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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

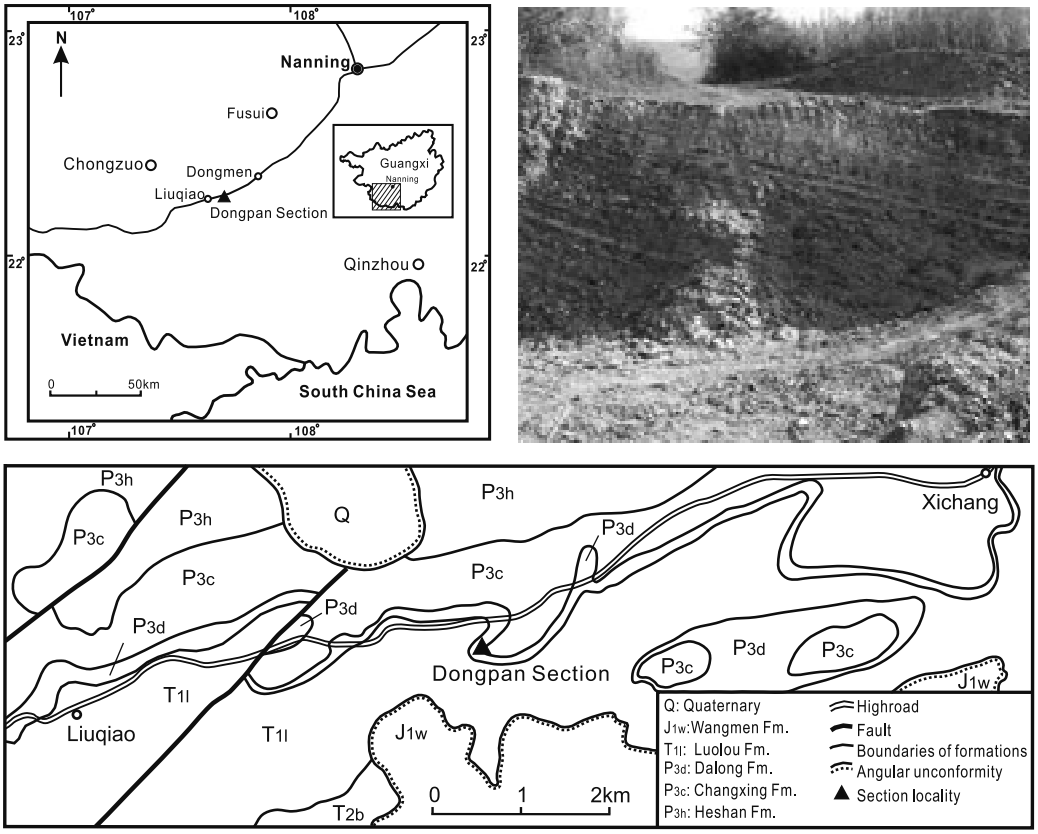

Fig. 1. Geographical and geological setting of Dongpan Section (after Feng *et al.*, 2006*a*).

