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Ostracod faunas from the Dalazi and Tongfosi formations (Yanji Basin, northeast China): Biostratigraphic, palaeogeographic and palaeoecological implications

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ABSTRACT

This work provides a detailed taxonomic study of ostracod species from the Dalazi and Tongfosi formations of the Yanji Basin (Jilin Province, NE China). Fourteen species including one new species belonging to nine genera have been recovered: *Scabriculocypris tonfosiensis*, *Scabriculocypris yanbianensis*, *Cypridea concinaformis*, *Mongolocypris yanjiensis*, *Mongolianella kyranbeki* sp. nov., *Lycopterocypris infantilis*, *Lycopterocypris* sp., *Yumenella toorojensis*, *Candona* spp., *Cyprois* sp., *Vlakomia ustinovskii* and *Vlakomia jilinensis*. With the recovery of well-preserved specimens, the sieve pore, ontogeny and sexual dimorphism of *Vlakomia jilinensis* and *Vlakomia ustinovskii* are recognized for the first time. The ostracod biostratigraphic correlations suggest that the age of the Tongfosi Formation is Albian and may extend upwards into the Upper Cretaceous, and the Dalazi Formation is not older than the Albian, probably of early Late Cretaceous age. The ostracod faunas of the Tongfosi and Dalazi formations show affinities to faunas of Eastern Mongolia and South Korea, providing evidence of potential faunal exchanges between Northeastern China, Eastern Mongolia and South Korea during the Albian to early Late Cretaceous time. On the basis of their ostracod faunas, the Tongfosi and Dalazi formations represent a shallow-littoral lacustrine depositional environment that potentially included small ephemeral water bodies.

1. Introduction

Ostracods, small crustacean arthropods characterised by a bivalved carapace that can totally enclose the body, have an excellent fossil record extending back to the Ordovician (e.g. Horne, 2009). Mesozoic to Recent non-marine ostracod faunas comprise taxa of the superfamilies Cypridoidea, Cytheroidea, and Darwinuloidea. Their remains are commonly abundant and widely distributed in sediments that accumulated in non-marine environments. This makes them as very useful indicators for palaeoenvironmental reconstruction, biostratigraphic studies and use in correlation of non-marine successions (e.g. Horne, 2002; Sames, 2011a,b; Sames and Horne, 2012; Wang et al., 2012, 2013, 2015).

The ostracod faunas from the Tongfosi and Dalazi formations of the Yanji Basin were first reported by Gou (1983). Since then, only one study has been carried out on Cretaceous ostracods from the Yanji Basin (Ye and Zhang, 1995). Gou (1983) provided the detailed descriptions of some ostracod species, but Ye and Zhang (1995) only listed ostracod species names from the Tongfosi and Dalazi formations of the Yanji Basin. However, the ontogeny, sexual dimorphism and carapaces/valves internal features of some ostracod taxa were not recognized in previous studies, because of the lack of well-preserved specimens. Additionally, the palaeoecology and palaeogeography of the non-marine ostracods of the Yanji Basin has only briefly been dealt with by Li et al. (2016). The age constraints of the Tongfosi and Dalazi formations have been under discussion for decades, and are controversial to date (e.g., Zhou et al., 1980; Gou, 1983; Zhang, 1986; Qiao et al., 2003; Nichols et al., 2006).

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In this paper, we restudy the ostracod faunas from the Tongfosi and Dalazi formations of the Yanji Basin based on newly collected samples. Our ostracod biostratigraphic data provide new age constraints for the non-marine Tongfosi and Dalazi formations. The ostracod faunas of the Tongfosi and Dalazi formations are also analysed with respect to their palaeoenvironmental and palaeogeographic interpretation.

2. Geological setting

The Yanji Basin is located in eastern Jilin Province, northeast China, near the boundary of China and North Korea (Fig. 1). The basement of the Yanji Basin consists of Palaeozoic granite (Yuan et al., 2015) on which the Cretaceous successions rest unconformably. The Cretaceous strata in the Yanji Basin consist of four formations: the Changcai, Tongfosi, Longjing and Dalazi formations (in ascending order) (e.g. Zhou et al., 1980; Chen and Chang, 1994) or the Changcai, Tongfosi, Dalazi and Longjing formations (in ascending order) (e.g. Zhang, 1986; Sun and Zheng, 2000). Among them, the Tongfosi and Dalazi formations yield abundant ostracod fossils (Gou, 1983; Ye and Zhang, 1995).

Generally, the Tongfosi Formation is divided into three members. The first member consists of conglomerates, sandstones and mudstones (Ye and Zhang, 1995). The second member of this formation is composed of grey sandstones, black mudstones and shales (Ye and Zhang, 1995). The third member consists of black shales, grey siltstones, sandstones and white conglomerates (Ye and Zhang, 1995). The age of the Tongfosi Formation has been in dispute. Gou (1983) and Ye and Zhang (1995) proposed an Early Cretaceous age to this formation based on ostracod fossils. Zhang (1986) assigned a Barremian – Aptian age to the Tongfosi Formation based on plant fossils. Chen and Chang (1994) suggested a Hauterivian – Barremian age, while without direct evidence (see Chen and Chang, 1994, fig. 2). Chen (2003) suggested that the Tongfosi Formation correlates with the Sunjiawan Formation of the western Liaoning area based on bivalve fossils. Wang et al. (2015) assigned an Albian age to the Sunjiawan Formation based on ostracod fossils. Studies on dinoflagellates and algae fossils suggested a Hauterivian – Aptian age to the Tongfosi Formation (Qiao et al., 2003). Whereas, a recent palynology study suggested the age of this formation as early Late Cretaceous (Cenomanian) (Nichols et al., 2006). A fresh– slightly saline water environment of the Tongfosi Formation is supported by the occurrence of dinoflagellates and other algae (Qiao et al., 2003).

The Dalazi Formation consists of well-developed conglomerates, sandstones, mudstones and fine laminated shales (including oil shales), indicating fluvial-lacustrine depositional environments (e.g., Zhang, 1986). The age of the Dalazi Formation is late Early Cretaceous (Aptian – Albian) based on fossil plants, pollens, spores, ostracods, clam shrimp and fossil fish (Chang et al., 1977; Zhou et al., 1980; Gou, 1983; Zhang, 1986; Tao and Zhang, 1990; Chen and Chang, 1994; Li et al., 2016). However, on the basis of insect fossils, Zhang (1997) assigned a Barremian to Aptian age to the Dalazi Formation. The pollens, spores and fossil plant assemblages indicate that the climate was warm and dry at the time when the Dalazi Formation deposited (Tao and Zhang, 1990; Huang and Zhang, 2002; Tao and Yang, 2003).

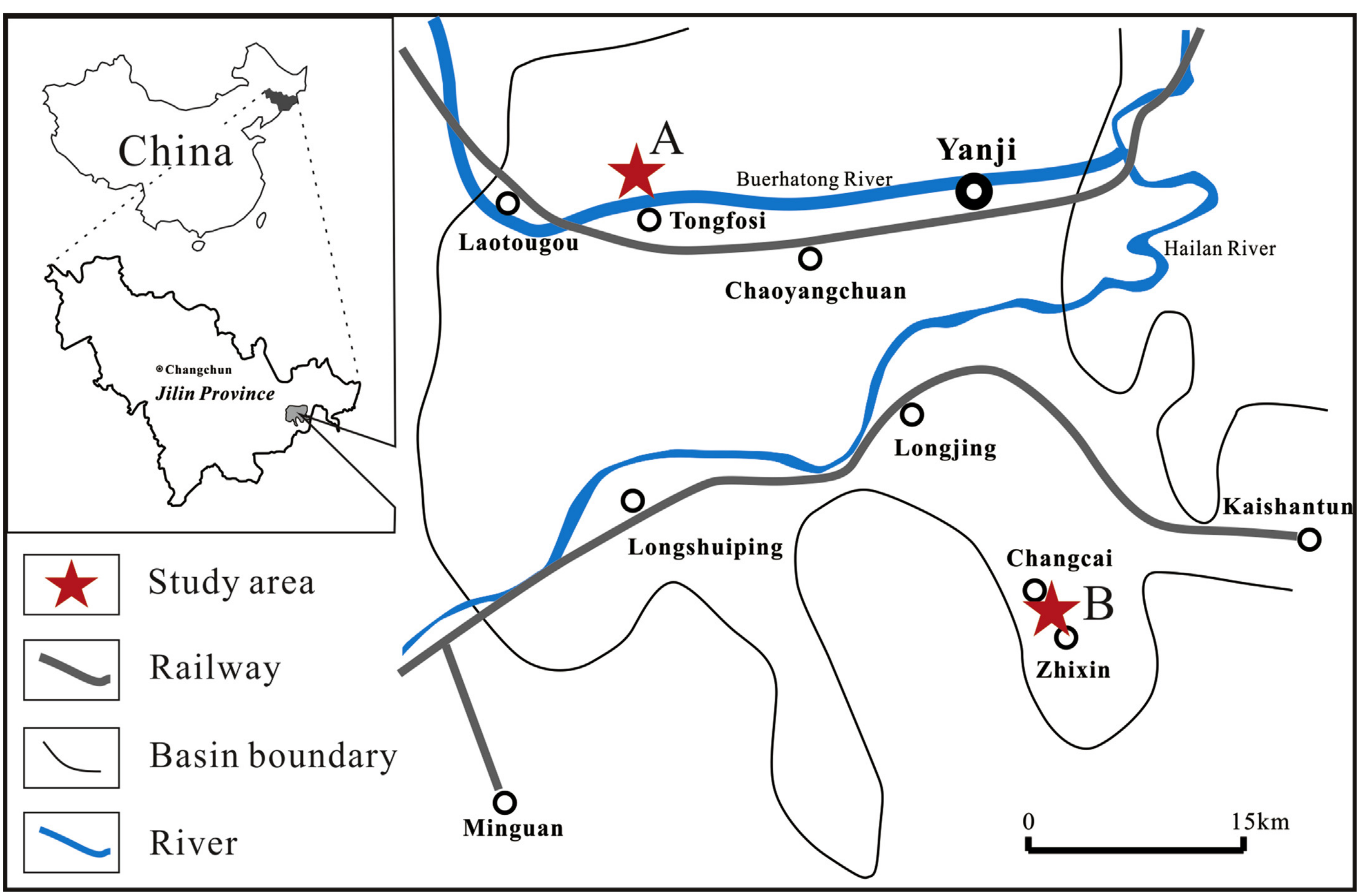

Fig. 1. Location map of the Tongfosi and Dalazi sections (modified from Qiao et al., 2003), A = Tongfosi Section; B = Dalazi Section.

3. Material and methods

Ostracod samples were collected from two sections: seven samples (sample number 16-TFS-3, 17-TFS-0 to 17-TFS-5, Figs. 2 and 3) from the Tongfosi section (Figs. 1 and 2) and twelve samples (sample number 16-DLZ-2 to 16-DLZ-5, 16-DLZ-7 to 16-DLZ-13 and 16-DLZ-17, Figs. 3 and 4) from the Longjing section (Figs. 1 and 4). The method introduced by Wang et al. (2016) is used to analysis the rock samples from the Dalazi section. However, ostracod shells from the black shales of the Tongfosi section are easily broken by using Wang et al. (2016)'s method. Thus, we used fine needles and blades to remove surrounding sediment of individual ostracod specimen under binocular microscope.

Ostracod carapaces and valves were scanned with LEO 1530 VP and Hitachi SU3500 scanning electron microscopes at the Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences (Nanjing, China). All specimens are housed in the Nanjing Institute of Geology and Palaeontology, Chinese Academy of

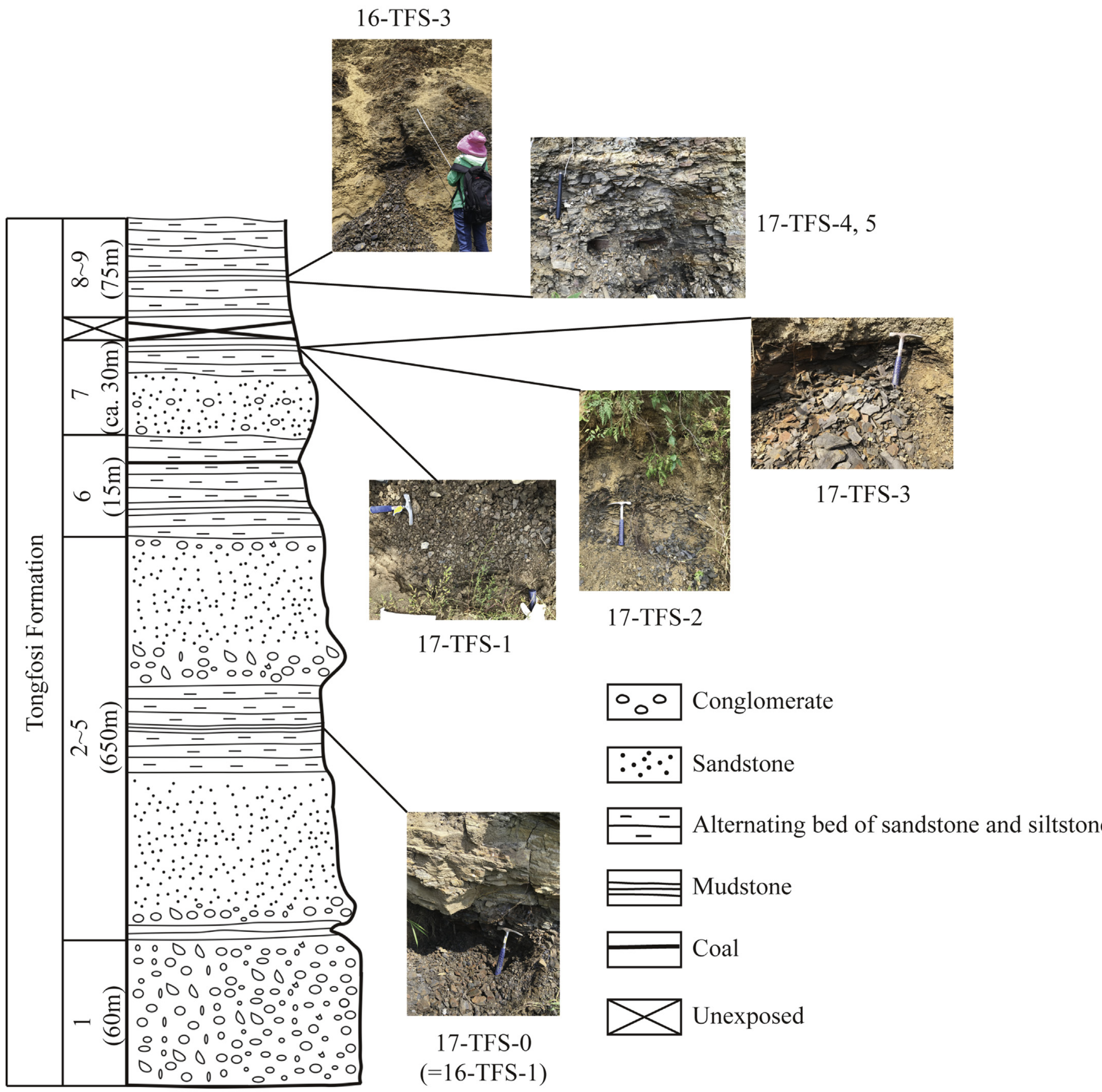

Fig. 2. Lithostratigraphic log of the Tongfosi Formation from the Tongfosi section based on the outcrop description of Zhou et al. (1980) and ostracod sample positions (17-TFS-0 (16-TFS-1): N 42° 53′ 40″ E 129° 14′ 07″; 17-TFS-1: N 42° 53′ 49″ E 129° 14′ 51″; 17-TFS-2: N 42° 53′ 37″ E 129° 14′ 53″; 17-TFS-3: N 42° 53′ 37″ E 129° 14′ 34″; 17-TFS-3: N 42° 53′ 37″ E 129° 14′ 34″; 17-TFS-4, 5: N 42° 53′ 30″ E 129° 14′ 42″; 16-TFS-3: N 42° 53′ 33″ E 129° 15′ 16″).

