Bairdia*** **aff.** ***birinae*** **Egorov, 1953** ***sensu*** **Yuan** ***et al.*****, 2007.** External view of left valve. Collection number X0301-126.

Fig.15 ***Bairdia*** **sp.1** ***sensu*** **Gründel & Kozur, 1975.** External view of left valve. Collection number X0301-205.

Figs 16, 17 ***Bairdia*** **cf.*austriaca*** **(Kollmann, 1963)** ***sensu*** **Gründel & Kozur, 1975.** External view of right valves. Collection numbers X0301-206 and X0301-207.

Fig.18 ***Bairdia*** **sp.1** ***sensu*** **Yuan** ***et al*****., 2007.** External view of right valve. Collection number X0301-133.

Plate 3

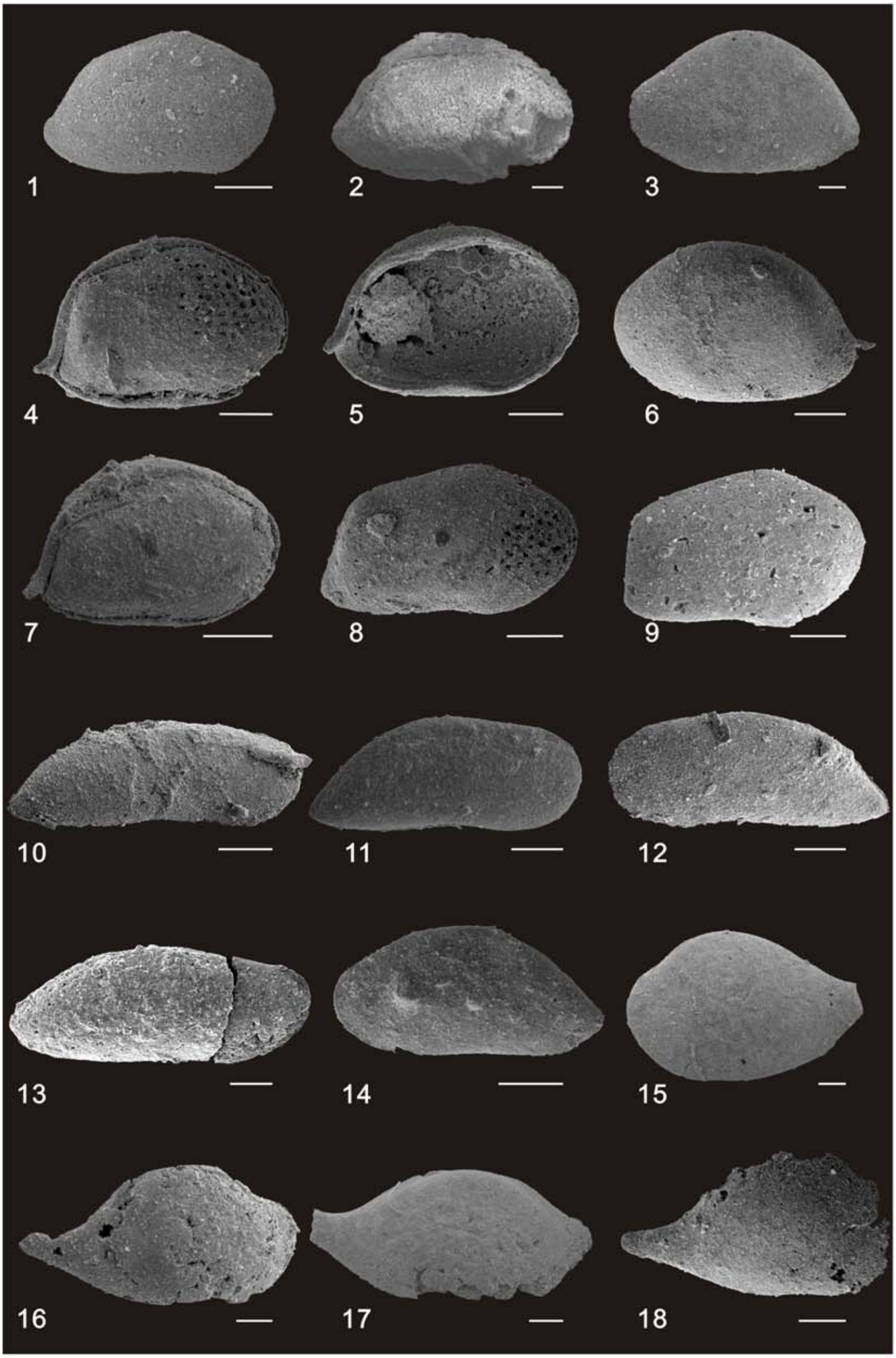

Plate 4

Scale bar is 100μm except in fig.15 where it is 200μm.

Fig.1 *Bairdia* sp.2 *sensu* Yuan *et al.*, 2007. External view of right valve. Collection number X0301-134.

Fig.2 *Bairdia* sp.4 *sensu* Yuan *et al.*, 2007. External view of right valve. Collection number X0301-125.

Fig.3 *Bairdia* sp.5. External view of right valve. Collection number X0301-208.

Figs 4, 5 *Bairdia* sp.6. External view of left valves. Collection numbers X0301-209 and X0301-210.

Fig.6 *Bairdia* sp.3 *sensu* Yuan *et al.*, 2007. External view of left valve. Collection number X0301-127.

Fig.7 *Bairdia* sp.7. External view of right valve. Collection number X0301-211.

Fig.8 *Bairdia* sp.8. External view of right valve. Collection number X0301-212.

Fig.9 *Bairdia* sp.9. Right lateral view of carapace. Collection number X0301-237.

Fig.10 *Bairdia* sp.10. External view of right valve. Collection number X0301-238.

Figs 11, 12 *Bairdia* sp.11. 11. inner view of left valve. Collection number X0301-239; **12.** External view of left valve. Collection number X0301-240.

Fig.13 *Bairdia* sp.13. External view of right valve. Collection number X0301-241.

Fig.14 Bairdiidae sp.4. External view of right valve. Collection number X0301-242.

Fig.15 *Bairdia* sp.12. External view of left valve. Collection number X0301-243.

Fig.16 *Bairdia* sp.14. Right lateral view of carapace. Collection number X0301-281.

Fig.17 *Bairdia* ? sp.15. External view of right valve. Collection number X0301-282.

Fig.18 Bairdiidae sp.5. External view of left valve. Collection number X0301-244.