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,

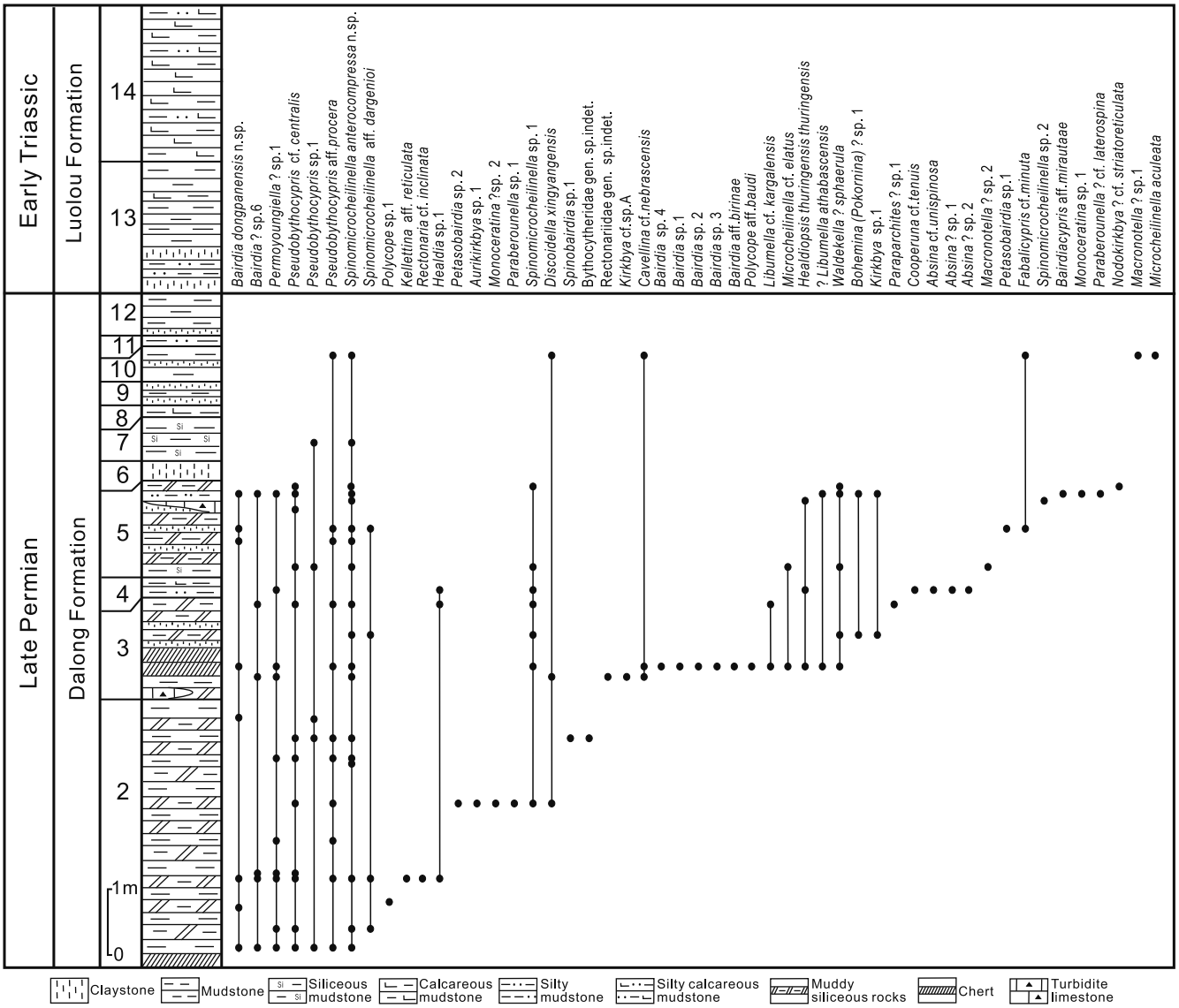

Fig. 2. Stratigraphic distribution of ostracods identified in this paper.

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.