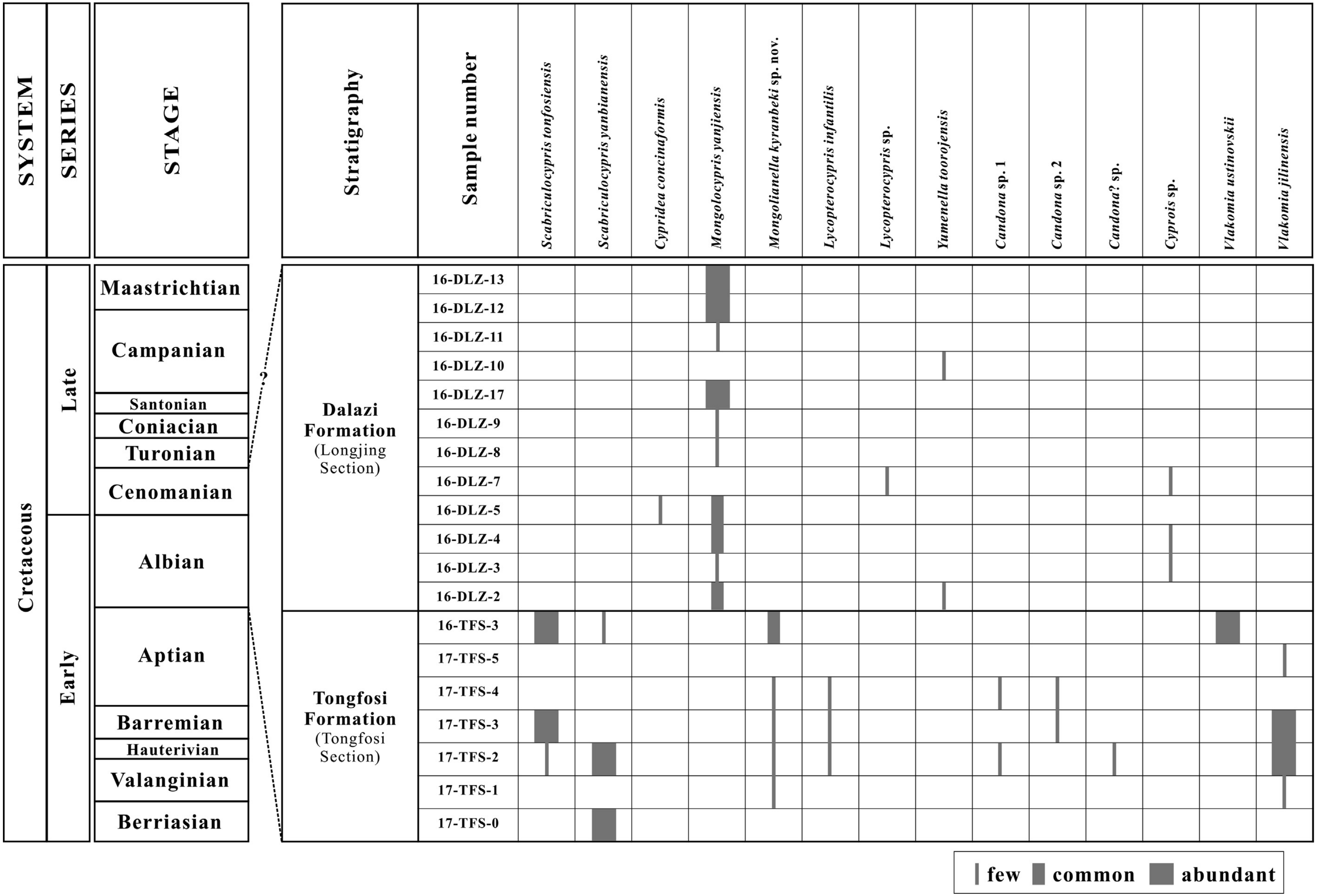

Fig. 3. Stratigraphic distribution and occurrence of ostracod species in the Tongfosi and Dalazi formations of the Yanji Basin.

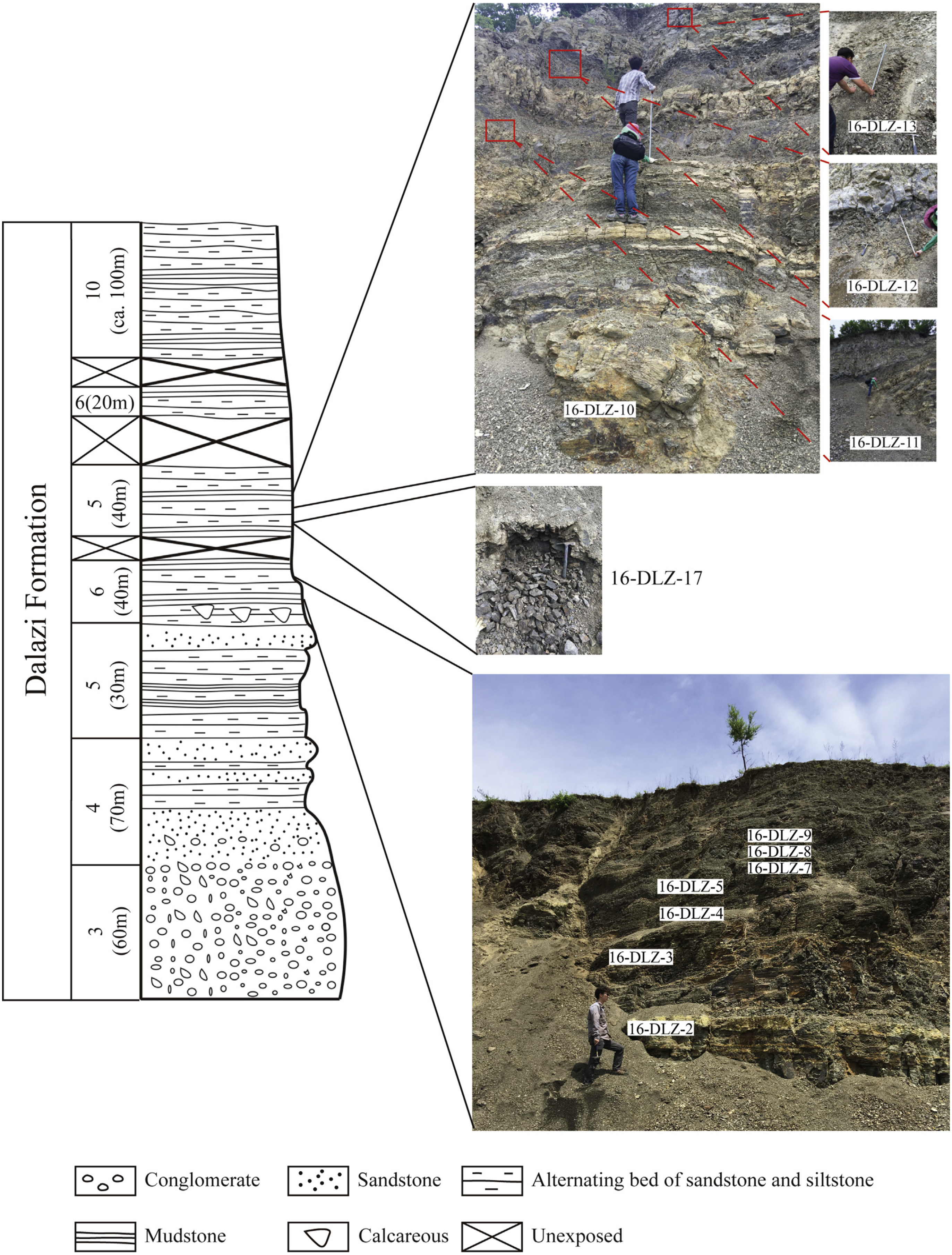

Fig. 4. Lithostratigraphic log of the Dalazi Formation from the Dalazi section based on the outcrop description of Zhou et al. (1980) and ostracod sample positions (16-DLZ-2, 3, 4, 5, 7, 8, 9: N 42° 39′ 58″ E 129° 32′ 57″; 16-DLZ-17: N 42° 39′ 53″ E 129° 33′ 06″; 16-DLZ-10, 11, 12, 13: N 42° 39′ 24″ E 129° 33′ 35″).

Sciences (NIGPAS), Nanjing, China under collection numbers given NIGP 168645–168712. We also re-scan the specimens which were described by Gou (1983) (collection number NIGP 68148–68185).

The ostracod species restudied in this paper have never given species' diagnoses in former reports. We gave the formal diagnoses of these species in this paper for the first time. Morphologic terminology of this study follows Sames (2011c, d). Abbreviations. H: height; L: length; W: width; LV: left valve; RV: right valve; AMS: adductor muscle scars; FS: frontal scars; MS: mandibular scars. Size intervals used are: very small: <0.40 mm, small: 0.40–0.50 mm, medium: 0.51–0.70 mm, large: 0.71–1.00 mm, very large: 1.01–2.00 mm, gigantic: >2.0 mm (e.g. Ayress and Whatley, 2014).

4. Systematic palaeontology

Class Ostracoda Latreille, 1802
Order Podocopida Müller, 1894
Suborder Cypridocopina Jones, 1901
Superfamily Cypridoidea Baird, 1845
Family Alloiocyprideidae Ayress and Whatley, 2014

Genus *Scabriculocypris* Anderson, 1941
Type species: *Scabriculocypris trapezoides* Anderson, 1941

Remarks. The genus *Scabriculocypris* had been assigned to several different (sub-)families by previous authors: the Subfamily Scabriculocypridinae of the Family Cyprideidae by Grekoff (1960), the Family Ilyocyprididae by Anderson and Bazley (1971), the Family Limnocyprididae by Hou et al. (2002), the Family Cyprididae by Horne (2002, p. 68) and Piovesan et al. (2013), and the Family Trapezoidellidae by Wang et al. (2016). However, the species of the extinct Family Cyprideidae have rostrum/beak and alveolus (alveolar notch and furrow) at anteroventral margin, and cyathus at posteroventral margin (Sames, 2011b); the species from the Family Ilyocyprididae develop one or two dorsomedian sulci (Meisch, 2000) and the species from the Family Trapezoidellidae show strong dorsal and ventral overreach/overlap (Sohn, 1979). According to Sohn (1979) the Family Limnocypridea Mandelstam (in Galeeva, 1955) is a *nomen nudum*, because the type genus *Limnocypridea* Lübimova, 1956 had not been validated in 1955. The Family Cyprididae has extant representatives, and the soft body/part morphology plays an important role in identification of the species from this family (Meisch, 2000). But, the soft part of *Scabriculocypris* has not been found yet. Here, we tentatively assign the Genus *Scabriculocypris* to the Family Alloiocyprideidae Ayress and Whatley, 2014, based on the general typical "*Cypridea*-like" carapace shape and absent rostrum, alveolus and cyathus

Scabriculocypris tonfosiensis Gou, 1983
Fig. 5A–F

1983 *Scabriculocypris tonfosiensis*, Gou, p. 48, pl. 1, figs. 12–13
2002 *Scabriculocypris tonfosiensis*, Hou et al., p. 618, pl. 1, figs. 12–13 (mis-spelled as *Scabriculocypris tongfosiensis* in Hou et al., 2002)

Material. Twenty valves and several fragments from samples 17-TFS-2, 17-TFS-3 and 16-TFS-3 (Fig. 3).
Size. Length: 0.96–1.12 mm; Height: 0.56–0.66 mm; Width: Unknown.
Size in literature. Length: 0.97 mm; Height: 0.60 mm; Width: Unknown (Gou, 1983).
Diagnosis (new). Large to very large sized valves, rounded subrectangular to oblong in lateral view. LV larger than RV. Anterior cardinal angle prominent, and posterior cardinal angle angular and distinct. Surface covered with reticulation and small tubercles.
Description. Large to very large sized valves, LV rounded subrectangular in lateral view, and RV rounded subrectangular to oblong in lateral view. Maximum length slightly below mid-height, maximum height at anterior cardinal angle (1/4 of length). LV larger than RV. Anterior margin broadly rounded and infracurvate; anterior cardinal angle distinct in both valves, but more remarkable in the LV, 135–140°. Posterior margin narrower than anterior margin and almost vertical, but slightly infracurvate in the LV, comparatively rounded in the RV; posterior cardinal angle well-marked and distinct in the LV, ca. 120°, rounded in the RV, 130–140°. Dorsal margin straight and moderately declined towards posterior end; hinge margin parallel to dorsal margin. Ventral margin straight to slightly concave. Surface ornamented by reticulation, and very small tubercles. Sexual dimorphism not observed.
Muscle scar pattern. AMS consisting of six scars, four of them are arranged in row being convex towards anterior end, the highest one is the largest and more elongated one, the lowest one is the smallest one; and two scars just behind the main group. MS, two scars with elongate (upper one) and crescent (lower one) shapes, and just below the AMS (Fig. 6A).
Internal characters. Hinge lophodont (?). Inner lamella moderately broad in the anteroventral and posteroventral margins.
Remarks. This species differs from *Scabriculocypris yanbianensis* by reticulated and without small spines and node-like tubercles. *S. tonfosiensis* is similar to *S. trapezoides* Anderson, 1941 from the 'Purbeck' type deposits (England, Germany, and Spain). But, the later one is smaller and with a shallow anterodorsal sulcus.

Scabriculocypris yanbianensis (Gou, 1983) emend
Fig. 5G–L

1983 *Ilyocyprimorpha yanbianensis*, Gou, p. 49, pl. 1, figs. 8–11; pl. 2, fig. 27.
2002 *Ilyocyprimorpha yanbianensis*, Hou et al., p. 626–627, pl. 261, figs. 16–17.

Material. Forty valves, one carapace and thirty carapaces without shells from sample 17-TFS-0 (= 16-TFS-1), 17-TFS-2 and 16-TFS-3 (Fig. 3).
Size. Length: 0.80–1.12 mm; Height: 0.52–0.68 mm. Width: 0.45.
Size in literature. Length: 0.91–0.97 mm; Height: 0.57–0.62 mm; Width: 0.44 mm (Gou, 1983).
Diagnosis (emended). Large to very large sized carapace, rounded subrectangular in lateral view. LV larger than RV; LV overlapping RV along all free margins. Surface ornamented by puncta with tubercles; small spines developed along the anterior and/or posterior margins, and node-like tubercles distributed in entire carapace surface except for the anterior and posterior margins.
Description. Large to very large sized carapace, rounded subrectangular in lateral view, and totally elliptic shape in dorsal view. Maximum length at mid-height, maximum height at anterior cardinal angle, maximum width at mid-length. LV larger than RV; LV overlapping RV along all free margin. Anterior margin equicurvate to slightly infracurvate; anterior cardinal angle rounded, but somewhat distinct in both valves, 130–150°. Posterior margin slightly rounded and nearly equicurvate; posterior cardinal angle rounded, but distinct, 115–125°. Dorsal margin straight and declined towards posterior end, hinge margin moderately incised forming a dorsal furrow. Ventral margin nearly straight, somewhat slightly concave at the middle part. Surface covered by puncta, small spines and tubercles; small spines distributed along the both anterior and posterior margins, and tubercles irregularly distributed in lateral surface of carapace. Sexual dimorphism not observed.
Muscle scar pattern. Unknown.
Internal characters. Unknown.