Plate 4

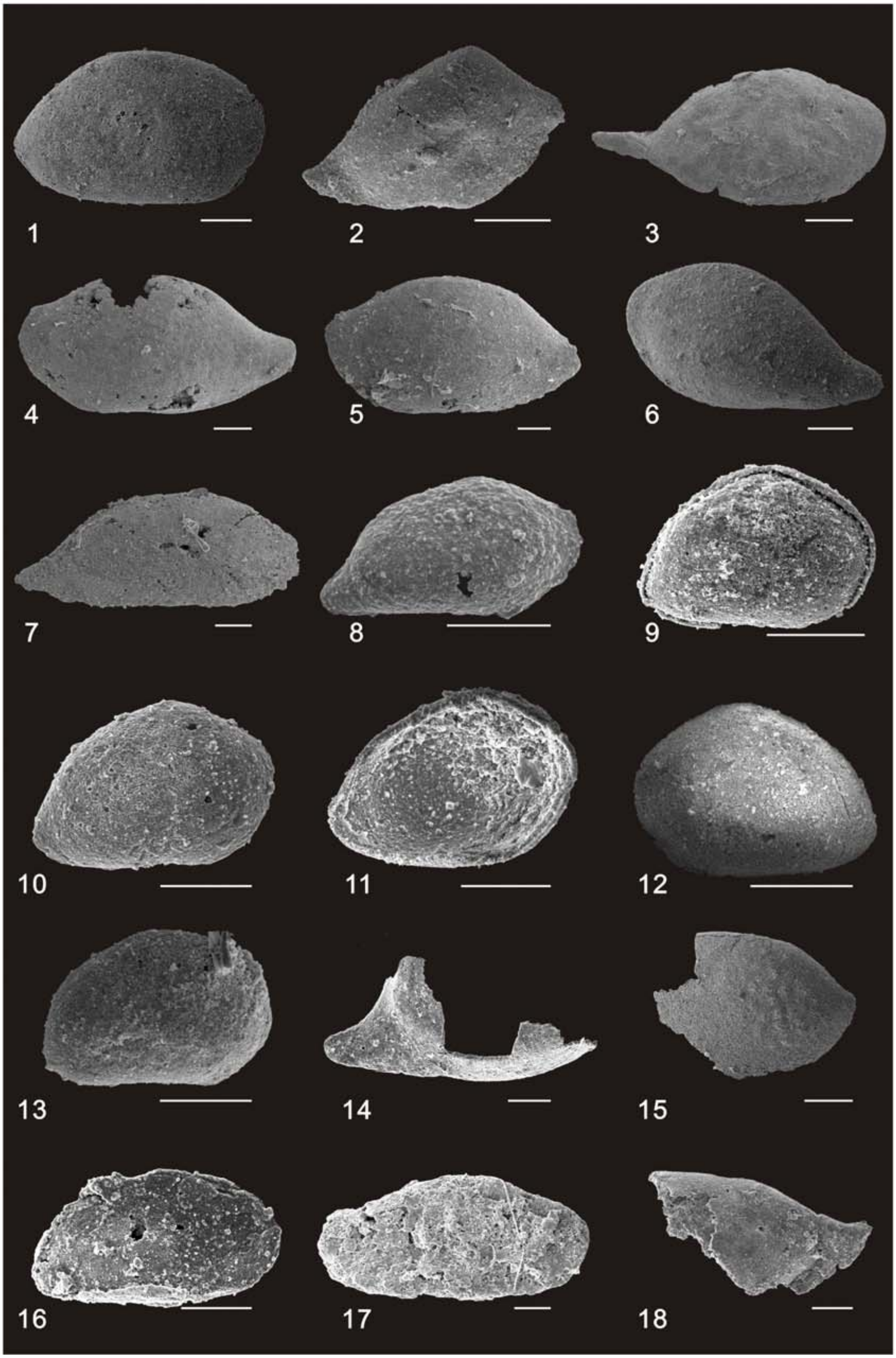

Plate 5

Scale bar is 100μm except in fig.14 where it is 300μm.

Figs 1, 2 *Abrobairdia* sp.1. External view of left valves. Collection numbers X0301-213 and X0301-214.

Fig.3 *Abrobairdia* sp.2. External view of left valve. Collection number X0301-215.

Figs 4, 5 *Mirabairdia comisa* Chen, 1982. External view of right valves. Collection numbers X0301-216 and X0301-217.

Fig.6 *Lobobairdia* cf.*rostriformis* Chen, 1982. External view of left valve. Collection number X0301-218.

Figs 7, 8 *Petasobairdia bicornuta* Chen, 1982. 7. external view of left valve. Collection number X0301-219; **8.** external view of left valve**.** Collection number X0301-312.

Fig.9 *Petasobairdia* sp. 2 *sensu* Yuan *et al*., 2007. External view of right valve. Collection number X0301-138.

Fig.10 *Petasobairdia* sp. 1 *sensu* Yuan *et al*., 2007. External view of right valve. Collection number X0301-137.

Fig.11 *Petasobairdia* sp.3. External view of left valve. Collection number X0301-220.

Fig.12 *Petasobairdia* sp.4. External view of left valve. Collection number X0301-245.

Fig.13 *Pustulobairdia* sp.1. External view of right valve. Collection number X0301-221.

Fig.14 *Pustulobairdia* aff.*spinosa* (Cooper, 1946). External view of left valve. Collection number X0301-222.

Fig.15 *Pustulobairdia* sp.2. External view of left valve. Collection number X0301-246.

Figs 16-18 Bairdiidae sp.3. External view of right valves. Collection numbers X0301-247, X0301-248 and X0301-249.