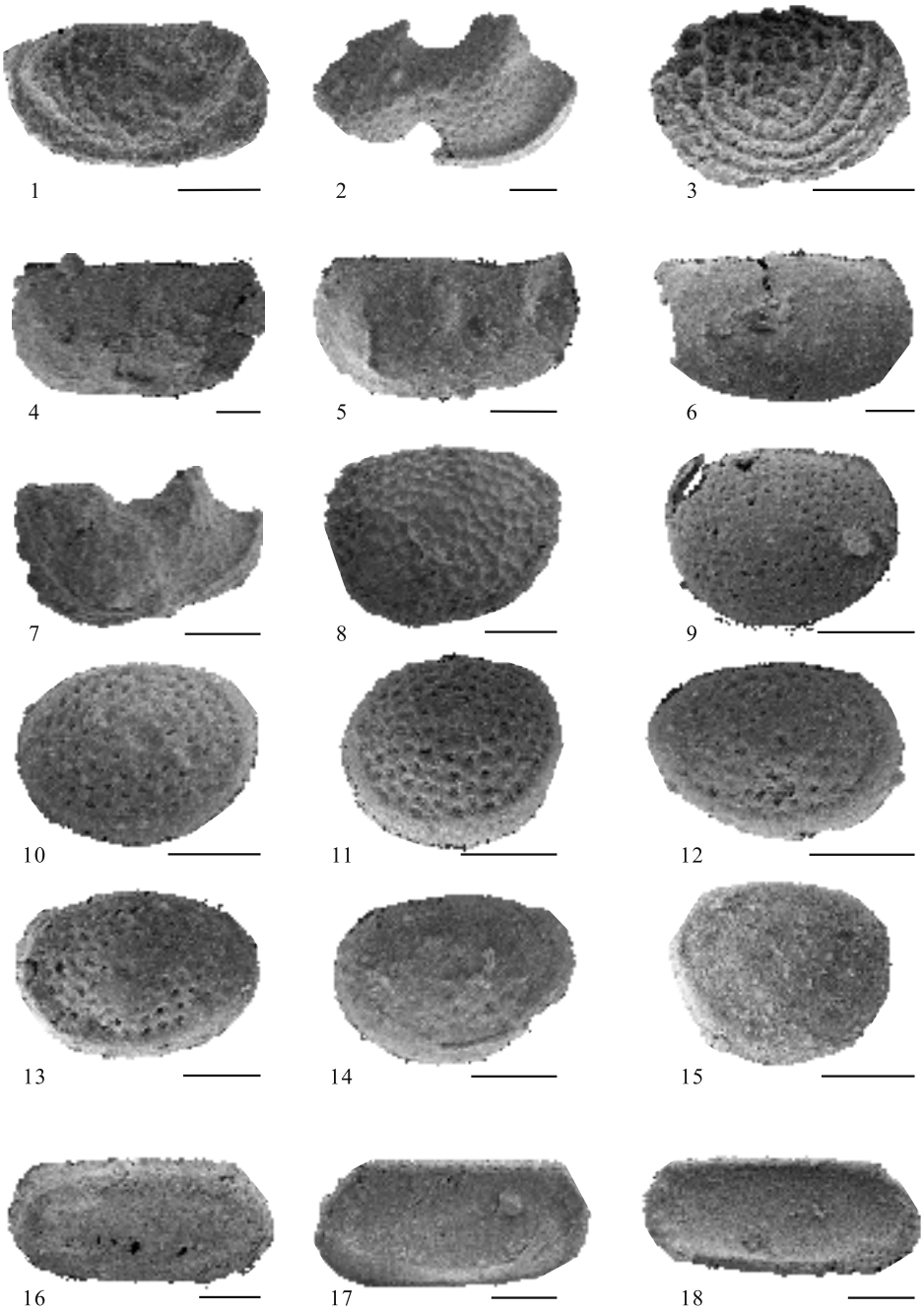

Plate 1.

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.