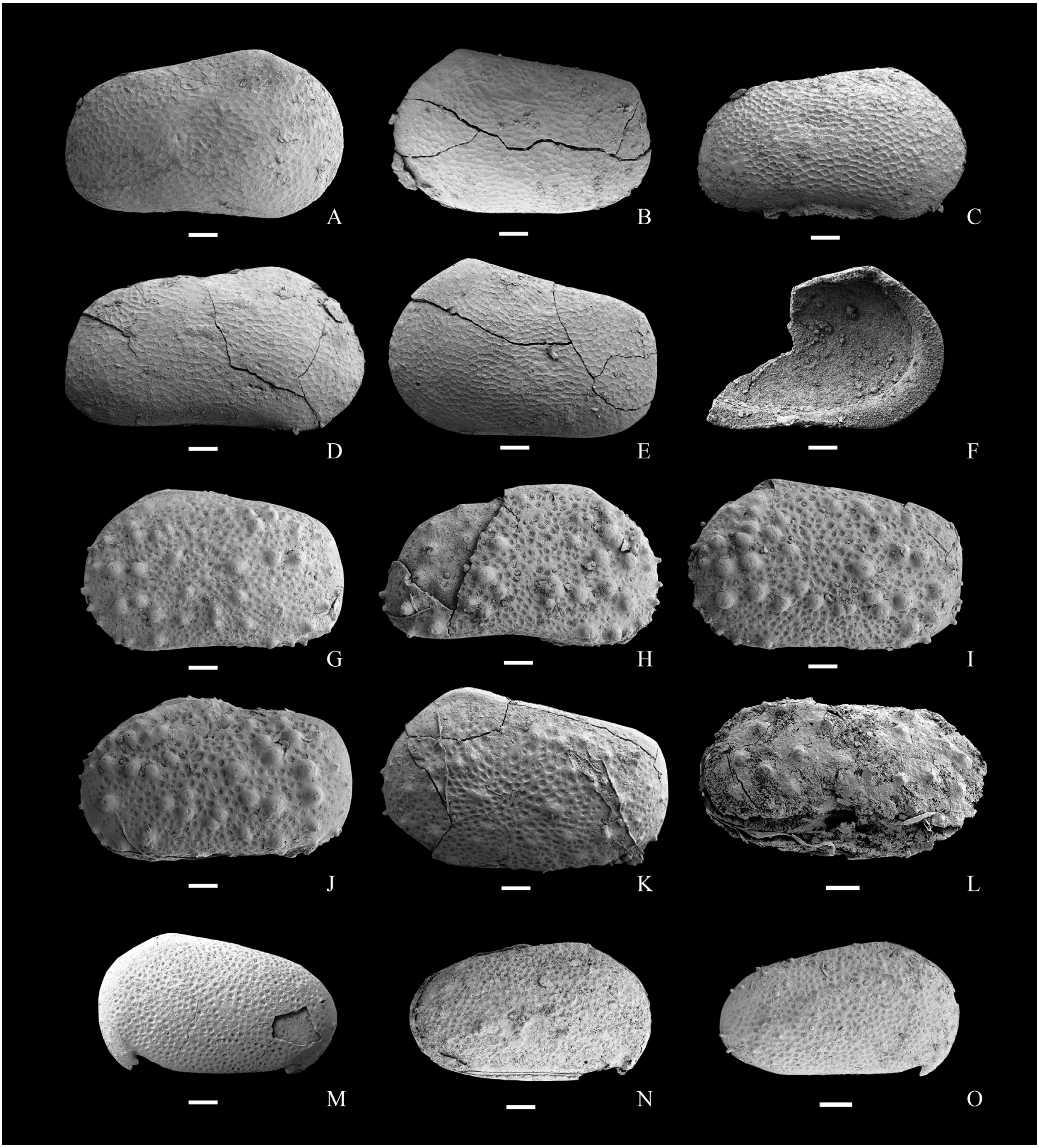

Fig. 5. A–F. *Scabriculocypris tonfosiensis* Gou, 1983; A, right view of valve, NIGP 68168 (Gou, 1983 holotype); B, left view of valve, NIGP 168645, sample 17-TFS-2; C, right view of valve, NIGP 168646, sample 17-TFS-3; D, right view of valve, NIGP 168647, sample 17-TFS-3; E, left view of valve, NIGP 168648, sample 17-TFS-3; F, internal view of partial anterior valve, NIGP 168649, sample 17-TFS-3; G–L. *Scabriculocypris yanbianensis* (Gou, 1983); G, left view of valve, NIGP 68169 (Gou, 1983 holotype); H, right view of valve, NIGP 68170 (Gou, 1983 paratype); I, left view of valve, NIGP 68171 (Gou, 1983 paratype); J, left view of valve, left view of valve, NIGP 68172 (Gou, 1983 paratype); K, left view of valve, NIGP 168650, sample 17-TFS-2; L, left view of core (no shell), NIGP 168651, sample 17-TFS-0; M–O. *Cypridea concinaformis* Su, 1974; M, left view of valve, NIGP 168652, sample 16-DLZ-5; N, right view of carapace, NIGP 68163 (Gou, 1983); O, right view of valve, NIGP 68164 (Gou, 1983). Scale bar is 100 μm.

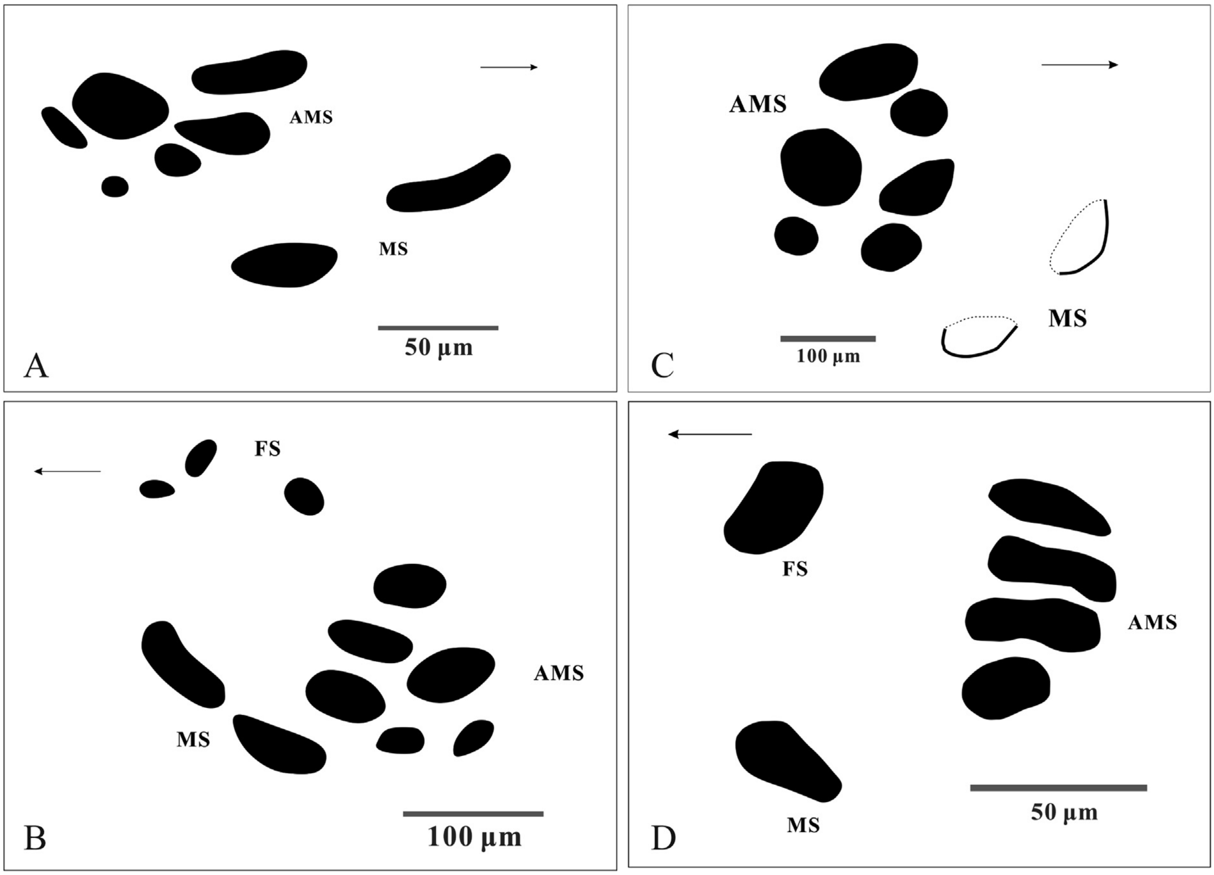

Fig. 6. Line drawing of muscle scars: A, *Scabriculocypris tonfosiensis* Gou, 1983; B, *Mongolianella kyranbeki* sp. nov.; C, *Yumenella toorojensis* (Khand, 1977); D, *Vlakomia jilinensis* Gou, 1983.

Morphologic variation. Two variations of local ornamentation elements are identified: 1) The development of small spines; it develops in the both anterior- and posterior margins or only developed in anterior margin, and or absent in both margins, 2) The tubercle size variation; some specimens have somewhat large tubercles namely node-like tubercles. The size variation of tubercles and/or spines between specimens is may related to ecophenotypic character.
Remarks. Gou (1983) assigned this species to the Genus *Ilyocyprimorpha* Mandelstam (in Lübimova, 1956). However, the species of the Genus *Ilyocyprimorpha* display two distinct spines at anterior- and posterior cardinal angle areas and a row of centroventral and/or centrodorsal tubercles, and show more overlap at the posterior cardinal angle area. This species well fit the diagnosis and description of the Genus *Scabriculocypris*. Thus, we transfer this species to the Genus *Scabriculocypris*. In addition, some unpublished specimens from the Albian Jinju Formation (the Gyeongsang Basin, South Korea) show same character with this species, probably belong to this species (Choi's unpublished data).

Family Cyprideidae Martin, 1940

Genus *Cypridea* Bosquet, 1852
Type species: *Cypris granulosa* Sowerby, 1836

Cypridea concinaformis Su (in Hao et al., 1974)
Fig. 5M–O.

1974 *Cypridea concinaformis*, Su (in Hao et al.), p. 35, pl. 9, figs. 4a–c; pl. 10, figs. 5a–c.
1983 *Cypridea concinaformis*, Gou, p. 48, pl. 2, figs. 23–26.
1984 *Cypridea concinaformis*, TIMR, p. 145, pl. 67, figs. 6–8; pl. 73, fig. 11.
1987 *Cypridea concinaformis*, Zhang, p. 63–64, pl. 1, figs. 4–5.
2002 *Cypridea concinaformis*, Hou et al., p. 438, pl. 185, figs. 14–20.

Material. Only one valve from sample 16-DLZ-5 (Fig. 3).
Size. Length: 0.88 mm; Height: 0.54 mm; Width: Unknown.
Size in literature. Length: 0.75–0.91 mm; Height: 0.42–0.48 mm; Width: 0.31–0.36 mm (Hao et al., 1974; Gou, 1983; Zhang, 1987a,b).
Diagnosis (new). Large sized carapace, ovate in lateral view. LV larger than RV; LV overlapping RV entire margins except for the hinge margin. Rostrum distinct, but its point not overreaching the ventral outline. Alveolar notch broad and somewhat deeply incised, alveolar furrow shallow and indistinct. Cyathus absent. Surface covered by moderate sized puncta, and very small spines developed along the anterior, posterior and dorsal margins.
Description. Carapace large sized, ovate in lateral view, elongate-ovate and slender in dorsal view. Maximum length at mid-length, maximum height at anterior cardinal angle, ca. 1/4 of length, maximum width at 2/3 of length. LV larger than RV; LV overlapping RV entire margins except for hinge margin. Anterior margin rounded and equicurvate to slightly infracurvate; anterior cardinal angle rounded, ca. 140°. Rostrum well-marked, its tip not overreaching the ventral outline. Alveolar notch broad and deeply incised, alveolar furrow shallow and indistinct. Posterior margin rounded and infracurvate, and distinctly narrower than anterior one; posterior cardinal angle strongly rounded and inconspicuous, about 160°. Dorsal margin straight and inclined towards posterior end. Ventral margin nearly straight to slightly convex in the LV, and

slightly concave in the RV. Cyathus absent. Surface covered by puncta, and small spines developed along the anterior, posterior and dorsal margins areas.
Muscle scar pattern. Unknown.
Internal characters. Unknown.
Remarks. Cypridea yanjiensis Gou, 1983 differs from this species by the general carapace shape, developed a node-like ridge in the anterior cardinal angle area of LV, broader alveolar furrow, and surface covered with small spines and tubercles.

Genus *Mongolocypris* Szczechura, 1978
Type species: *Cypridea distributa* Stankevitch (in Stankevitch and Sochava, 1974)

Mongolocypris yanjiensis Gou, 1983.
Fig. 7A–K.

1983 *Mongolocypris yanjiensis*, Gou, p. 48, pl. 3, figs. 1–4.

Material. More than 100 carapaces and several valves from samples 16-DLZ-2, 16-DLZ-3, 16-DLZ-4, 16-DLZ-5, 16-DLZ-8, 16-DLZ-9, 16-DLZ-11, 16-DLZ-12, 16-DLZ-13 and 16-DLZ-17 (Fig. 3).
Size. Length: 1.16–1.76 mm; Height: 0.68–1.04 mm; Width: 0.56–0.84 mm.
Size in literature. Length: 1.47–1.54 mm; Height: 0.89–0.99 mm; Width: 0.73–75 mm (Gou, 1983).
Diagnosis (new). Very large sized carapace with rounded-suboblong shape in lateral view. LV larger than RV. Rostrum distinctly and strongly bending backwards, its point acute and considerably overreaching the RV's ventral outline. Alveolar notch well-developed and rounded shape, more distinct in the RV.
Description. Carapace very large, thick shell, rounded-suboblong in lateral view, elongate-subovate in dorsal view. Maximum length slightly below mid-height, maximum height at anterior cardinal angle, maximum width at ca. 3/5 of length. LV larger than RV; LV overlapping RV along all margins except for the hinge margin. Anterior margin broad and infracurvate; anterior cardinal angle strongly rounded and inconspicuous in both valves, ca. 160°. Rostrum short and small, but distinct and strongly bending backwards, its point acute and considerably overreaching the ventral margin of the RV, but slightly overreaching the LV; RV's one sharper than LV, whereas later somewhat broader. Alveolar notch well-developed and rounded shape, more distinct in the RV. Alveolar furrow absent. Posterior margin broader than anterior one, and almost infracurvate to somewhat equicurvate; posterior cardinal angle rounded and relatively well-marked than anterior cardinal angle, 130–145°. Dorsal margin almost straight and slightly declined towards posterior end. Hinge margin slightly incised, forming a shallow dorsal furrow. Ventral margin nearly straight in both valves, but somewhat concave in mid-length of the RV. Surface smooth. Sexual dimorphism not observed.
Muscle scar pattern. Unknown.
Internal characters. Unknown.
Remarks. Mongolocypris yanjiensis is the dominated species in the Dalazi Formation. *M. yanjiensis* differs from other *Mongolocypris* species from the adjacent areas in its rostrum and alveolus, the former developing a sharp and relatively narrow rostrum and a deeply incised alveolar notch. *M. globra* Hou, 1958 is similar to *M. yanjiensis* in lateral view. However, its rostrum almost overreaches the ventral margin in both valves. *M. limpida* Zhang, 1987a,b differs from *M. yanjiensis* by more angular posterior cardinal angle and subtrapezoidal carapace shape. *M. unornata* Pang (in TIMR, 1984) from the Upper Cretaceous Zhaoying Formation of the Xixia Basin (Henan Province) is close to *M. yanjiensis*. But, *M. unornata* has more elongated carapace, strongly infracurvate posterior margin, and a concave ventral margin.