Plate 5

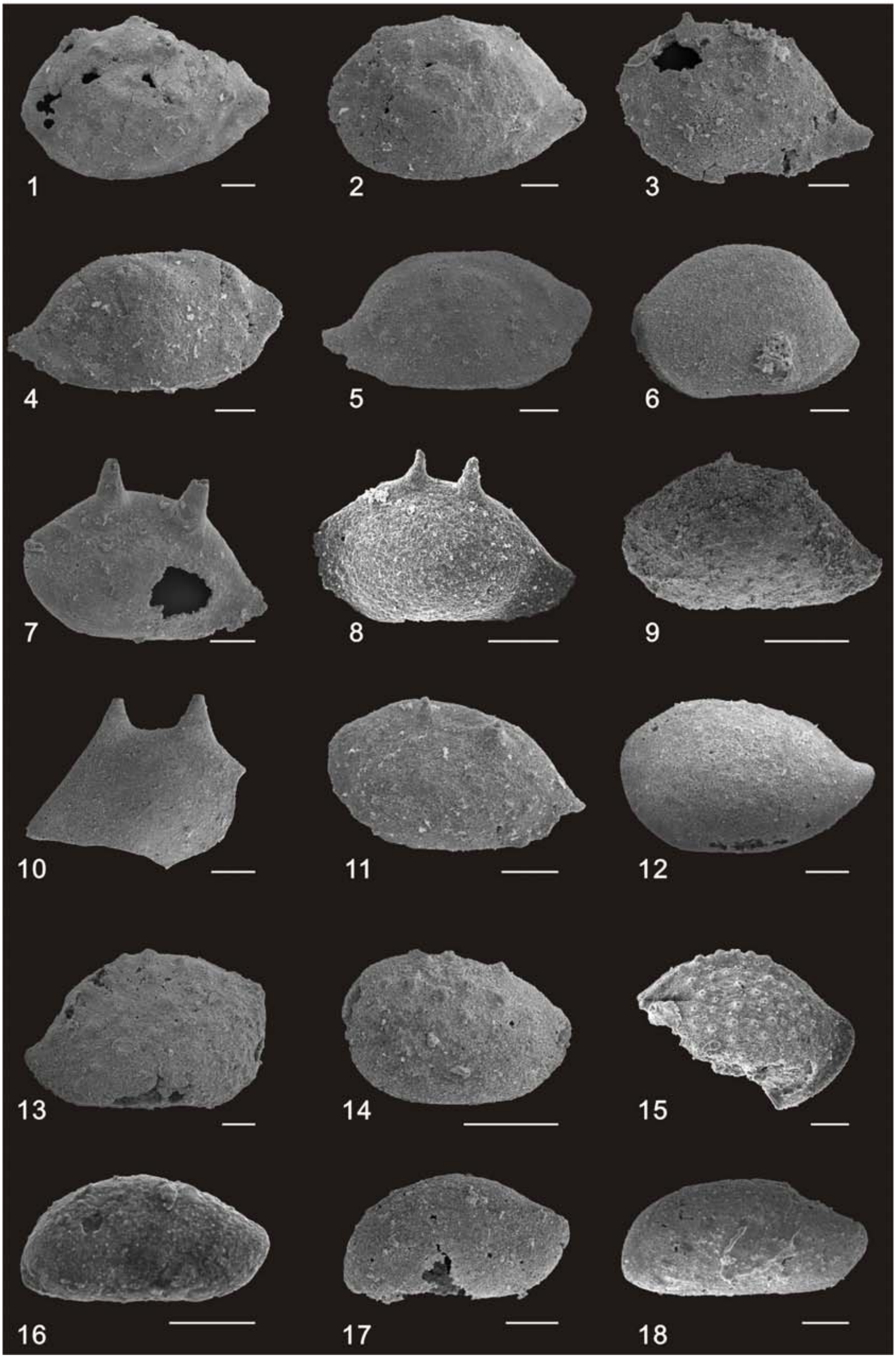

Plate 6

Scale bar is 100µm except in fig.8 where it is 300µm.

Fig.1 *Spinobairdia* sp. 1 *sensu* Yuan *et al.*, 2007. External view of right valve. Collection number X0301-135.

Fig.2 *Bairdiacypris* aff. *mirautaae* Crasquin-Soleau, 1996 *sensu* Yuan *et al.*, 2007. External view of left valve. Collection number X0301-142.

Fig.3 *Bairdiacypris* sp.1. External view of right valve. Collection number X0301-250.

Fig.4 *Bairdiacypris* sp.2. Right lateral view of carapace. Collection number X0301-283.

Fig.5 *Bairdiacypris* ? sp.3. External view of right valve. Collection number X0301-284.

Fig.6 *Bairdiacypris* ? sp.4. External view of right valve. Collection number X0301-285.

Fig.7 *Bythocypris* ? sp.1. External view of left valve. Collection number X0301-251.

Fig.8 *Fabalicypris glennensis* (Harlton, 1927) *sensu* Yi, 1993. External view of right valve. Collection number X0301-223.

Fig.9 Bairdiidae sp.2. External view of right valve. Collection number X0301-252.

Figs 10-13 *Fabalicypris* cf. *minuta* Cooper, 1946 *sensu* Yuan *et al.*, 2007. 10, 12. right lateral view of carapaces. Collection numbers X0301-139 and X0301-140; **11.** ventral view of carapace. Collection number X0301-141; **13.** right lateral view of carapace. Collection number X0301-298.

Figs 14-18 Bairdiidae sp.1. 14. inner view of incomplete right valve. Collection numbers X0301-253; **15.** right lateral view of carapace. Collection number X0301-313; **16.** inner view of right valve. Collection number X0301-174; **17, 18.** external view of right valves. Collection numbers X0301-171 and X0301-173.