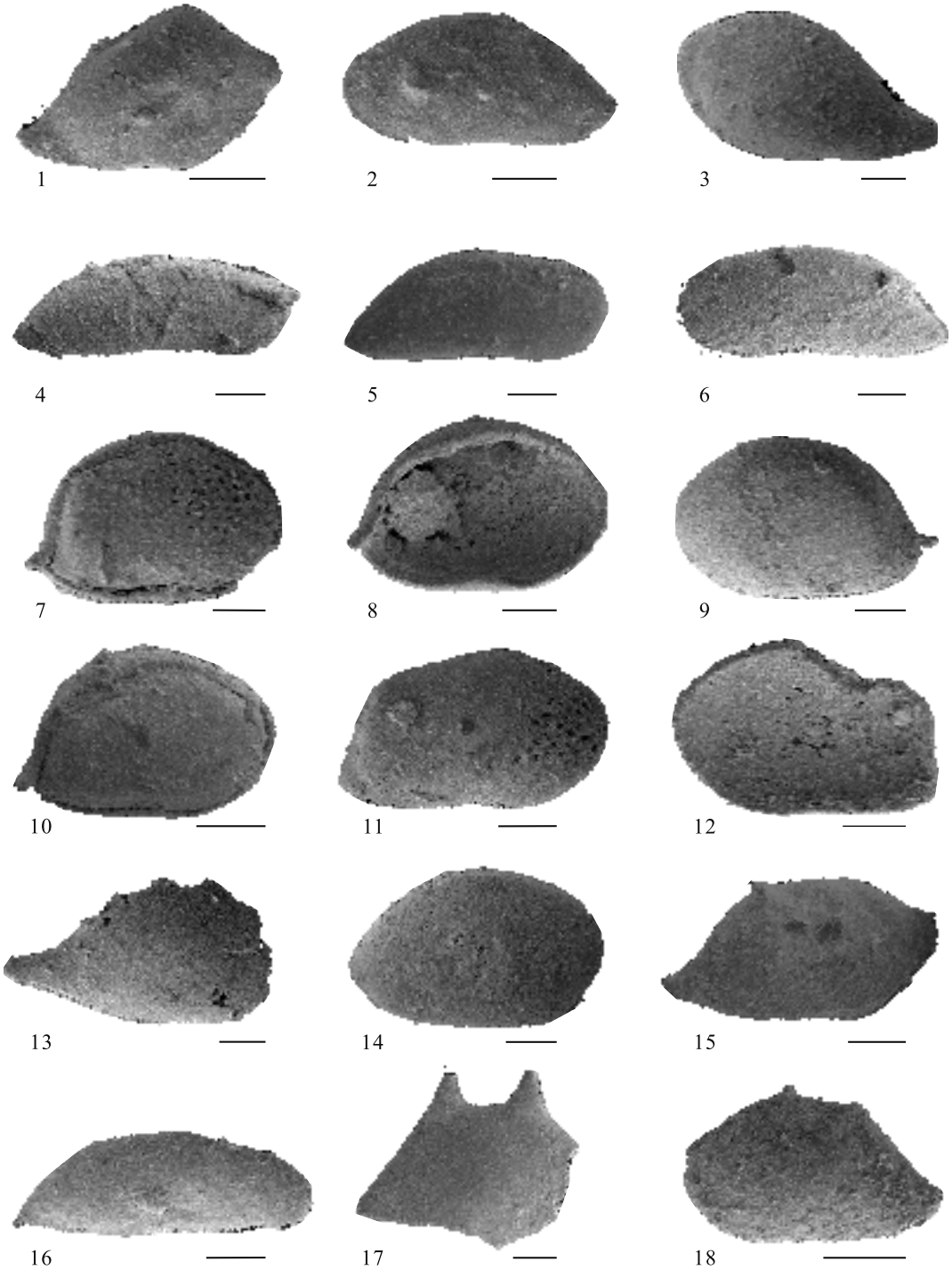

Plate 2.

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.