Family Cyprididae Baird, 1845
Subfamily Mongolianellinae Neustrueva, 1989

Genus *Mongolianella* Mandelstam (in Galeeva, 1955)
Type species: *Mongolianella palmosa* Mandelstam (in Galeeva, 1955)

Remarks. Neustrueva (1989) and Nikolaeva and Neustrueva (1999) assigned the Genus *Mongolianella* to the Subfamily Monglianellinae of the Family Trapezoidellidae. Yet, the Family Trapezoidellidae is in need of modern taxonomic revision as internal features of most relevant taxa. Gou and Hou (in Hou et al., 2002) erected the Family Djungarididae to accommodate the Genus *Mongolianella*. However, they only provided a brief description of the family: 'very large elongated carapace with nearly kidney-shaped, LV larger than RV, strong overlap along dorsal and ventral margins, anterior margin rounded, Cypridoidea muscle scars type. Jurassic to Cretaceous of China' (translated from Hou et al., 2002 p. 629), which remains to be reviewed and evaluated. Whatley et al. (2003) thought *Mongolianella* belongs to the Subfamily Herpetocypridinae of the Family Cyprididae. But the assignment of species of the extinct Genus *Mongolianella* to the extant Subfamily Herpetocypridinae remains to be thoroughly discussed. Thus, we temporarily assign the Genus *Mongolianella* to the Subfamily Monglianellinae of the Family Cyprididae.

Mongolianella kyranbeki sp. nov., Wang
LSID urn:lsid:zoobank.org:act:40E71DE2-271F-4734-B706-C7FA92F8B408.
Figs. 7L–N, 8A.

1983 *Mongolianella* sp. 2, Gou, p. 49, pl. 3, fig. 8.
2002 ?*Mongolianella* sp. 4, Hou et al., p. 640, pl. 268, figs. 9–10.

Material. Thirty valves from samples 17-TFS-1, 17-TFS-2, 17-TFS-3, 17-TFS-4 and 16-TFS-3 (Fig. 3).
Size. Length: 1.80–2.16 mm; Height: 0.92–1.08 mm; Width: Unknown.
Size in literature. Length: 1.94 mm; Height: 0.79 mm; Width: Unknown (Gou, 1983).
Holotype. Right valve (Fig. 7L), NIGP 168663, sample number 16-TFS-3 from the upper part of the Tongfosi section, Length: 1.90 mm; Height: 0.92 mm.
Type locality and horizon. Tongfosi Formation (Albian–Cenomanian?), Tongfosi Town, Longjing City, Jilin Province of Northeast China; Horizon number (equals to sample number) 16-TFS-3 of the Tongfosi section.
Stratigraphic distribution/occurrence. Only known from the Tongfosi Formation.
Etymology. Named for the famous Chinese basketball player Kelanbaike Makan (in Kyrgyz and Uygur languages: 'Kyranbek Makhan') (可兰白克·马坎) (the captain of the Xinjiang Flying Tigers Team) of his great contribution to the development of the Xinjiang Uygur Autonomous Region basketball course; he helped the team won the 2016–2017 CBA Championship.
Diagnosis. Very large to gigantic sized *Mongolianella*, elongated and oblique subtrapezoidal to subtriangular in lateral view, with rounded triangular posterior margin; dorsal margin arched and ventral margin concave; calcified inner lamella well-developed in anterior and posterior margins; surface smooth.
Description. Very large to gigantic sized, elongated and oblique subtrapezoidal to subtriangular in lateral view. Maximum length at ca. 1/5 height, maximum height at 2/5 of length. Anterior margin broad and almost equicurvate; anterior cardinal angle rounded and poorly defined, ca. 150°. Dorsal margin arched and declined to posterior end, with ventral margin formed a rounded triangular posteroventral margin (protrusion-like posteroventral margin);

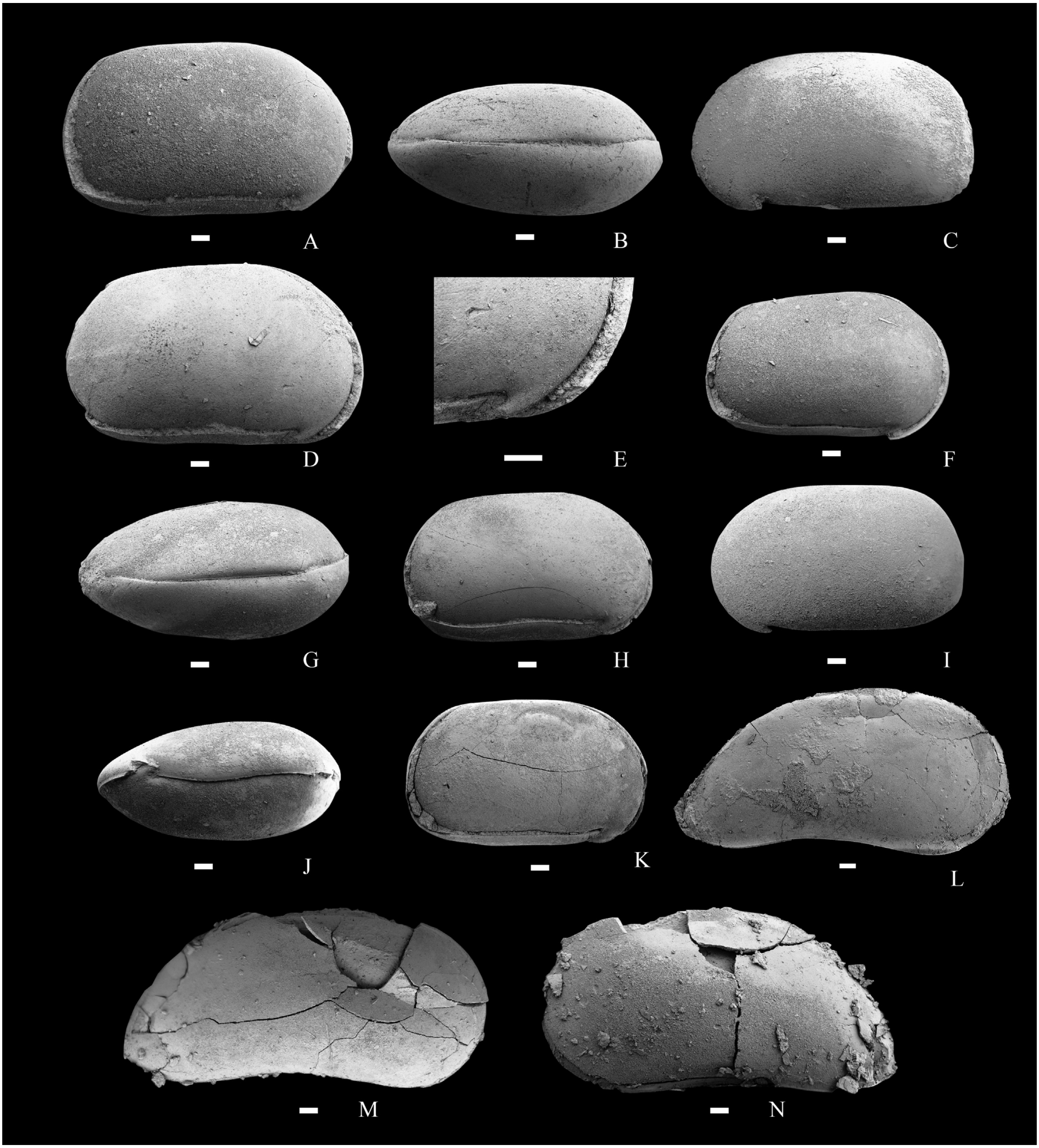

Fig. 7. A–K. *Mongolocypris yanjiensis* Gou, 1983; A, right view of carapace (adult), NIGP 168653, sample 16-DLZ-12; B, dorsal view of carapace (adult), anterior end to the left, NIGP 168654, sample 16-DLZ-13; C, left view of carapace (adult), NIGP 168655, sample 16-DLZ-12; D, right view of carapace, NIGP 168656, sample 16-DLZ-13; E, idem, right lateral of anteroventral region, rostrum and alveolus; F, right view of carapace (A1 instar), NIGP 168657, sample, 16-DLZ-17; G, dorsal view of carapace (adult), anterior end to the left, NIGP 168658, sample 17-DLZ-17; H, right view of carapace (A-1 instar), NIGP 168659, sample 16-DLZ-17; I, left view of carapace (A-1 instar), NIGP 168660, sample 16-DLZ-17; J, ventral view of carapace (A-1 instar), anterior end to the left, NIGP 168661, sample 16-DLZ-17; K, right view of carapace (A-1 instar), NIGP 168662, sample 16-DLZ-17; L–N. *Mongolianella kyranbeki* sp. nov.; L, lateral view of right valve, NIGP 168663 (holotype), sample 16-TFS-3; M, lateral view of right valve, NIGP 168664, sample 17-TFS-2; N, lateral view of left valve, NIGP 168665, sample 17-TFS-2. Scale bar is 100 μm.

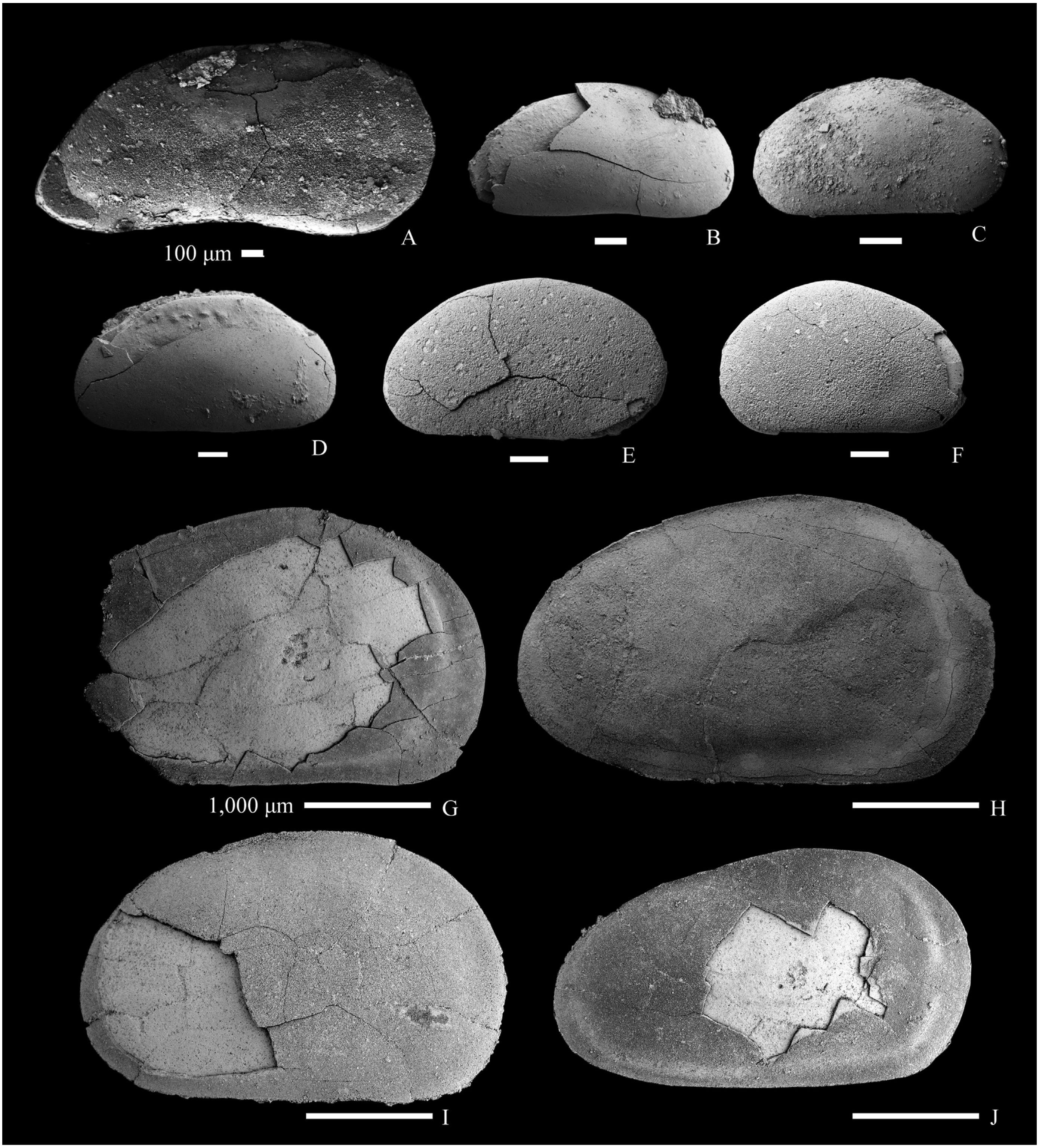

Fig. 8. A. *Mongolianella kyranbeki* sp. nov., right view of valve, NIGP 168666, sample 17-TFS-2; B—D. *Lycopterocypris infantilis*; B, lateral view of right valve, NIGP 168667, sample, C, right view of valve, NIGP 168668, sample 17-TFS-3; D, left view of valve, NIGP 168669, sample 17-TFS-4; E—F. *Lycopterocypris* sp.; E, right view of valve, NIGP 168670, sample 16-DLZ-7; F, left view of valve, NIGP 168671, sample 16-DLZ-7; G—J. *Yumenella toorojensis* (Khand, 1977); G, right view of presumed female valve, NIGP 168672, sample 16-DLZ-2; H, right view of presumed male valve, NIGP 168673, sample 16-DLZ-2; I, right view of female valve, NIGP 168674, sample 16-DLZ-2; J, right view of presumed male valve, NIGP 168675, sample 16-DLZ-2.

posterior cardinal angle rounded and inconspicuous, 140–145°. Ventral margin concave. Surface smooth.
Muscle scar pattern. AMS, four muscle scars arched, another two scars just behind the main group; MS, two elongated round scars just in front of AMS; FS, three small rounded scars, situated above and relatively distant to AMS-field, two small ones slightly above and distant to the largest one (Fig. 6B).
Internal characters. Calcified inner lamella well developed, and broader in anteroventral and posteroventral margins areas, especially forming a rounded triangular shape in the posteroventral margin.
Remarks. The new species strongly resembles the species of *Mongolianella* from the lower Cretaceous sediments of Mongolia, as described by Galeeva (1955); however, *M. gigantea* Galeeva, 1955 is distinctly smaller and *M. palmosa* Mandelstam (in Galeeva, 1955) has more convex ventral margin. *Mongolianella kyranbeki* sp. nov. differs from other *Mongolianella* species from China by its more arched dorsal margin, concave ventral margin and protrusion-like posteroventral margin.

Family Cyprididae Baird, 1845

Genus *Lycopterocypris* Mandelstam (in Lübimova, 1956)
Type species: *Cypris faba* Egger, 1910.

Remarks. The genus *Lycopterocypris* was established by Mandelstam (in Lübimova, 1956). Based on statistical analysis of external features, Geng (1979) stated that *Lycopterocypris* Mandelstam (in Lübimova, 1956) is a junior synonym of *Eucypris* Vávra, 1891. Hou et al. (2002) followed this view. Since the differentiation between *Lycopterocypris* and *Eucypris* is unclear, particularly lack of any observation of internal structural details. Geng's hypothesis has not been followed by many authors and remains to be re-examined (e.g. Van Itterbeeck et al., 2004; Wang et al., 2016).

Lycopterocypris infantilis Lübimova, 1956
Fig. 8B–D.

1956 *Lycopterocypris infantilis*, Lübimova, p. 106, pl. 21, figs.1a–b, 2a, 3a–b.
2016 *Lycopterocypris infantilis*, Wang et al., p. 213, 215; fig. 5f–g.