Plate 6

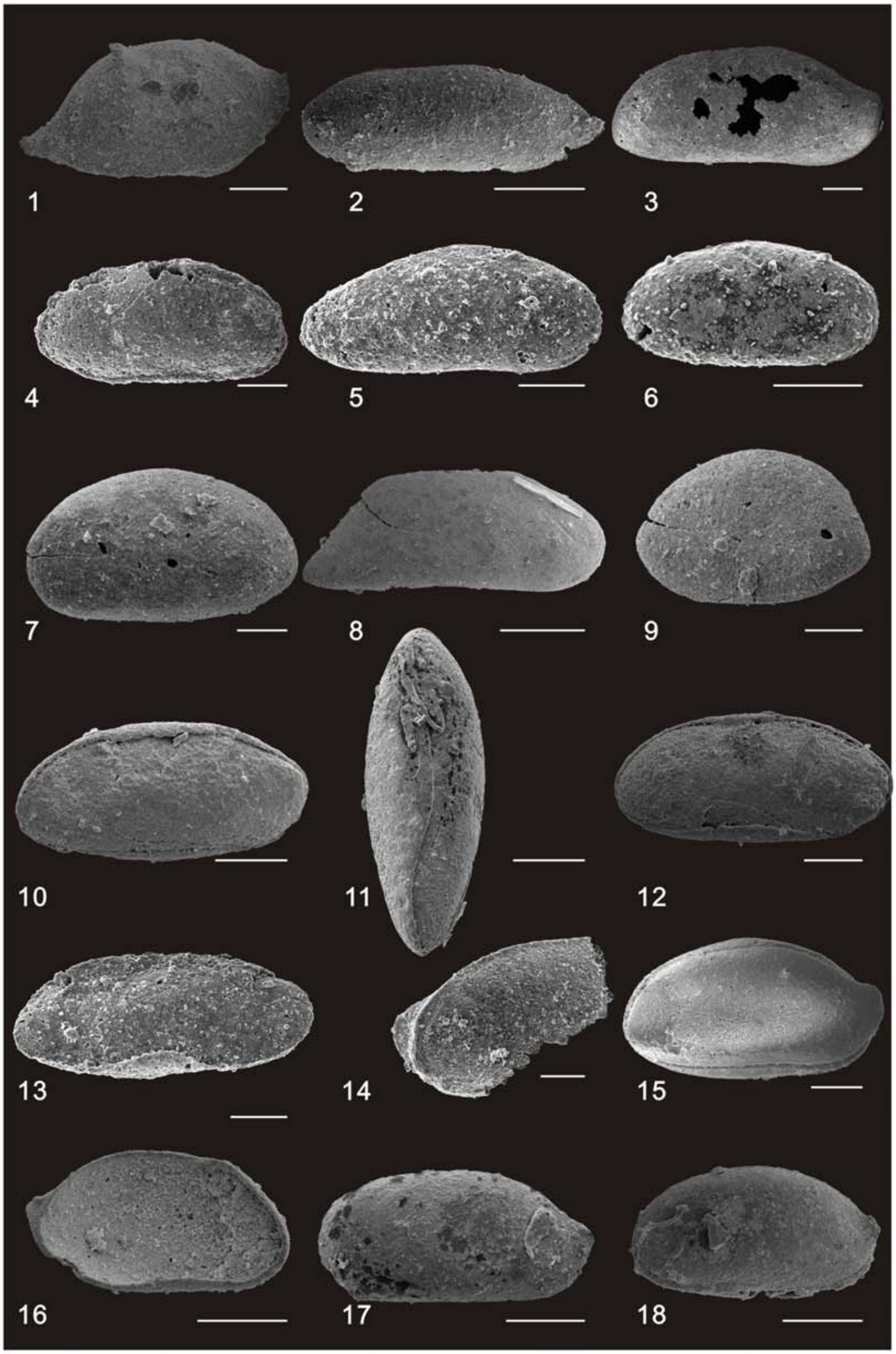

Plate 7

Scale bar is 100µm except in fig.16 where it is 200µm.

Figs 1-12 *Fabalicypris parva* Wang, 1978. 1, 2, 10. external view of right valves. Collection numbers X0301-286, X0301-287 and X0301-295; **3-7.** right lateral view of carapaces. Collection numbers X0301-288 to X0301-292; **8, 9.** inner view of right valves. Collection numbers X0301-293 and X0301-294; **11, 12.** external view of left valves. Collection numbers X0301-296 and X0301-297.

Figs 13, 14 *Fabalicypris* sp.1. Right lateral view of carapaces. Collection numbers X0301-299 and X0301-300.

Fig.15 Bythocytheridae gen. *et* sp. indet. *sensu* Yuan *et al.*, 2007. External view of right valve. Collection number X0301-144.

Fig.16 *Acratia* sp.1. External view of left valve. Collection number X0301-254.

Fig.17 *Cooperuna* cf. *tenuis* Kozur, 1985a *sensu* Yuan *et al.*, 2007. External view of right valve. Collection number X0301-136.

Fig.18 Bythocytheridae indet. 2. External view of left valve. Collection number X0301-255.