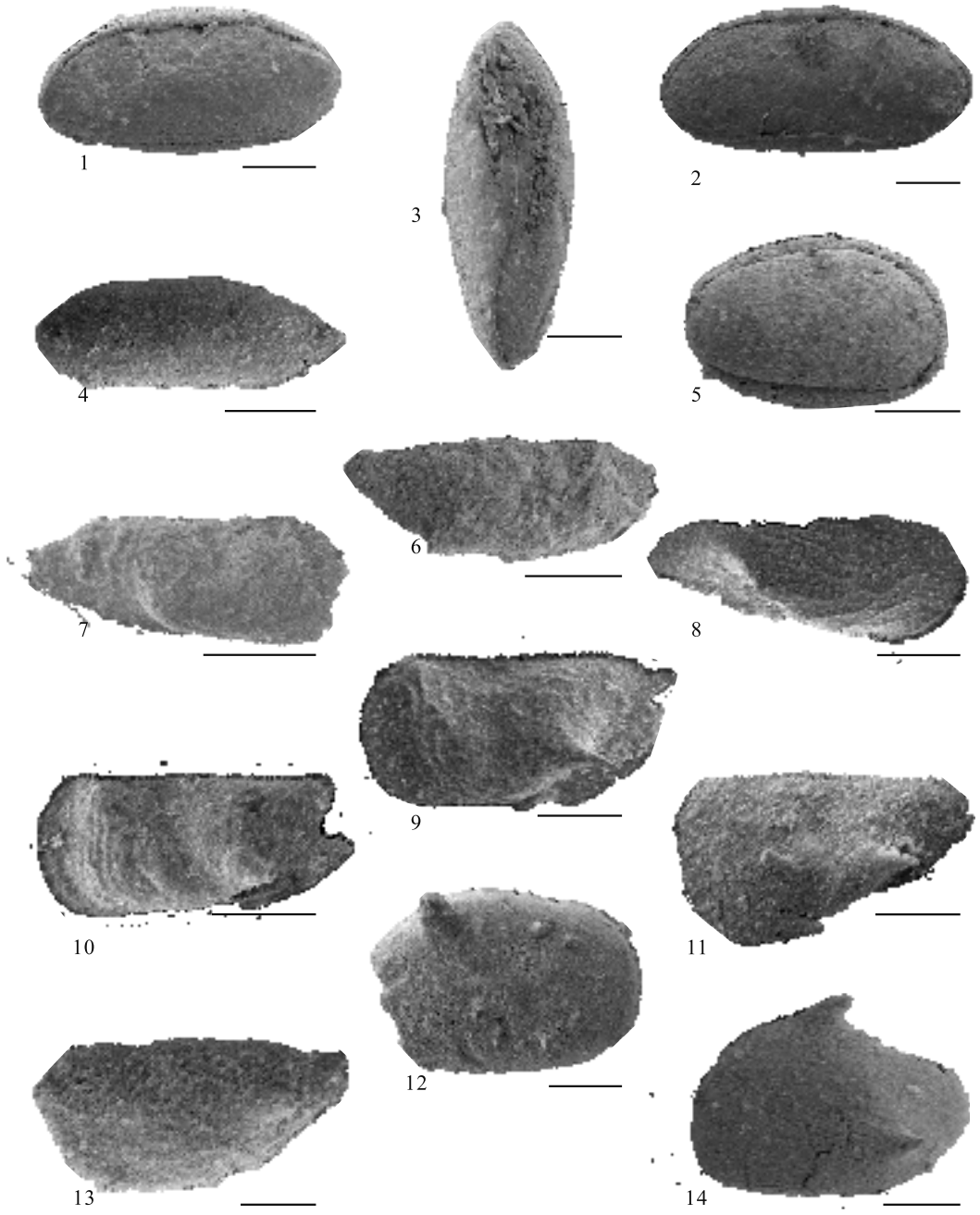

Plate 3.