Material. Seven valves from samples 17-TFS-2, 17-TFS-3 and 17-TFS-4 (Fig. 3).
Size. Length: 0.52–1.00 mm; Height: 0.24–0.56 mm; Width: Unknown.
Remarks. Our specimens fit the illustration and description of *Lycopterocypris infantilis* from Early to early Late Cretaceous deposits of East Asia (China, Mongolia, and Russia) very well.

Lycopterocypris sp.
Fig. 8E–F.

Material. Two valves from sample 16-DLZ-7 (Fig. 3).
Size. Length: 0.72–0.84 mm; Height: 0.44–0.48 mm; Width: Unknown.
Description. Large sized valves, rounded-subtriangular in lateral view. Maximum length slightly below the mid-height, maximum height slightly in front of the mid-length. Anterior margin rounded and infracurvate with long straight to somewhat rounded dorsal part. Posterior margin narrower than anterior one, rounded and infracurvate. Dorsal margin rounded in the RV, rounded and more convex in the LV. Ventral margin nearly straight. Surface smooth.
Muscle scar pattern. Unknown.
Internal characters. Unknown.
Remarks. This species is similar to '*Lycopterocypris debilis*' in Neustrueva et al. (2005), which shows also triangular carapace shape. However, 'true' *L. debilis* has an elongated-ovate shape, and the maximum height is always located at the anterior cardinal angle (refer to figures in Lübimova, 1956; Qi and Wang, 1981; Hou et al., 2002; Wang et al., 2016). Thus, the specimens in Neustrueva et al. (2005) may represent a new *Lycopterocypris* species, and probably relate to *L.* sp. herein. In addition, *L.* sp. resembles *L.* celsa Lübimova, 1956 and *L.* cuneataeformis Sinitsa, 1993, but these two species have concave ventral margins in the RV.

Genus *Yumenella* Li and Zhang, 1981
Type species: *Yumenella xiagouensis* Li and Zhang, 1981

Remarks. The genus *Yumenella* was established by Li and Zhang (1981), which is characterised by its giant-sized valve (larger than 2.5 mm), thin shell and well-developed marginal zone along the free margins. Whatley et al. (2012) reported another gigantic ostracod genus *Periosocypris* from the Maastrichtian Lameta Formation of India, which displays several same diagnostic characters as *Yumenella*, such as gigantic size, subrectangular to subovate valve shape and smooth surface. But, no internal and marginal features were recognized by Whatley et al. (2012).

Yumenella toorojensis (Khand, 1977) emend.
Figs. 8G–J, 9A–B.

1977 *Eucypris toorojensis*, Khand, p. 109, pl. 1, fig. 4.
1983 Gen. et sp. 1, Gou, p. 49, pl. 3, figs. 9, 10.
?2002 *Yumenella jingguensis*, Gou (in Hou et al., 2002), p. 643, pl. 271, figs. 10–13, pl. 297, fig. 17.
2005 *Eucypris toorojensis*, Van Itterbeeck et al., p. 709, fig. 6A.

Material. One carapace, eight valves and several fragments from samples 16-DLZ-2 and 16-DLZ-10 (Fig. 3).
Size. Length: 3.40–4.50 mm; Height: 2.00–2.70 mm; Width: Unknown.
Size in literature. Length: 3.25–4.50 mm; Height: 1.71–2.40 mm; Width: 1.20 mm (Khand, 1977; Gou, 1983; Van Itterbeeck et al., 2005).
Diagnosis (emended). Gigantic sized carapace, subovate to elongated subovate in lateral view. LV larger than RV. Both cardinal angles rounded. Maximum height at anterior cardinal angle. Marginal zone well-developed. Surface smooth. Presumed sexual dimorphism identified.
Description. Gigantic sized carapace, subovate to elongated subovate in lateral view. Maximum length at slightly below mid-height, maximum height at anterior cardinal angle, maximum width unknown. LV larger than RV. Anterior margin broadly rounded and nearly equicurvate to slightly infracurvate; anterior cardinal angel rounded and indistinct. Posterior margin narrower than anterior one, and infracurvate; posterior cardinal angle rounded and/or inconspicuous. Dorsal margin somewhat arched. Ventral margin almost straight. Marginal zone well-developed along all the free margins, the marginal pore canals extend through it. Surface smooth.
Muscle scar pattern. Muscle scar pattern consisting of six AMS and two MS; AMS, anterior four scars slightly arched and two rounded scars just behind the anterior scars. MS, two crescent or elliptic shape scars slightly below the AMS (Fig. 6C).
Internal characters. Unknown.
Sexual dimorphism. Presumed sexual dimorphism is identified. Presumed male morph has more elongated valve with a narrow posterior margin. The general shape of presumed female morph is more rounded, with a more broadly rounded posterior margin.
Remarks. Khand (1977) described a new species *Eucypris toorojensis* from the Nemegt Formation of Mongolia. But, this species is quite larger than living *Eucypris* species, and modern *Eucypris* species is identified by its soft part. On the basis of carapace/valve features, such as gigantic size, subovate to elongated subovate valve shape and well-developed marginal pore canals, we re-assign this species to the

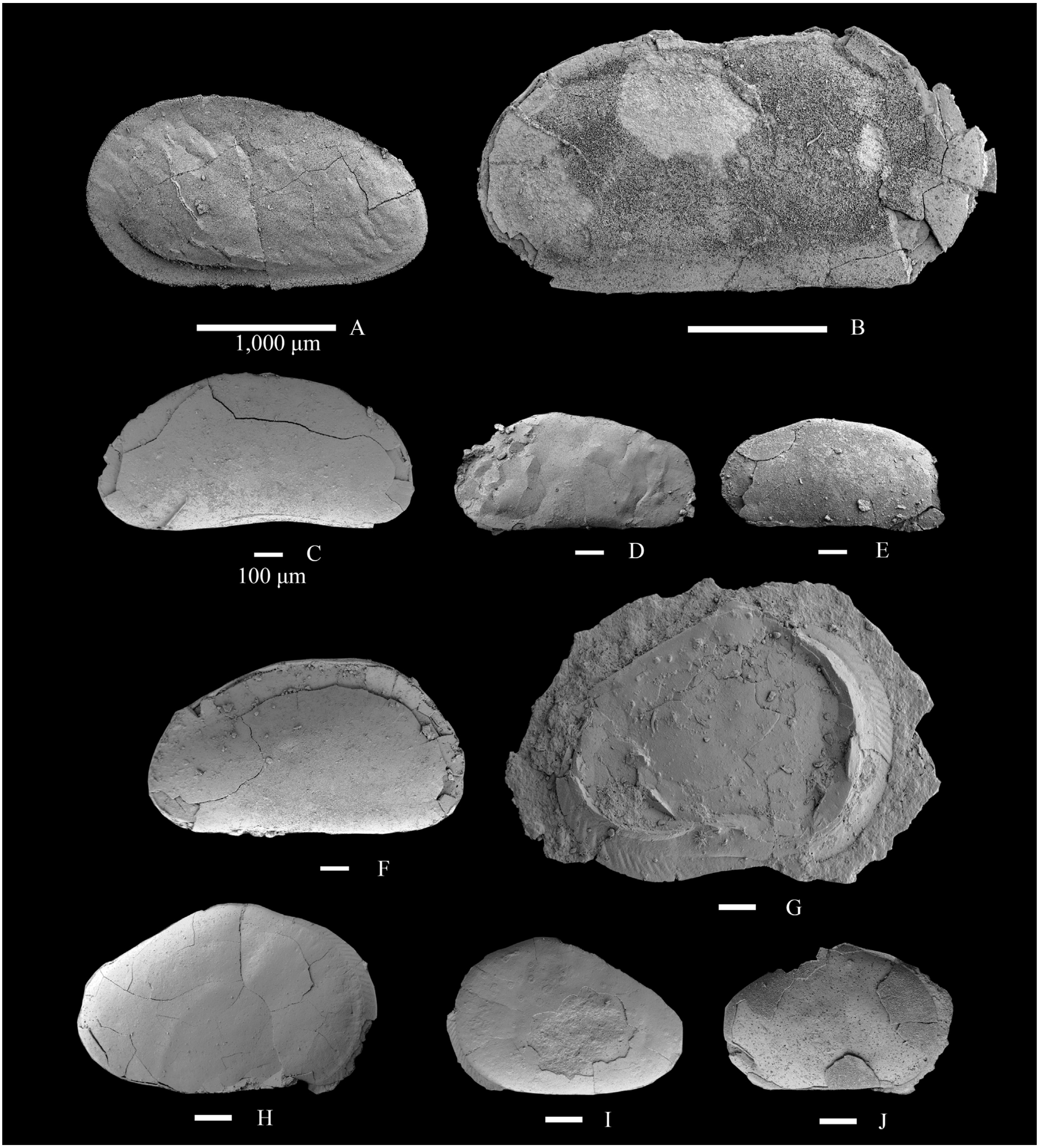

Fig. 9. A–B. *Yumenella toorojensis* (Khand, 1977); A, left view of presumed male valve, NIGP 168676, sample 16-DLZ-2; B, right view of presumed male carapace, NIGP 168677, sample 16-DLZ-2; C. *Candona* sp. 1; left view of valve, NIGP 168678, sample 17-TFS-2; D–E. *Candona* sp. 2; D, right view of valve, NIGP 168679, sample 17-TFS-4; E, right view of valve, NIGP 168680, sample 17-TFS-3; F. *Candona*? sp.; left view of valve, NIGP 168681, sample 17-TFS-2; G–J. *Cyprois* sp.; G, right view of presumed female valve (adult), NIGP 68177; H, right view of valve (juvenile), NIGP 168682, sample 16-DLZ-4; I, left view of valve (juvenile), NIGP 168683, sample 16-DLZ-7; J, right view of valve (juvenile), NIGP 168684, sample 16-DLZ-7.

Genus *Yumenella*. *Y. oblonga* Li and Zhang, 1981 is similar to *Y. toorojensis*, but distinguished by equicurvate to supracurvate posterior margin and the maximum height of *Y. oblonga* occurred at the near middle of length. *Y. xiagouensis* Li and Zhang, 1981 and *Y. hemiseleneata* Li and Zhang, 1981 differ from *Y. toorojensis* by an elongated-ovate carapace with a high Length/Height ratio. *Y. semirotunda* Li and Zhang, 1981 shows a downturned posterior margin and straight dorsal part. *Y. toorojensis* is similar to *Y. jingguensis* Gou, 2002 (in Hou et al., 2002) by the general outline and size. However, all illustrated specimens of *Y. jingguensis* in Hou et al. (2002) do not have shell. Therefore, for further investigation, supplementary collection of topotypes is required. So, we use a question mark here.

Family Candonidae Kaufmann, 1900

Genus *Candona* Baird, 1845
Type species: *Cypris candida* Müller, 1776

Candona sp. 1
Fig. 9C.

Material. Three valves from samples 17-TFS-2 and 17-TFS-4 (Fig. 3).
Size. Length: 0.48–1.08 mm; Height: 0.26–0.52 mm; Width: Unknown.
Description. Medium to large sized carapace, thin shell, ovate to subtrapezoidal in lateral view. Maximum length at 1/3 of height, maximum height at anterior cardinal angle. Anterior margin rounded and slightly equicurvate to infracurvate; anterior cardinal angle broadly rounded and indistinct. Posterior margin slightly infracurvate and narrower than anterior one; posterior cardinal angle rounded and indistinct. Dorsal margin nearly straight and slightly inclined towards posterior end. Ventral margin concave at mid-length. Surface smooth.
Muscle scar pattern. Unknown.
Internal characters. Unknown.
Remarks. *Candona* sp. 1 is similar to '*C.* sp.' (in Wang et al., 2016) from the Yixian Formation of China. However, the latter shows much larger size. *Mongolianella khamariniensis* Lübimova, 1956 of Van Itterbeeck et al. (2004) from the Lower Cretaceous Dashuiguo Formation of Inner Mongolia, China resembles *C.* sp. 1. However, the specimens of *M. khamariniensis* develop a broad inner marginal zone. Our *Candona* sp. 1 specimens lack the information of the shell internal characters. Therefore, for further investigation, more well-preserved material is required.

Candona sp. 2
Fig. 9D–E.

Material. Two valves from samples 17-TFS-3 and 17-TFS-4 (Fig. 3).
Size. Length: 0.84 mm; Height: 0.42–0.44 mm; Width: Unknown.
Description. Medium to large sized carapace, thin shell, reniform in lateral view. Maximum length slightly below the mid-height, maximum height at 2/3 of length. Anterior margin nearly equicurvate; anterior cardinal angle rounded and inconspicuous. Posterior margin infracurvate. Dorsal margin convex with somewhat rounded angular dorsal hump. Ventral margin almost straight. Surface smooth.
Muscle scar pattern. Unknown.
Internal characters. Unknown.
Remarks. C. sp. 2 is similar to C. sp. 1, but the later one displays more arch dorsal margin and much larger size.

Candona? sp.
Fig. 9F.

Material. Only one valve from sample 17-TFS-2 (Fig. 3).
Size. Length: 1.20 mm; Height: 0.64 mm; Width: Unknown.
Description. Very large sized carapace, nearly ovate in lateral view. Maximum length at 1/4 of height, maximum height at 3/4 of length. Anterior margin equicurvate; anterior cardinal angle inconspicuous. Posterior margin slightly infracurvate; posterior cardinal angle rounded and indistinct. Dorsal margin convex and ventral margin straight. Surface smooth.
Muscle scar pattern. Unknown.
Internal characters. Unknown.
Remarks. *Candona*? sp. differs from the other *Candona* species from the Yanji Basin and adjacent areas by its much larger size and straight ventral margin. However, we collected only one broken specimen, therefore, we temporarily assign this species to the Genus *Candona*.

Family Notodromadidae Kaufmann, 1900
Subfamily Cyproidinae Hartmann, 1963

Genus *Cyprois* Zenker, 1854
Type species: *Cyprois marginata* Straus, 1821

Remarks. Developed anterior and posterior marginal flanges were defined as a diagnostic feature of the Genus *Mantelliana* Anderson, 1966 (Anderson, 1966). Three *Mantelliana* species from the Purbeck-Wealden deposits were described in Anderson's (1966) paper. Following Anderson's view, most of Mesozoic ostracod species with flanges were assigned into the Genus *Mantelliana* by different authors (e.g. Zhang, 1985; Hou et al., 2002; Choi et al., 2017). However, one of us (Wang) re-investigated the type specimens of *Mantelliana mantelli* (type species of the Genus *Mantelliana*), *M. phillipsiana* and *M. purbeckensis*, which were documented by Anderson (1966) (which are housed in the collections of British Geological Survey). Interestingly, only the type specimen of *M. phillipsiana* displays an anterior marginal flange, but the type specimen of the type species *Mantelliana mantelli* does not develop marginal flange. Thus, the definition of the Genus *Mantelliana* needs to be revised, but it is out of our topic here. The recent notodromadidaen species all develop marginal flanges, and the prominent striated marginal flanges are always found in the Subfamily Cyproidinae (Smith et al., 2015; Wang pers. comm. with Prof. David J. Horne in July 2018). Meanwhile, this subfamily has only one genus – *Cyprois*. Consequently, we transfer *M. philipsiana* of Anderson (1966) to *Cyprois*, based on development striated anterior marginal flange.

Cyprois sp.
Fig. 9G–J.

1983 *Cyprois* sp., Gou, p. 49–50, pl. 3, fig. 7.