Plate 7

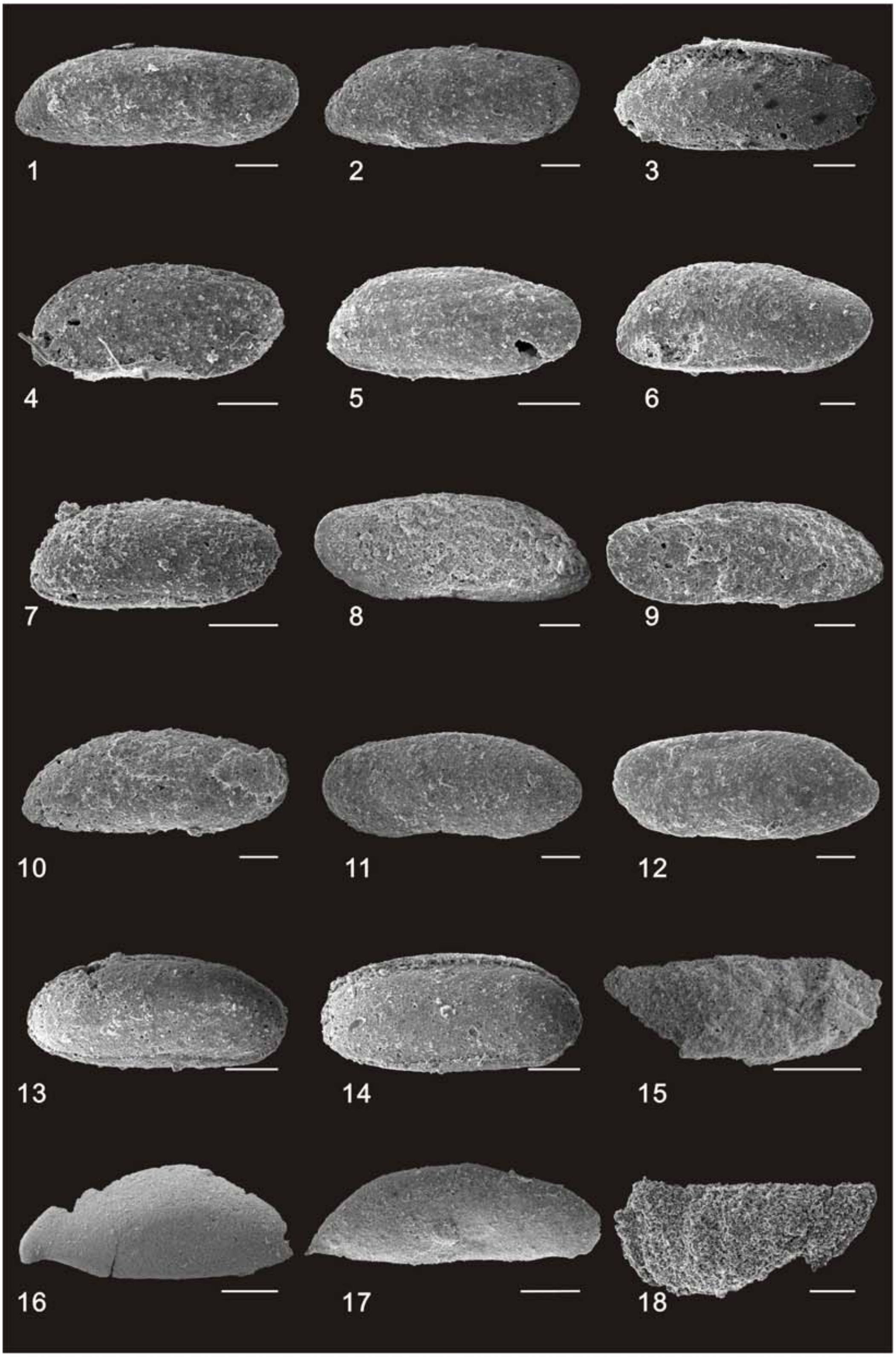

Plate 8

Scale bar is 100µm except in figs 3, 7 where it is 50µm.

Fig.1 ***Monoceratina*** **sp. 1** ***sensu*** **Yuan** ***et al.*****, 2007.** External view of right valve. Collection number X0301-146.

Fig.2 ***Monoceratina*** **? sp. 2** ***sensu*** **Yuan** ***et al.*****, 2007.** External view of right valve. Collection number X0301-145.

Fig.3 ***Bohemina*** **(*****Pokornina*****) ? sp.1** ***sensu*** **Gründel & Kozur, 1975.** External view of left valve. Collection number X0301-149.

Fig.4 ***Bohemina*** **(*****Pokornina*****) ? cf. sp.1** ***sensu*** **Gründel & Kozur, 1975.** External view of left valve. Collection number X0301-256.

Figs 5, 6 ***Paraberounella*** **? cf.** ***laterospina*** **Kozur, 1991a** ***sensu*** **Yuan** ***et al.*****, 2007.** External view of left valves. Collection numbers X0301-148 and X0301-147.

Fig.7 ***Paraberounella*** **sp. 1** ***sensu*** **Yuan** ***et al.*****, 2007.** External view of left valve. Collection number X0301-147.

Fig.8 Rectonariidae gen. ***et*** **sp. indet.** ***sensu*** **Yuan** ***et al.*****, 2007.** External view of right valve. Collection number X0301-150.

Fig.9 ***Rectonaria*** **cf.** ***inclinata*** **Gründel, 1961** ***sensu*** **Yuan** ***et al.*****, 2007.** External view of left valve. Collection number X0301-152.

Figs 10-15 ***Denticupachydomella spinosa*** **n.gen.n.sp.. 10.** right lateral view of carapace, holotype, collection number X0301-183; **11.** external view of left valve, paratype, collection number X0301-184; **12.** external view of left valve, paratype, collection number X0301-186; **13**. inner view of left valve, paratype, collection number X0301-185; **14.** external view of left valve, collection number X0301-187; **15.** external view of right valve, collection number X0301-188.

Plate 8

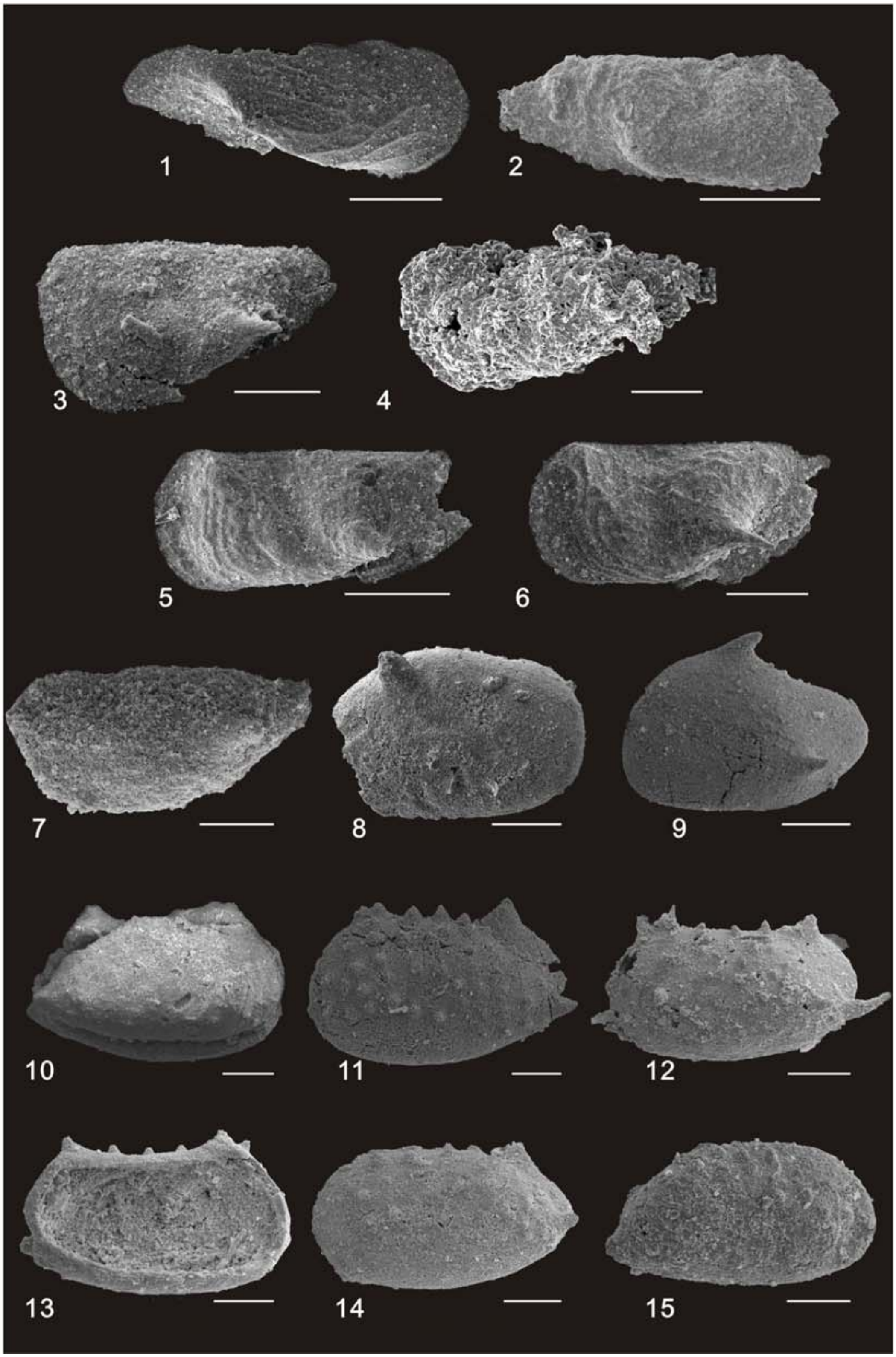

Plate 9

Scale bar is 100µm.