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

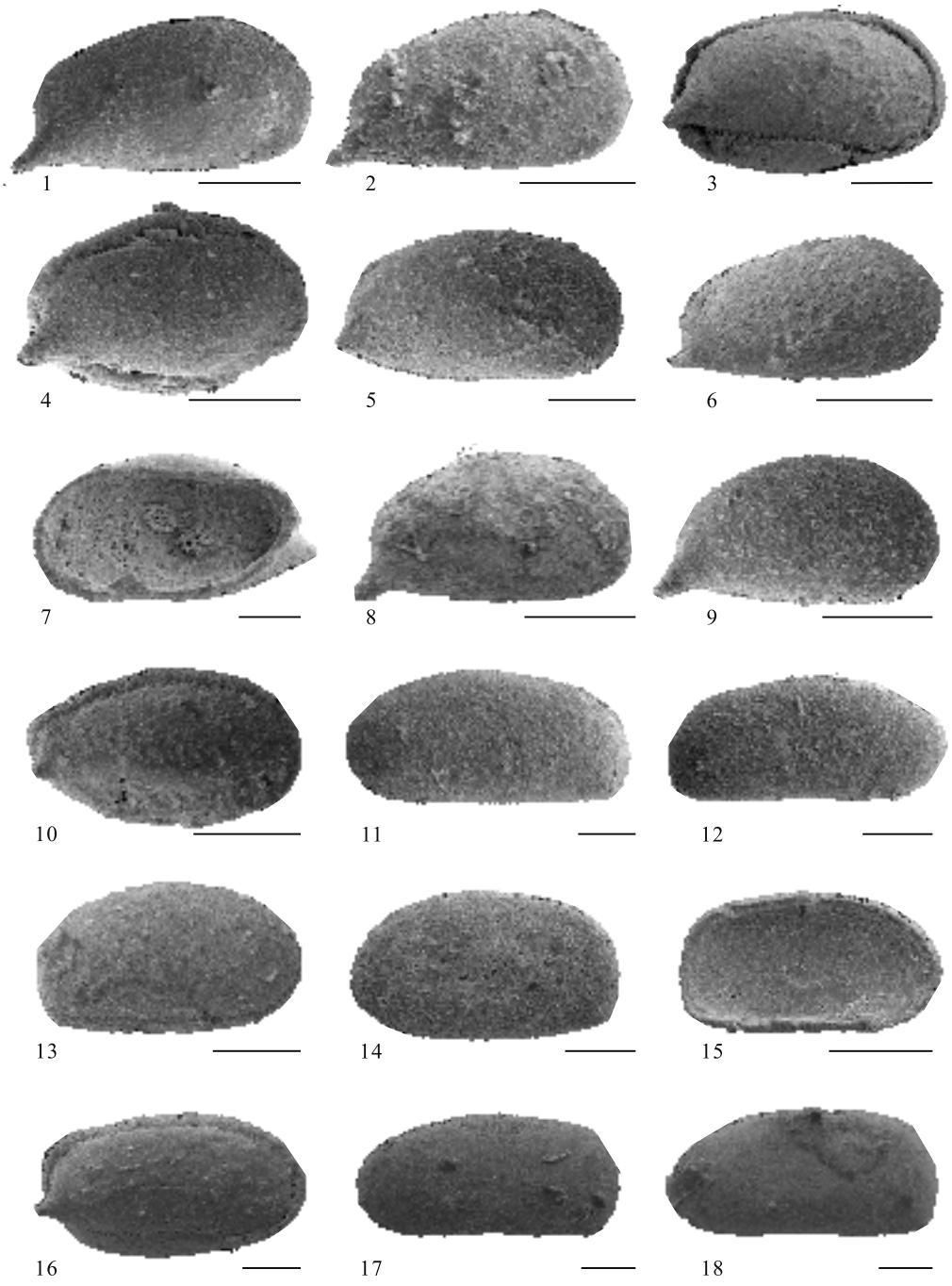

Plate 4.

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.