Material. One adult valve of Gou (1983); five juveniles from samples 16-DLZ-3, 16-DLZ-4 and 16-DLZ-7 (Fig. 3).
Size. Length: 0.44–0.88 mm; Height: 0.32–0.52 mm; Width: Unknown.
Size in literature. Length: 0.92 mm; Height: 0.66 mm; Width: Unknown (Gou, 1983).
Description. Medium to large sized carapace, subtriangular to suboblong in lateral view. Maximum length at slightly below the mid-height, maximum height at anterior cardinal angle, maximum width unknown. Anterior margin broadly rounded and nearly equicurvate to slightly supracurvate; anterior cardinal angle rounded. Posterior margin moderately broad and nearly equicurvate in adult, whereas narrow and almost equicurvate to supracurvate in juvenile; posterior cardinal angel rounded, but distinct. Dorsal margin straight and strongly inclined towards posterior end; hinge margin straight and short. Ventral margin nearly straight to somewhat convex in both valves. Marginal flanges well-developed along the anterior and posterior margins (extending up to the cardinal angle areas); but juvenile valve has a moderately developed anterior marginal flange, posterior marginal flange absent (it may be due to bad preservation, or covered by outer lamella). Surface smooth.

Muscle scar pattern. Unknown.
Internal characters. Unknown.
Remarks. *Cyprois* sp. is distinguished by other late Mesozoic notodromadid species from Europe and East Asia in straight, considerably inclined posterodorsal margin with narrow posterior margin and well-developed anterior and posterovenral marginal flanges. *Mantelliana pustulosa* Zhang 1985 (may also belong to the Genus *Cyprois*) differs from *C.* sp. by the elongated shape and much larger sized carapace. *M. alta* Qi, 1985 (may also belong to genus *Cyprois*) from the Upper Jurassic Kushuixia Formation of China is similar to *C.* sp., but distinguished by more broadly rounded posterior margin.

Superfamily Cytheroidea Baird, 1850
Family Limnocytheridae Klie, 1938
Subfamily Limnocytherinae Klie, 1938

Remarks. Gramm (1966) assigned the Genus *Vlakomia* to the Superfamily Cytheroidea based on AMS. Hou (in Hou and Gou, 2007) placed the Genus *Vlakomia* into her new Family Chinocytheridae. However, this new family was poorly defined – "Carapace ovate to quadrilateral, dorsal margin straight, cardinal angles remarkable; ornamentation variable; Cytheroidea muscle scar pattern (translation from Hou and Gou, 2007, p. 161, p. 161)". The usefulness of the Family Chinocytheridae remains to be reviewed and evaluated. Colin and Danielopol (1978, 1980) assumed that the Genus *Vlakomia* belongs to the *Theriosynoecum*-group of the Subfamily Timiriaseviinae. In this study, we assign the Genus *Vlakomia* to the Subfamily Limnocytherinae, based on the presence of sieve-type pore canal (StPC) of type C (i.e. having a sieve formed by tubuli and a space left by the disappearance of a seta) (Fig. 11B) and the sexual dimorphism – male morph is larger than female one (typical character of the Subfamily Limnocytherinae) (Danielopol et al., 2018).

Genus *Vlakomia* Gramm, 1966 emend.
Type species: *Vlakomia ustinovskii* Gramm, 1966

Diagnosis (emended). Small to medium sized carapace, subrhomboidal in lateral view. LV larger than RV; LV weakly overlapping RV along free margins. Each valve with two dorsomedian sulci. Two conical to rounded tubercle-like nodes developed in the dorsal part; two or three rounded/horn-like shape nodes developed in the ventromedian and central area. Ventral lobe developed or absent. Normal pores both simple and sieve-type. Surface totally or partially covered with reticulation. Hinge lophodont. Sexual dimorphism present, precocious sexual dimorphism also does occur. Males always larger than females, the males more elongate in lateral and more elongate-elliptical in dorsal view than the females.
Description. Small to large sized carapace, subrhomboidal in lateral view, and nearly arrowhead-shape (by central or ventrolateral nodes) to elliptic shape in dorsal view. Each valve with two dorsomedian sulci, the anterior one shallow and short just reaching at 1/4 of length, the posterior one wider and almost reaching at half to 3/4 of length. Two conical to rounded tubercle-like nodes developed in the dorsal part; one just behind the anterior sulcus, another one between these two sulci. Two or three rounded/horn-like shape nodes developed in the ventromedian and central area. LV larger than RV; LV weakly overlapping RV along the all free margins. Anterior margin broad and infracurvate to somewhat equicurvate. Posterior margin broadly rounded with nearly equicurvate to somewhat supracurvate or narrow with supracurvate to slightly equicurvate. Cardinal angles well-defined. Hinge margin straight; hinge lophodont. Ventral margin concave, more visible in the RV. Normal pores both simple and sieve-type, simple pore shows two types: normal pore without a lip and normal pore with a lip (Fig. 11A); sieve pore, sieve plate with a central pore (Fig. 11C); normal pore with large hole on the inner side (Fig. 11D). Marginal pore canals developed in the anterior margin. Calcified inner lamella well developed along the free margin in both valves and extending up to posterior tooth; fused zone narrowly to moderately developed with a distinct selvage. Surface covered with reticulation (except on the nodes).
Muscle scar pattern. AMS in central to centroventral area, consisting of vertical row of four elongated (upper three) to rounded (lower one) scars. FS situated slightly above and relatively distant to AMS-field. MS situated below the FS and in front of the AMS (Fig. 6D).
Sexual dimorphism. Male carapace/valve more elongate in lateral and more elongate-elliptical in dorsal view than female one. Also, the overall length of male valve quite bigger in comparison to female valve. Female carapaces show more inflation in dorsal view; with broader anterior margin and strongly supracurvate posterior margin; female morph always developed more degree of development of nodes in the ventromedian and central area, but less degree of development of dorsal nodes or ridge-like node. Precocious sexual dimorphism present, is may occur in A-1 or earlier instars.
Ontogenetic trends. Instars of *Vlakomia* can be identified by several characteristic features. The younger the instars, the smaller is the size, the thinner is the shell, the lesser is the development of the anterior sulcus, and the narrower is the width of calcified inner lamella.
Remarks. Since Gramm (1966) established the genus *Vlakomia* with the type species *V. ustinovskii*, this genus had been only discovered from the Lower to Upper Cretaceous deposits of East Asian region thus far (Gramm, 1966; Gou, 1983; Hou and Gou, 2007). Three *Vlakomia* species had been reported in China, *V. ustinovskii* Gramm, 1966, *V. jilinensis* Gou, 1983 and *V. pristina* Zhang, 1982. The former two are detailed described in this study (see below). But, *V. pristina* Zhang, 1982 from the Aptian Yunshan Formation of Heilongjiang Province of China is considered invalid, since, this species was established based on one broken specimen without shell (Zhang, 1982).

Berthou et al. (1994) described "*Vlakomia*"(?) sp. from the Santana Formation of the Araripe Basin, Brazil, but did not figure it. We presume that *V*(?). sp. of Brazil may be a juvenile specimen of a species of the Genus *Theriosynoecum*, based on its co-occurrence with specimens of *T. munizi* and *T. quadrinodosa*. Whatley and Moguilevsky (1998) figured the Genus *Vlakomia* as a "Triassic" taxon of the Limnocytheridae (p. 283, pl. 2 therein). However, no detailed locality and formation information were documented in Whatley and Moguilevsky (1998). Thus, the stratigraphic range of *Vlakomia* downwards into Triassic is not accepted here.

Genus *Praevlakomia* Neustrueva, 1974 from the Jurassic of Fergana area, Uzbekistan may be close to *Vlakomia.* It differs from *Vlakomia* by absence of ridge-like nodes in dorsolateral region and small sized puncta. However, because of a very sparse fossil record and lacking data about the pore type of *Praevlakomia*, the phylogenetic relationship between the two genera needs further investigation. If *Praevlakomia* is a true ancestor of *Vlakomia*, representatives of the *Praevlakomia-Vlakomia* lineage probably migrated from Central Asia to East Asia during the late Mesozoic.

Species of the Genus *Tsetsenia* Sinitsa, 1993 from central Mongolia are similar to *Vlakomia* by general carapace shape and the development of nodes. But, because of lacking information on the central muscle scar pattern and internal characters of shell, Sinitsa (1993) temporarily assigned this genus to the Family Limnocytheridae (with a question mark in Sinitsa, 1993) as well as to the Superfamily Cytheroidea. Therefore, *Tsetsenia* belongs to the Limnocytheridae and is considered to be in need of further investigation.

Vlakomia ustinovskii Gramm, 1966 emend.
Figs. 10A–Q, 11A–D.

1966 *Vlakomia ustinovskii*, Gramm, p. 85, pl. 9, figs. 8–16.

Material. Fifteen carapaces and forty valves from sample 16-TFS-3 (Fig. 3).
Size. Length: 0.31–0.76 mm; Height: 0.21–0.46 mm; Width: 0.52–0.6 mm.
Diagnosis (emended). Small to large sized carapace/valve, subrhomboidal in lateral view. LV larger than RV. Each valve with two dorsomedian sulci. Two dorsal nodes with conical shape. Anterocentral node large and 'horn-like' shape in dorsal view, and posterocentral node larger than anterocentral one, rounded and fused with long and winding ventral lobe. Anterior margin, posterocentral, posterolateral and ventrolateral areas covered with puncta, but smooth in anterolateral, anterocentral and centrodorsal regions. Hinge lophodont. Normal pores both simple and sieve-type. Sexual dimorphism present.
Description. Small to large sized carapace, subrhomboidal in lateral view. Maximum length at mid-height, maximum height at 1/4 of length (anterior cardinal angle) and maximum width at 4/5 of length due to the protruded posterocentral nodes. In dorsal view, lateral outline basically piriform with tapered anterior end, but two large nodes of each valves forming 'double barbed arrowhead' shape. LV larger than RV; LV slightly overlapping RV. Anterior margin rounded and slightly infracurvate to nearly equicurvate; anterior cardinal angle prominent and somewhat obtuse in the LV. Posterior margin slightly equicurvate to nearly supracurvate; posterior cardinal angle well-angulated and somewhat protruded in the LV, whereas more rounded shape in the RV. Hinge margin straight and moderately inclined towards posterior end. Ventral margin concave in the middle part; ventral lateral outline curve uptowards to poster end. Each valve with two dorsomedian sulci. Anterior sulcus weakly incised just in front of the anterodorsal node; dorsomedian sulcus more visible in dorsal view and somewhat reaching 2/3 of length. Two dorsal nodes in each of valve with conical shape, the anterior one somewhat small than the posterior one, and its point overreaching or not overreaching dorsal margin; posterior one more rounded and its point always overreaching dorsal margin. Two median or ventromedian large nodes with sharp tips which always point the posterior end in each of valve; a winding ventral lobe well-developed in ventrolateral region, which fused with posterocentral node. Anterocentral node 'horn-like' shape in dorsal view. Posterocentral node somewhat larger than anterocentral one, and broadly rounded in dorsal view, sometimes the posterodorsal node connect with the posterocentral node formed a ridge-like node. Ventral lobe fused with posterocentral node and its direction curved to anterior end (with 'L' shape in lateral view of the RV), extending up to anterocentral node (thus occasionally also fused with anterocentral node). Lateral outline of ventral lobe winding shape due to the three 'node-like' humps. Surface smooth or faintly reticulated. Normal pores both simple and sieve-type, simple pore shows two types: normal pore without a lip and normal pore with a lip (Fig. 11A); sieve pore, sieve plate with a central pore (Fig. 11C); normal pore with large hole on the inner side (Fig. 11D). Marginal pore canals developed in the anterior margin. Calcified inner lamella well developed along the free margin in both valves, but broader in anterior margin.
Muscle scar pattern. According to Gramm (1966, p. 84, fig. 3 therein), muscle scar pattern consisting four AMS, two FS, and one mandibular scar (MS). General shapes of muscle scars are same as in *V. jilinensis*, however, *V. ustinovskii* has one more FS?.
Internal characters. Hinge lophodont, well-developed teeth in the RV and corresponding sockets in the LV; hinge bar as a median hinge element in the LV and corresponding groove in the RV. Calcified inner lamella much broader in anterior margin. Selvage of LV overlapping that of RV.
Sexual dimorphism. Males larger and more elongated than females. Posterior margin nearly equicurvate in male morph, but supracurvate in female morph. Male individual develops less degree of development of the posterocentral node and lobe.
Ontogenetic variation. General outline of A1 instar is quite similar with female adult. However, A2? to A3? instars show strongly inclined dorsal margin with very narrow posterior margin (especially A3?). Surface reticulation, the pattern of reticula being the same as in adults, but the size of reticula is much smaller and shallower in juveniles. Nodes positions and shapes are same with adult.
Remarks. Gramm (1966) first identified the sexual dimorphism of this species: female morph with larger and more elongated carapace/valve; and male one with smaller and shorter carapace/valve. He also documented that he found a large number of male specimens (Gramm, 1966). However, Gramm's sexual dimorphism hypothesis of *V. jilinensis* is challenged and rejected here. On the basis of our newly discovery of sieve-type pore canal (StPC) of type C, we confirm that *Vlakomia* belongs to the Subfamily Limnocytherinae. Furthermore, the limnocytherine taxa display generally a different carapace dimorphism, namely the male morph is generally larger than the female one (Danielopol et al., 2018). Consequently, we consider that the larger, more elongated valve with narrower anterior margin belongs to a male (Fig. 10L) and the smaller carapace/valve with broader anterior margin belongs to a female (Fig. 10A–K). Males are extremely rare in our sample.

V. ustinovskii is distinguished from *V. jilinensis* by the horn-like shaped anterocentral node, ventral lobe and partially developed reticulation.

Vlakomia jilinensis (Gou, 1983) emend.
Figs. 11E–P, 12A–J.

1983 *Vlakomia jilinensis*, Gou, p. 50, pl. 2, figs. 1–8.
2007 *Vlakomia jilinensis*, Hou and Gou, p. 198, pl. 82, figs. 7–15.