Fig.1 ***Microcheilinella*** **cf.** ***elatus*** **(Lethiers, 1978)** ***sensu*** **Lethiers,1981.** Right lateral view of carapace. Collection number X0301-143.

Fig.2 ***Microcheilinella aculeata*** **Buschmina, 1975.** Right lateral view of carapace. Collection number X0301-165.

Fig.3 ***Microcheilinella*** **sp.1.** Right lateral view of carapace. Collection number X0301-257.

Figs 4-6 ***Spinomicrocheilinella anterocompressa*** **Yuan & Crasquin-Soleau, 2007. 4.** external view of right valve, paratype, collection number X0301-105; **5.** external view of right valve, paratype, collection number X0301-106; **6.** right lateral view of carapace, holotype, collection number X0301-104.

Figs 7-9, 12 ***Spinomicrocheilinella*** **aff.** ***dargenioi*** **Kozur, 1991a** ***sensu*** **Yuan** ***et al.*****, 2007. 7, 8.** external view of right valves. Collection numbers X0301-154 and X0301-155; **9.** external view of right valve. Collection number X0301-278; **12.** inner view of right valve. Collection number X0301-279.

Figs 10, 11 ***Spinomicrocheilinella*** **sp. 1** ***sensu*** **Yuan** ***et al.*****, 2007.** External view of right valves. Collection numbers X0301-157 and X0301-159.

Fig.13 ***Spinomicrocheilinella*** **sp. 2** ***sensu*** **Yuan** ***et al.*****, 2007.** Right lateral view of carapace. Collection number X0301-158.

Figs 14, 15 ***Spinomicrocheilinella*** **sp.3.** External view of right valves. Collection numbers X0301-258 and X0301-259.

Fig.16 ***Spinomicrocheilinella*** **sp.4.** External view of right valve. Collection number X0301-277.

Figs 17, 18 ***Pseudobythocypris concava*** **(Cooper, 1941). 17.** right lateral view of carapace. Collection number X0301-301; **18.** inner view of left valve. Collection number X0301-302.

Plate 9

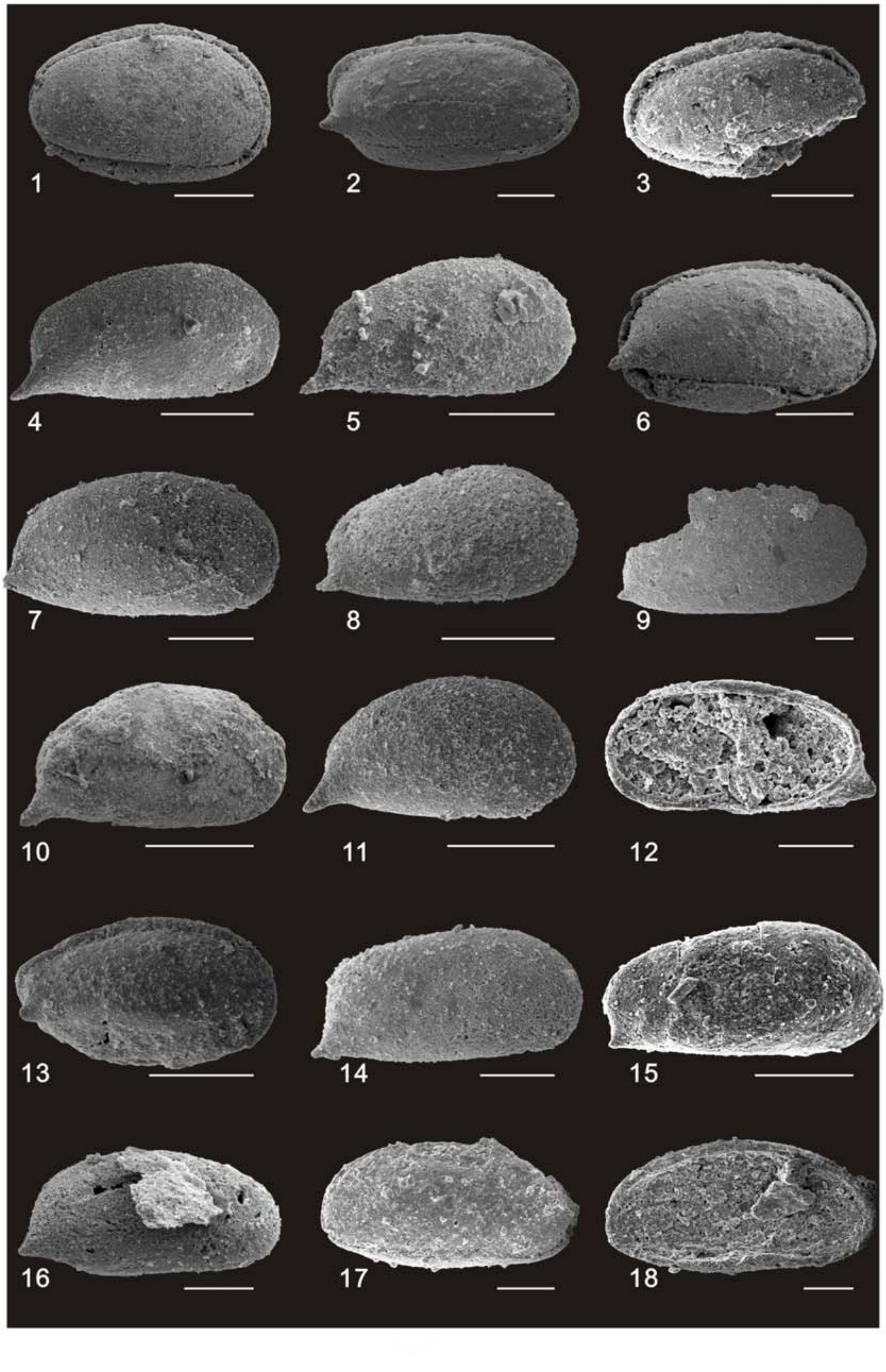

Plate 10

Scale bar is 100µm.