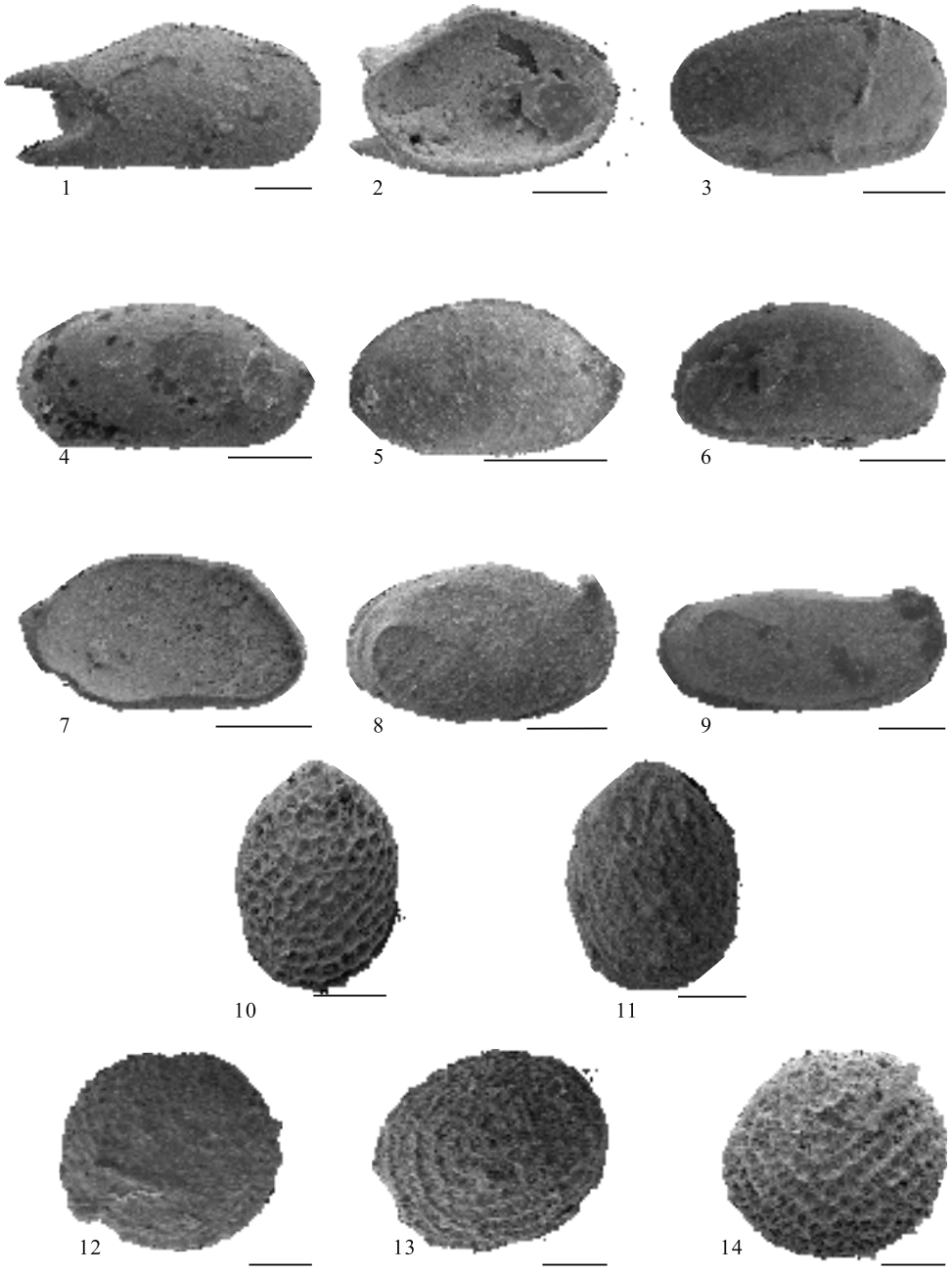

Plate 5.

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 &

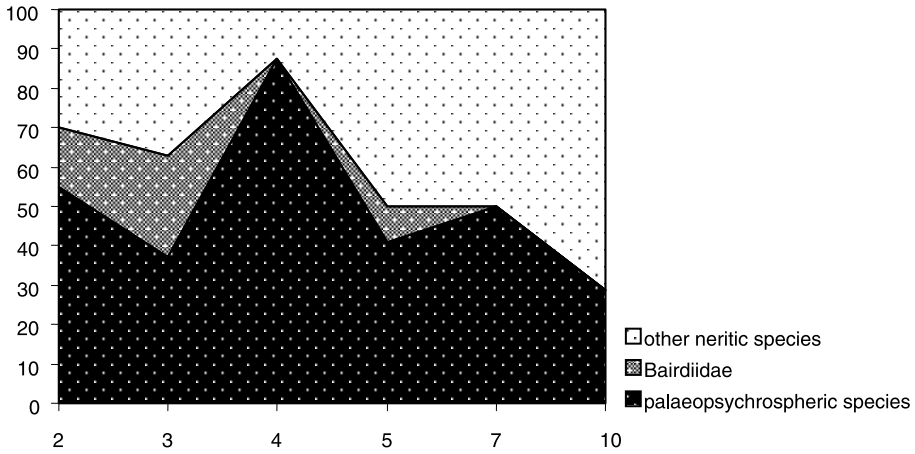

Fig. 3. Ostracod composition in each bed of the Dongpan Section. In abscissa: percentage of species; in ordinate: sample numbers.