Material. Four carapaces and forty valves from samples 17-TFS-1, 17-TFS-2, 17-TFS-3 and 17-TFS-5 (Fig. 3).
Size. Length: 0.40–0.64 mm; Height: 0.28–0.38 mm; Width: 0.28–0.32 mm.
Size in literature. Length: 0.60–0.62 mm; Height: 0.35–0.37 mm; Width: 0.31 mm (Gou, 1983).
Diagnosis (emended). Small to medium sized carapace, subrhomboidal in lateral view, and elliptical to rounded arrowhead shape (due to distinct ventrolateral nodes) in dorsal view. LV larger than RV. Anterior and posterior cardinal angles rounded or angular but distinct, especially in the LV. Ridge-like node rounded (adult to A-1 instar) to conical shape (A-2 to A-3?), and overreaching dorsal margin. Surface ornamented reticulation-like punctation and five nodes in each valve; anterodorsal node in behind anterior cardinal angle, ridge-like node in posterodorsal region, and three arranged in ventrolateral region.
Description. Small to medium sized carapace, thin shell, subrhomboidal in lateral view. Maximum length at mid-height, maximum height at 1/4 of length (anterior cardinal angle) and maximum width at 3/4 of length. In dorsal view, lateral outline somewhat elliptical to rounded arrowhead shape (due to the distinct ventrolateral nodes), and anterior marginal zone narrow. LV larger than RV; LV somewhat overlapping RV along the free margin, but nearly equivalve in dorsal margin. Anterior margin broad and slightly infracurvate, anterior cardinal angle well-defined and somewhat obtuse in the LV; slightly inflated smooth surface below the anterior cardinal angle. Posterior margin broadly rounded and slightly supracurvate to equicurvate; posterior

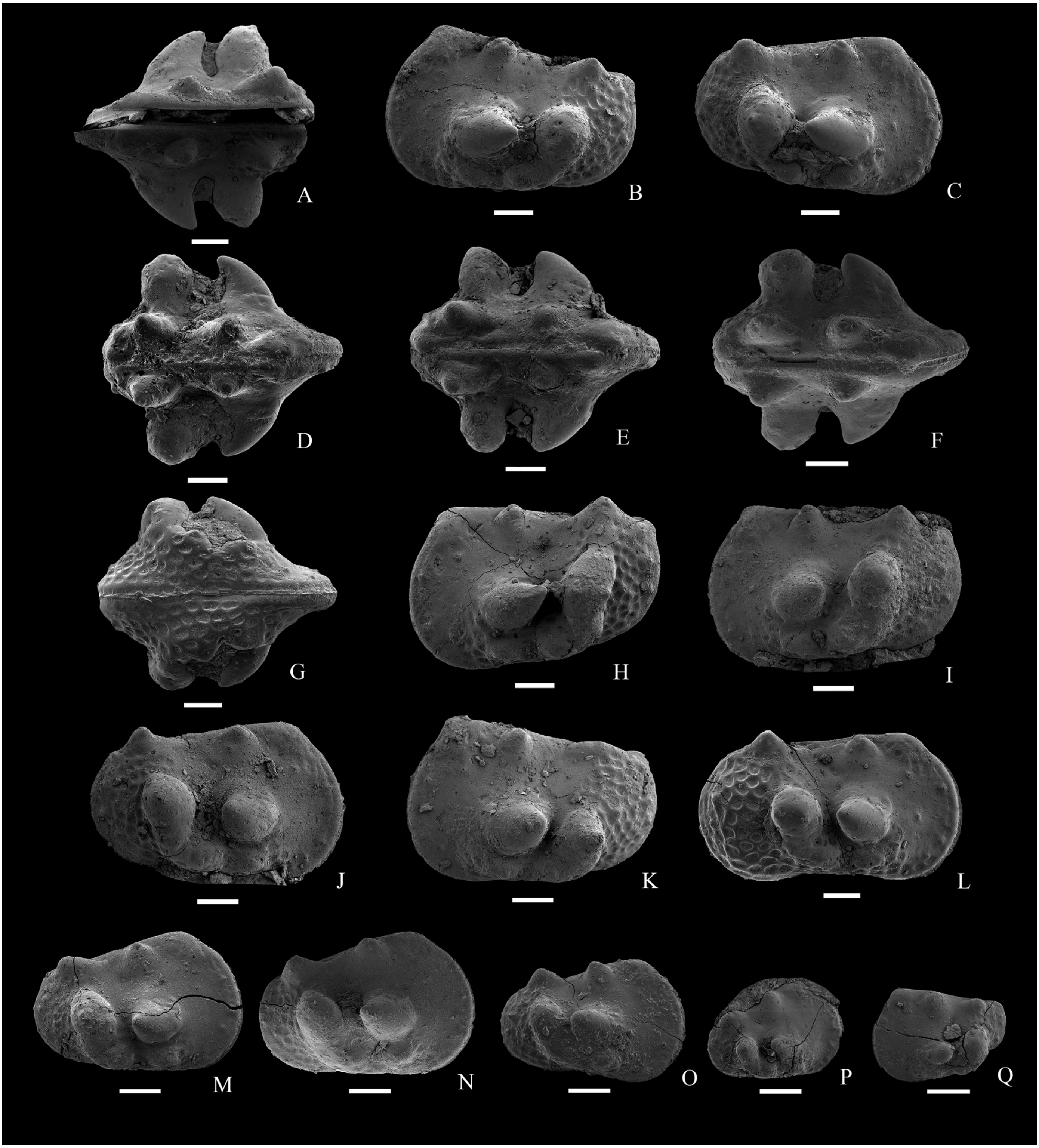

Fig. 10. A–Q. *Vlakomia ustinovskii* Gramm, 1966; A, dorsal view of female carapace, NIGP 168685, sample 16-TFS-3; B, lateral view of female left valve, NIGP 168685, sample 16-TFS-3; C, lateral view of female right valve, NIGP 168685, sample 16-TFS-3; D, dorsal view of female carapace, NIGP 168686, sample 16-TFS-3; E, dorsal view of female carapace, NIGP 168687, sample 16-TFS-3; F, dorsal view of female carapace (adult), NIGP 168688, sample 16-TFS-3; G, ventral view of female carapace (adult), NIGP 168689, sample 16-TFS-3; H, lateral view of female left valve (adult), NIGP 168690, sample 16-TFS-3; I, lateral view of female left valve (adult), NIGP 168691, sample 16-TFS-3; J, lateral view of female right valve (adult), NIGP 168692, sample 16-TFS-3; K, lateral view of female left valve (adult), NIGP 168693, sample 16-TFS-3; L, lateral view of male right valve (adult), NIGP168694, sample 16-TFS-3; M, lateral view of right valve (A-1 instar), NIGP 168695, sample 16-TFS-3; N, lateral view of right valve (A-1 instar), NIGP 168696, sample 16-TFS-3; O, lateral view of right valve (A-2? instar), NIGP 168697, sample 16-TFS-3; P, lateral view of right valve (A-3? instar), NIGP 168698, sample 16-TFS-3; Q, lateral view of left valve (A-3? instar), NIGP 168699, sample 16-TFS-3. Scale bar is 100 μm.

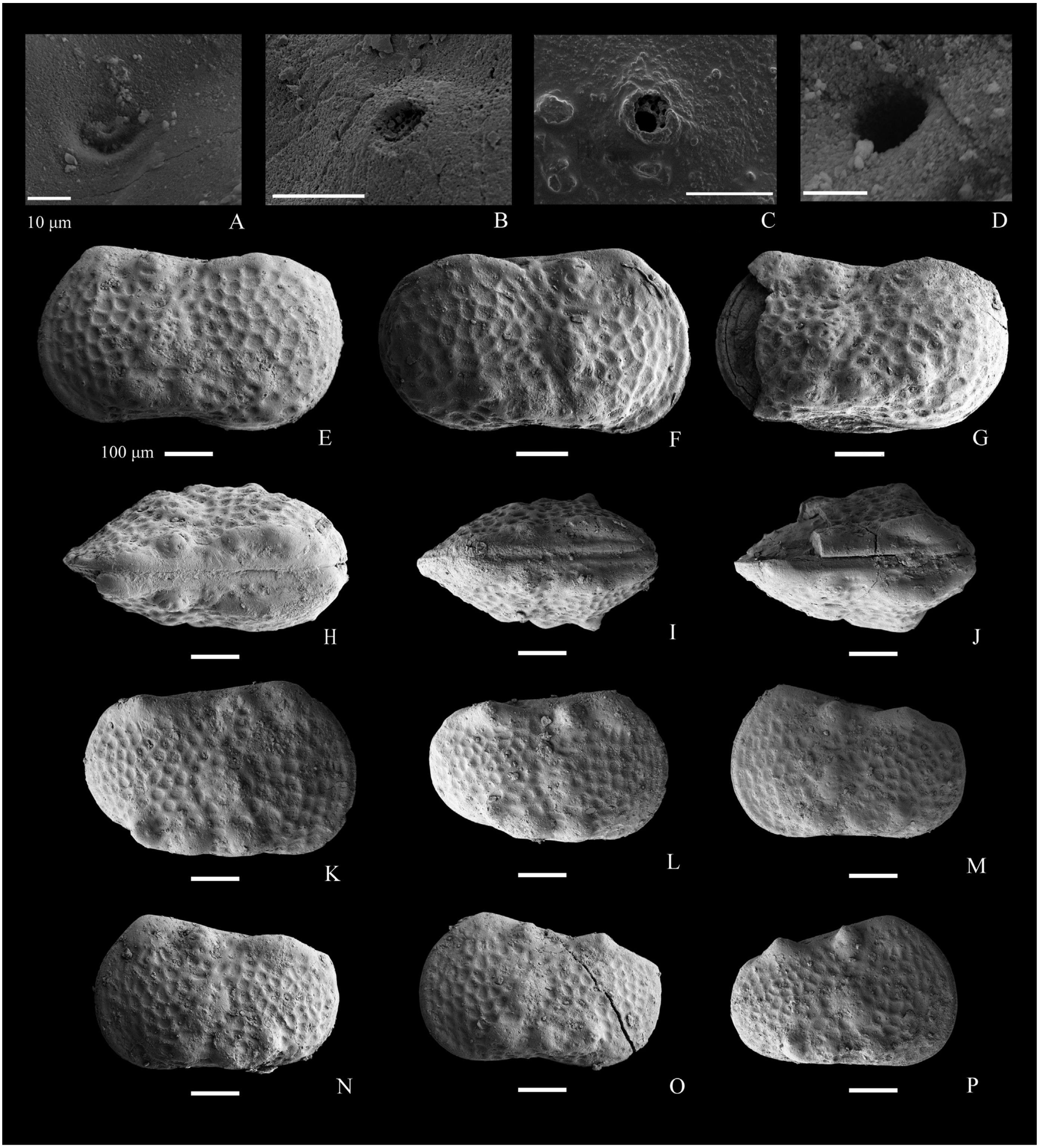

Fig. 11. A–D. Normal pores of *Vlakomia ustinovskii* Gramm, 1966; A, large normal pore with lip, B, sieve pore, C, sieve pore with sieve plate and central pore, D, canal of pore, inner side view; E–P. *Vlakomia jilinensis* Gou, 1983; E, left view of male valve (adult), NIGP 168700, sample 17-TFS-3; F, right view of male valve (adult), NIGP 68181 (Gou, 1983); G, left view of male carapace (adult), NIGP 68178 (Gou, 1983); H, idem, dorsal view, anterior end to the left; I, dorsal view of male carapace (A-1 instar), anterior end to the left, NIGP 168701, sample 17-TFS-3; J, dorsal view of female carapace (A-1 instar), anterior end to the left, NIGP 168702, sample 17-TFS-2; K, right view of female valve (adult), NIGP 168703, sample 17-TFS-2; L, right view of female valve (A-1 instar), NIGP 168704, sample 17-TFS-3; M, left view of female valve (A-1 instar), NIGP 168705, sample TFS-3; N, left view of female valve (A-1 instar), NIGP 168706, sample 17-TFS-2; O, left view of female valve (A-1 instar), NIGP 168707, sample 17-TFS-3; P, right view of juvenile valve (A-2 instar), NIGP 168708, sample 17-TFS-3.

cardinal angle rounded in the RV, but more angular shape in the LV. Dorsal margin straight along the hinge margin and slightly inclined towards posterior margin. Dorsolateral sulcus very weak at the front of anterodorsal node. Hinge margin straight and parallel with dorsal margin; in the LV, hinge margin somewhat incised forming a very narrow dorsal furrow. Ventral margin strongly concave in the middle of the RV, whereas moderately to strongly concave in the LV. Surface covered by reticulation/reticulation-like punctation, except for node surface; the pattern of punctation consisting round to polygonal-shaped puncta in almost area of carapace surface, but elongated puncta being located along the anterior margin. Centrolateral region somewhat inflated form which covered by small puncta, and coincident with muscle scar field area. Several sieve pores on the intersection of smooth surface (muri). Local-area ornamentation consists five distinct nodes in dorsolateral (both antero- and posterior parts) and ventrolateral parts; anterodorsal node small to medium size, but distinct and roundish form behind the anterior cardinal angle. Ridge-like node broadly rounded (males) or narrow to wide conical shape (females and A2 to A3? instars), overreaching the dorsal margin. Three ventrolateral nodes arranged or connected each other in a horizontal row along 2/5 to 4/5 of length.

Muscle scar pattern. Muscle scar pattern consists of AMS, FS and MS. AMS in centroventral, three reniform-shaped scars and one round scar in a vertical row. FS, one scar comparatively large, relatively close to AMS, and slightly above the highest scar of AMS. MS, one rounded located slightly below the AMS (Fig. 6D).

Internal characters. Hinge lophodont, RV with the anterior and posterior tooth (terminal element) and a groove (Fig. 12E); LV with anterior and posterior sockets (terminal element) and a hinge bar (median hinge element) (Fig. 12G).

Calcified inner lamella is well-developed along the free margin in adult stage and much broader in anterior margin. Juvenile specimens show less development of calcified inner lamella or absent. Selvage of LV overlapping that of RV.

Sexual dimorphism. Male morph is larger than female one with strongly concave ventral margin, as well as broad posterior margin. Ridge-like nodes always broadly round in males, but wide conical shape in females. Precocious sexual dimorphism (protofemale) present in A-1 instar.

Ontogenetic variation. General outline of instars of *Vlakomia jilinensis* (A-2 to A-3? instars) subrhomboidal. Posterior margin lower than the anterior one. Hinge margin deeply inclined towards posterior end, but dorsal margin of adult and A-1 instar is less inclined than younger juveniles. Surface reticulation, the pattern of reticula being the same as in adults, but the size of reticula is much smaller and shallower in juveniles. Ridge-like node shows a narrow conical shape in A-2 and A-3? instars, whereas A-1 instar shows a broad conical shape being the same as in adults. Calcified inner lamella of A-2 and A-3? is much narrower than adults, especially the anterior one; selvage distinct.

Remarks. Vlakomia jilinensis differs from *V. ustinovskii* in that it exhibits the male morphotype in general shape, the ornamentation pattern and the degree development of nodes in both female and male. The latter one has a very large 'horn-like' shaped anterocentral node and a large posterocentral node which is fused with the ventral lobe, as well as punctation partially developed. Extant species *Gomphocythere coheni* Park and Martens, 2001 (which belongs to the Subfamily Timiriaseviinae) from Lake Tanganyika of East Africa is very similar to *V. jilinensis* by carapace outline, node distribution and punctation pattern. However, this species has a large brood pouch and the female morph is larger than male one. *Limnocythere inopinata* is also similar to *V. jilinensis*, but the former one develops a medio-dorsal transverse groove in each valve and its ventral margin is more concave in the middle (Meisch, 2000).

5. Biostratigraphy, palaeoecology and palaeogeography

5.1. Biostratigraphy

The ostracod biostratigraphy of the Tongfosi and Dalazi formations has been discussed by Gou (1983) and Ye and Zhang (1995) respectively. Gou (1983) established three ostracod assemblages of the Tongfosi Formation: *Cypridea yanjiensis* – *Yanjiella jilinensis*, *Mongolocypris yanjiensis* – *Ziziphocypris costata* and *Vlakomia jilinensis* – *Ilyocyprimorpha yanbianensis* (= *Scabriculocypris yanbianensis* in this study) – *Scabriculocypris tonfosiensis*; and one assemblage of the Dalazi Formation: *Mongolocypris yanjiensis* – Gen. et sp. 1 (= *Yumenella toorojensis* of this study) – *Cypridea concinaformis*. On the basis of biostratigraphic correlations, she suggested the Dalazi and Tongfosi formations to be of Early Cretaceous age (Gou, 1983). Ye and Zhang (1995) restudied the ostracod biostratigraphy of the Tongfosi and Dalazi formations, and gave a wider age of Early Cretaceous to them. They established *Vlakomia* zone of the Tongfosi Formation, which is subdivided into three sub-zones: *Mongolianella robusta* sub-zone, *Vlakomia ustinovskii* – *Darwinula contraeta* sub-zone and *Ilyocyprimorpha yanbianensis* (= *Scabriculocypris yanbianensis* in this study) – *Vlakmia jilinensis* sub-zone; and *Triangulicypris* zone for the Dalazi Formation which consists of *Mantelliana papulosa*, *Triangulicypris oviformis* – *Cypridea yangliutunensis* and *Triangulicypris obtusangularis*– *Cypridea judaolingensis* sub-zones (Ye and Zhang, 1995). However, there are no descriptions or pictures of any studied ostracods, so their ostracod zones and sub-zones (Ye and Zhang, 1995) are doubtful. Furthermore, even the dominated species *Mongolocypris yanjiensis* in the Dalazi Formation (Gou, 1983) is not included in any of their ostracod zones and sub-zones (Ye and Zhang, 1995).