Figs 1-8 ***Pseudobythocypris guiqianensis*** **n.sp.. 1.** right lateral view of carapace, holotype: collection number X0301-162; **2.** external view of left valve, paratype, collection number X0301-160; **3.** external view of right valve, paratype, collection number X0301-228. **4, 6.** external view of right valves. Collection number X0301-229 and X0301-231; **5.** external view of left valve. Collection number X0301-230; **7, 8.** inner view of right valves. Collection number X0301-232 and X0301-233.

Fig.9 ***Pseudobythocypris*** **cf.** ***guiqianensis*** **n.sp..** External view of left valve. Collection number X0301-260.

Figs 10, 11 ***Pseudobythocypris*** **sp.1** ***sensu*** **Yuan** ***et al.*****, 2007. 10.** external view of left valve. Collection number X0301-166; **11.** external view of left valve. Collection number X0301-167.

Fig.12 ***Cavellina*** **cf.** ***nebrascensis*** **(Geinitz, 1867)** ***sensu*** **Yuan** ***et al.*****, 2007.** Left lateral view of carapace. Collection number X0301-170.

Figs 13-15 ***Pseudobythocypris*** **sp.2. 13.** external view of right valve. Collection number X0301-304; **14, 15.** external view of left valves. Collection numbers X0301-305 and X0301-306.

Fig.16 ***Healdia*** **sp. 1** ***sensu*** **Yuan** ***et al.*****, 2007.** External view of right valve. Collection number X0301-168.

Fig.17 ***Healdia*** **sp.2.** External view of right valve. Collection number X0301-224.

Fig.18 ***Healdiopsis thuringensis thuringensis*** **(Gründel, 1961).** Inner view of left valve. Collection number X0301-169.

Plate 10

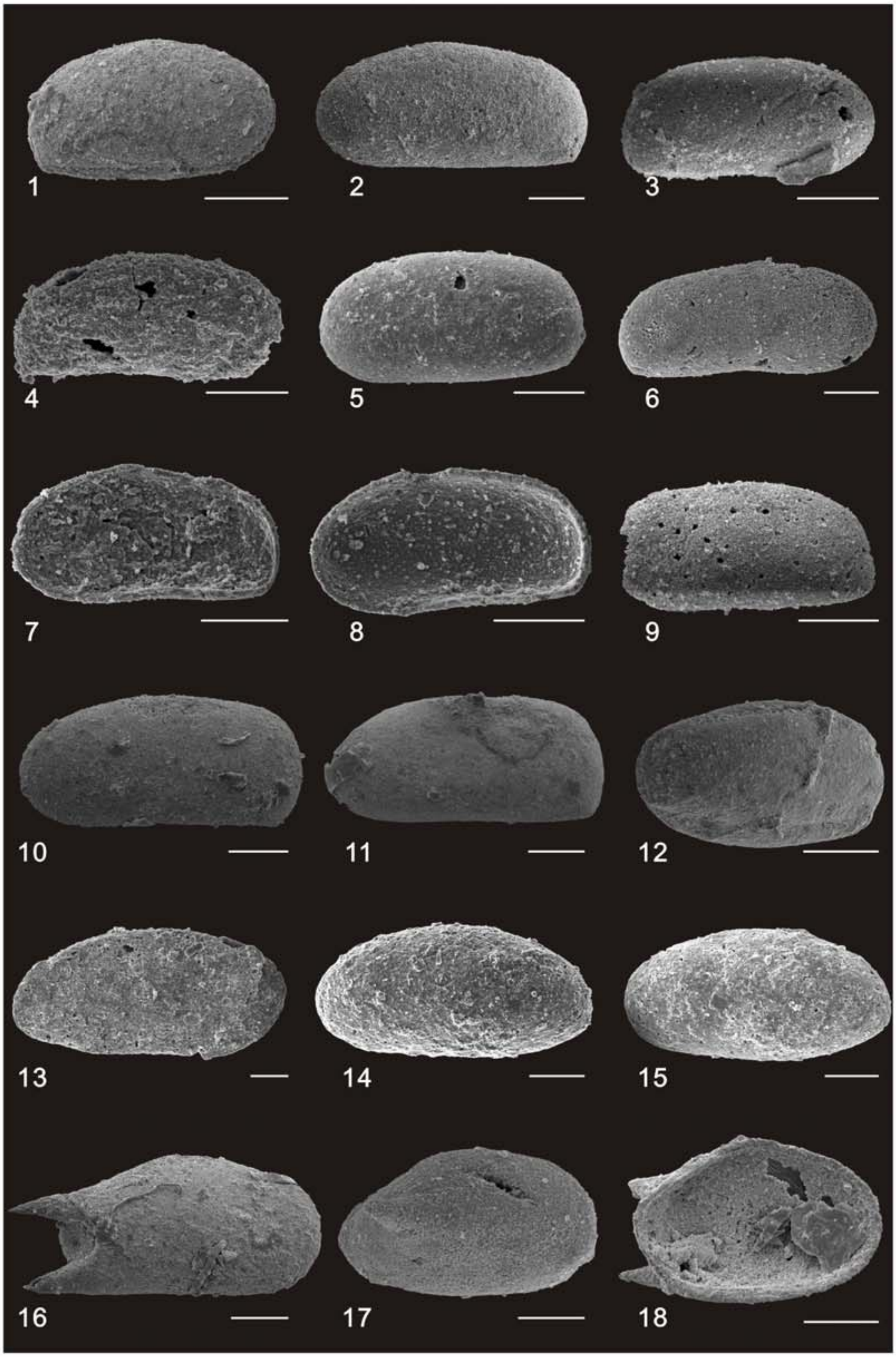

Plate 11

Scale bar is 100µm except in fig.2 where it is 200µm.

Fig.1 ***Marginohealdia*** **cf. sp.nov.2** ***sensu*** **Crasquin-Soleau** ***et al.*** **(in press).** External view of right valve. Collection number X0301-261.