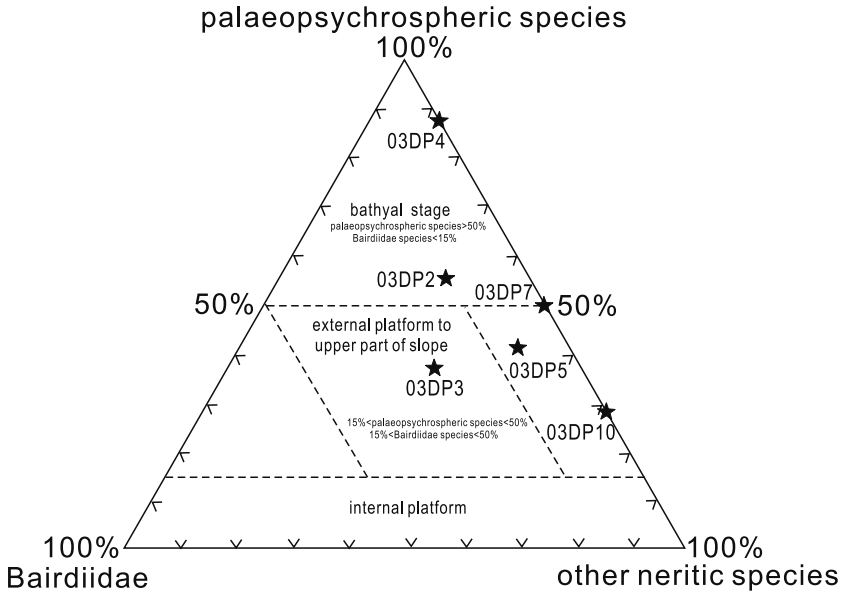

Fig. 4. Triangular diagram of ostracod composition, bed by bed (based on Lethiers & Raymond, 1991).

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.

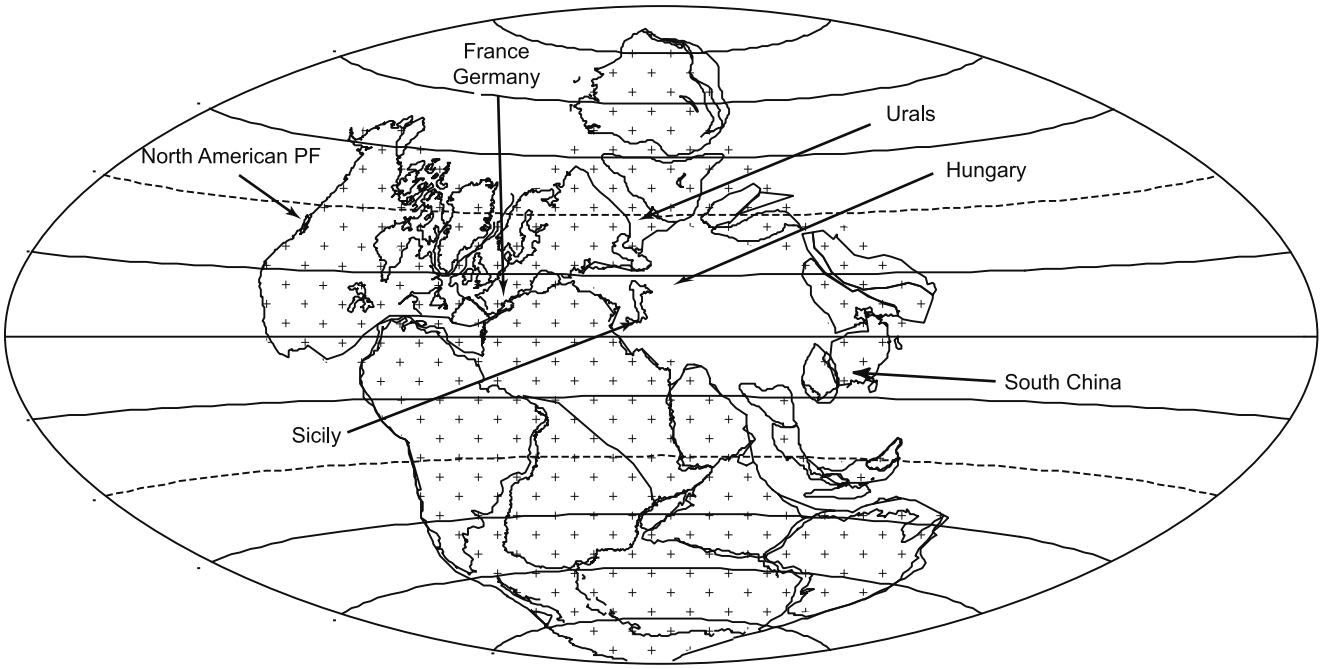

Fig. 5. Wordian palaeogeographical map – Pangaea B reconstruction (modified after Crasquin-Soleau *et al.*, 2001). PF: platform.

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 southwest 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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