Fig.2 ***Waylandella*** **cf.*dartyensis*** **Benson & Collinson, 1958.** External view of right valve. Collection number X0301-262.

Fig.3 ***Triplacera*** **? sp. 1.** External view of right valve. Collection number X0301-263.

Figs 4-9 ***Marginohealdia*** **sp.1. 4.** External view of left valve e; **5.** inner view of right valve; **6-9.** external view of right valves. Collection numbers X0301-264 to X0301-269.

Figs 10, 11 ***Absina*** **? sp.1** ***sensu*** **Yuan** ***et al.*****, 2007.** External view of right valves. Collection numbers X0301-175 and X0301-225.

Fig.12 ***Absina*** **? sp.2** ***sensu*** **Yuan** ***et al.*****, 2007.** External view of right valve. Collection number X0301-176.

Fig.13 Podocopida indet.1. External view of left valve. Collection number X0301-270.

Fig.14 Podocopida indet.2. External view of right valve. Collection number X0301-271.

Fig.15 Podocopida indet.3. External view of right valve. Collection number X0301-272.

Fig.16 Podocopida indet.4. Right lateral view of carapace. Collection number X0301-273.

Fig.17 Podocopida indet.5. External view of right valve. Collection number X0301-274.

Fig.18 Podocopida indet.6. Right lateral view of carapace. Collection number X0301-275.

Plate 11

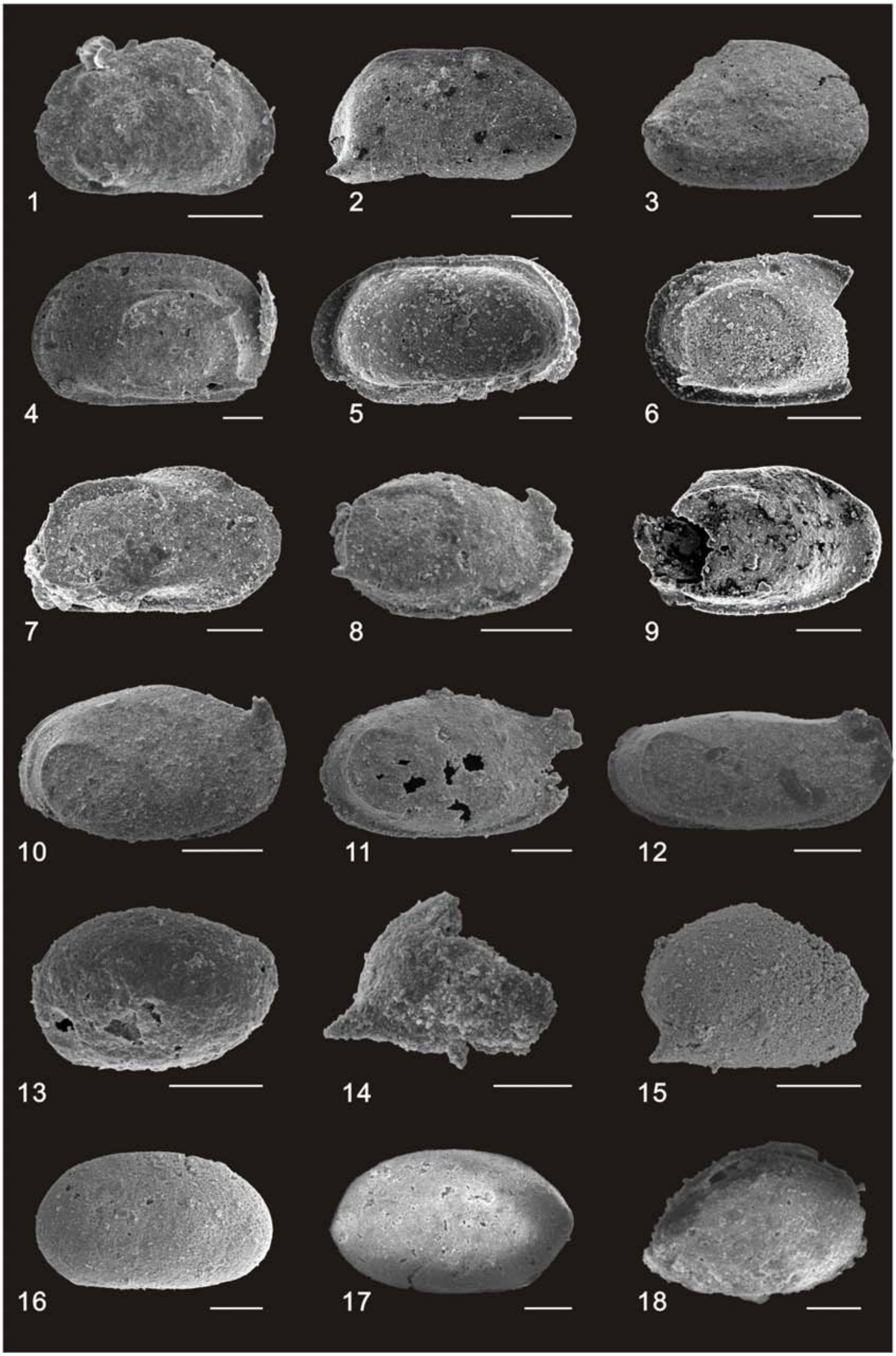

Plate 12

Scale bar is 100µm.

Fig.1 Podocopida indet.7. External view of valve. Collection number X0301-303.

Figs 2, 3 *Waldeckella* ? *sphaerula* (Gründel, 1961) *sensu* Becker, 1999. External view of left valves. Collection numbers X0301-177 and X0301-178.

Figs 4, 5 *Polycope* aff. *baudi* Crasquin-Soleau, 1996 *sensu* Yuan *et al.*, 2007. 4. external view of left valve. Collection number X0301-180; **5.** external view of right valve. Collection number X0301-226.

Fig.6 *Polycope* sp. 1 *sensu* Yuan *et al.*, 2007. External view of right valve. Collection number X0301-179.

Figs 7, 8 *Polycope* sp. 3. 7. external view of valve; **8.** inner view of valve. Collection numbers X0301-307 and X0301-308.

Figs 9, 10 *Discoidella xingyangensis* Zhang, 1987. External view of left valves. Collection numbers X0301-181 and X0301-227.

Figs 11-13 *Polycope* sp. 2. 11. inner view of valve; **12, 13.** external view of valves. Collection numbers X0301-309, X0301-310 and X0301-311.

Plate 12