Here, nine species of five genera are identified from the ostracod fauna from the Tongfosi Formation. Among them, *Lycoperocypris infantilis* is widely distributed in Hauterivian to Cenomanian strata of Mongolia, China and Russia (Khand et al., 2000; Van Itterbeeck et al., 2004; Wang et al., 2016). *Scabriculocypris yanbianensis* is probably indicated an Albian age, because the presumed same species was found in the Jinju Formation of Gyeongsang Basin of South Korea (Choi's unpublished data). According to radiometric dates, the Jinju Formation is Albian (e.g., Lee et al., 2010; Kim et al., 2011; Kang and Paik, 2013; Lee et al., 2018). The stratigraphic range of *Vlakomia ustinovskii* is Albian to ?Cenomanian (Gramm, 1966). Consequently, the Tongfosi Formation is mainly Albian but may extend upwards into the Upper Cretaceous.

The ostracod fauna from the Dalazi Formation consists of five species from five genera. Among them, *Cypridea concinaformis* was reported from the Santonian Yaojia Formation and the Campanian Nenjiang Formation of the Songliao Basin (Hao et al., 1974). *Mongolocyrpis* has been frequently reported from upper Lower to Upper Cretaceous non-marine deposits of Asia. In China, Ye (1994) considered that its ranges from Albian to Paleocene (Danian), however, Wang et al. (2015) gave the first precise age – Aptian for the occurrence of *Mongolocypris*. In Mongolia, species of *Mongolocyrpis* are regarded as index taxa of Upper Cretaceous rocks (Khand, 2000). However, updated stratigraphic distribution data extend the range of some species of *Mongolocypris* downwards into uppermost Lower Cretaceous in Mongolia (latest Albian, Choi pers. comm. with Dr. Khand Yondon in 2015). The first record of *Mongolocypris* species from Korea was reported by Choi and Huh (2016), it comes from the Albian Jinju Formation. Thus, the updated biostratigraphic range of species of *Mongolocypris* is from Aptian to

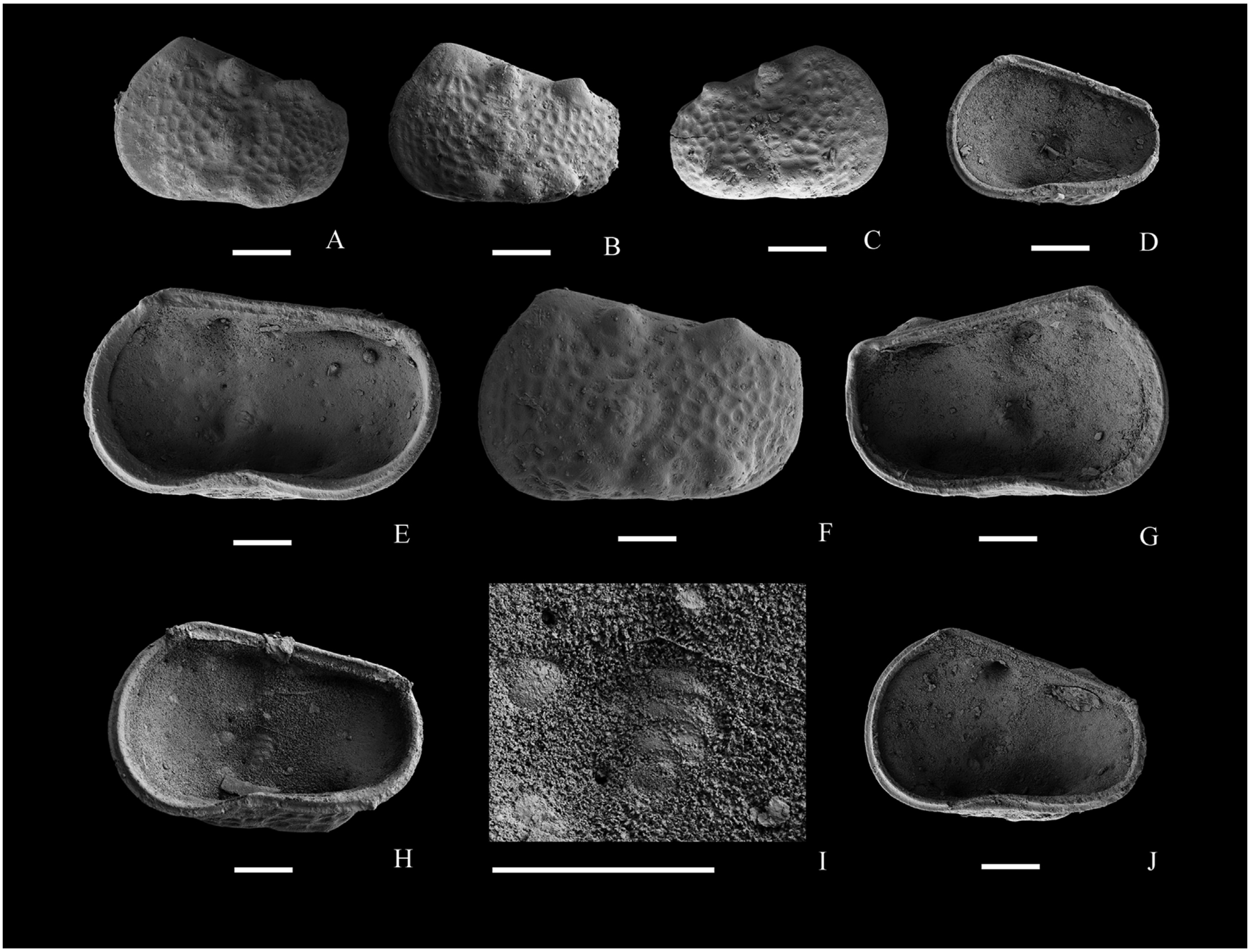

Fig. 12. A–J. *Vlakomia jilinensis* Gou, 1983; A, left view of juvenile valve (A-3? instar), NIGP 168709, sample 17-TFS-3; B, left view of juvenile valve (A-3? instar), NIGP 168710, sample 17-TFS-2; C, lateral view of juvenile right valve (A-3? instar), NIGP 168711, sample 17-TFS-3; D, internal view of valve (A-3? instar), NIGP 168711, sample 17-TFS-3; E, internal view of male valve (adult), NIGP 68181 (Gou, 1983); F, lateral view of left female valve (adult), NIGP 68182 (Gou, 1983); G, idem, internal view; H, internal view of female valve (adult), NIGP 168712, sample 17-TFS-2; I, idem, muscle scar pattern; J, internal view of juvenile valve (A-2 instar), NIGP 168708, sample 17-TFS-3. Scale bar is 100 μm.

Paleocene but mainly Albian to Paleocene. *Yumenella toorojensis* has been found from the Nemegt Formation in Mongolia and the Iren Dabasu Formation in China. Van Itterbeeck et al. (2005) suggested that the age of the Iren Dabasu Formation is latest Campanian to early Maastrichtian. The Dalazi Formation overlies the Tongfosi Formation, which is mainly Albian. Therefore, the age of the Dalazi Formation is not older than the Albian, thus probably early Late Cretaceous in age.

5.2. Palaeoecology and palaeogeography

The depositional environment of the Tongfosi and Dalazi formations has been disputed for a long time. Based on sedimentological analysis and the discovery of dinosaur tracks, an alluvial fan to lacustrine environment was proposed for the Tongfosi Formation (Matsukawa et al., 1995). Yuan et al. (2015) studied twenty cores and logs, and suggested a fan-delta lacustrine environment for the Tongfosi Formation. Huang and Zhang (2002) interpreted that the Dalazi Formation was deposited in a shallow to littoral-marginal lacustrine environment. However, based on sedimentological analysis and associated ostracods, clam shrimps, bivalves and gastropods fossils, Li et al. (2016) proposed a fan-delta lacustrine depositional environment for the Dalazi Formation.

Ostracods as palaeoenvironmental proxy have been widely applied to interpret the depositional environment of the Lower Cretaceous non-marine strata (e.g. Carbonel et al., 1988; Rosenfeld et al., 1988; Horne, 2002; Antonietto et al., 2012; Trabelsi et al., 2015; Carignano et al., 2017; Wang et al., 2017; Do Carmo et al., 2018). However, the role of the ostracods for palaeoenvironmental reconstruction of the Tongfosi and Dalazi formations has not been discussed in detail, only briefly mentioned in Li et al. (2016).

The population structure (e.g., adult/juvenile ratio) and preservation pattern (e.g., valve/carapace ratio) of ostracods can be used for palaeoenvironmental reconstruction (Whatley, 1983; Boomer et al., 2003). In the Tongfosi Formation, sample 17-TFS-0 contains only one species *Scabriculocypris yanbianensis* and all the specimens lack shells. The samples 17-TFS-2, 17-TFS-3 and 16-TFS-3 show high species diversity mainly represented by adult and juvenile valves with rare carapaces. Following the clear steps outlined by Boomer et al. (2003 p. 156–157), they represent a moderate energy thanatocoenosis. The early juvenile instars were probably removed by currents, but the assemblages are still good palaeoecological indicators. The sample 17-TFS-5 displays less species diversity than samples 17-TFS-2, 17-TFS-3 and 16-TFS-3 and absent *Vlakomia* species, it may indicate that the environment became unstable or unfavourable.

Samples from the Dalazi Formation show relative low species diversities compared to that from the Tongfosi Formation. The samples 16-DLZ-2, 5, 8 and 9 are characterised by large to gigantic sized valves, a high valve/carapace ratio, abundant adults and absence of younger juveniles (earlier stages than A1 instar), which may indicate a high energy taphocoenosis (see Boomer et al., 2003, fig. 2). The articulated valves were disarticulated and younger instars or small sized specimens were sorted out by post-mortem transport. While samples 16-DLZ-12, 13 and 17 are represented mainly by complete adult carapaces and A-1 juvenile instars. According to Whatley (1988) and Boomer et al. (2003), they indicated a high energy biocoenosis or thanatocoenosis.

The Tongfosi and Dalazi ostracod faunas are characterised by members from two superfamilies: Cypridoidea and Cytheroidea, the representatives of which are living in non-marine waters today. The typical Tongfosi ostracod element is Genus *Vlakomia* from the Subfamily Limnocytherinae of Superfamily Cytheroidea. Cytheroideans are non-swimming ostracods that crawl, climb or burrow (e.g. Meisch, 2000; Karanovic, 2012). Recent limnocytherine taxa tolerate a wide range of environmental conditions (Meisch, 2000; Karanovic, 2012). They occur in both small and large fresh water bodies (such as, ponds, swamps, lakes and rice fields) and also occur in superficial interstitial habitats, slightly salty coastal water and the slightly brackish areas of Sea (Meisch, 2000; Karanovic, 2012). In addition, the dinoflagellate assemblage indicates that the environment of the Tongfosi Formation may be slightly saline water (Qiao et al., 2003). Thus, the Genus *Vlakomia* probably inhabits temporary and permanent water bodies with fresh to slightly saline water environment.

The other members from the Tongfosi and Dalazi ostracod faunas, i.e. *Mongolocypris*, *Cypridea*, *Scabriculocypris*, *Mongolianella*, *Yumenella*, *Candona* and *Cyprois*, are assigned to the Superfamily Cypridoidea. Like many recent cypridoidean taxa, they are almost certainly able to lay resistant eggs, which enables them to colonize ephemeral pools, survive long periods of drought and transport long distance by wind and animals (Horne and Martens, 1998; Horne, 2002). *Cypridea* is closely related to the living *Bennelongia* for the anterior rostrum structure (Horne and Colin, 2005). The living *Bennelongia* species inhabit temporary and permanent fresh water bodies, but rarely inhabit water bodies with higher salinity (Karanovic, 2012; Martens et al., 2012). The living *Cyprois* species are usually found in temporary pools with rare records permanent waters, and ditches with pure water and much vegetation (Meisch, 2000; Karanovic, 2012). All living species of *Candona* adapt to crawling and/or digging, and living on or in the muddy bottom of lakes and springs (Meisch, 2000; Karanovic, 2012). Consequently, the ostracod fauna from the Tongfosi and Dalazi formations can be interpreted as indicating the prevalence of small temporary water bodies in the Yanji area during late Early Cretaceous to early Late Cretaceous time.

Based on this, we interpret the Tongfosi and Dalazi formations of the Yanji Basin to be deposited in a shallow-littoral lacustrine environment but with fluvial influence that potentially included some small ephemeral water bodies.

Palaeobiogeographic relationships of the non-marine Cretaceous ostracod fauna from the Yanji Basin have to re-analyzed based on new taxonomic revisions in the supraregional context, including considerations of modern insights into ostracod palaeobiology and dispersal mechanisms (Sames and Horne, 2012). Species of *Mongolocypris* have been found from non-marine Cretaceous sediments of Asia (mainly China, Mongolia, Korea, Japan and Baikal region of Russia) and North America (Alaska) (See Browers and De Deckker, 1993; Choi and Huh, 2016, fig. 2). Species of *Cypridea* have been reported from Late Jurassic to Cretaceous non-marine deposits almost worldwide except for Australia and Antarctica (Horne and Colin, 2005; Sames, 2011b). *Scabriculocypris* and *Cyprois* (which equals to those *Mantelliana* species with flange in typical Purbeck-Wealden deposits in Europe) species are known from China, Mongolia, Korea, Europe and North American (e.g. Anderson, 1985; Nikolaeva and Neustrueva, 1999; Hou et al., 2002; Neustrueva et al., 2005; Schudack and Schudack, 2009; Wang et al., 2016; Choi et al., 2017). *Scabriculocypris yanbianensis* is found in China and South Korea. Species of *Mongolianella* and *Lycopterocypris* have been reported from Cretaceous non-marine deposits of China and Mongolia (e.g. Nikolaeva and Neustrueva, 1999; Hou et al., 2002; Van Itterbeeck et al., 2004; Neustrueva et al., 2005; Wang et al., 2016). *Candona* is known from Cretaceous deposits almost worldwide. Up to now, *Yumenella toorojensis* is endemic to China and Mongolia (Khand, 1977; Van Itterbeeck et al., 2005), and *Vlakomia ustinovskii* and *V. jilinensis* only distributed in Jilin and Heilongjiang? provinces of China based on the present state knowledge (Gramm, 1966; Gou, 1983; Hou and Gou, 2007). Consequently, our non-marine ostracod taxa from the Yanji Basin provide the evidence of potential faunal exchanges between Northeastern China, Eastern Mongolia and South Korea during the Albian to early Late Cretaceous.

6. Conclusions

The ostracod faunas from the Tongfosi Formation (Tongfosi section) and from the Dalazi Formation (Longjing section) have provided significantly new biostratigraphic, palaeoecological and palaeogeographic data for the non-marine Cretaceous ostracod fauna in China.

The ostracod fauna from the Tongfosi Formation is dominated by *Vlakomia jilinensis* co-occurred with *Scabriculocypris tonfosiensis*, *Scabriculocypris yanbianensis*, *Mongolianella kyranbeki* sp. nov., *Lycopterocypris infantilis*, *Candona* spp. and *Vlakomia ustinovskii*. We recognize the sieve pore, ontogenetic stages and sexual dimorphism in *Vlakomia jilinensis* and *V. ustinovskii* for the first time. The sexual dimorphism of *V. jilinensis* precociously occurs in A-1 instar (see detailed discussion above). These taxonomic features provide new data for the future discussion on the phylogeny and evolution of the limnocytherid Subfamily Limnocytherinae.

This ostracod fauna suggests the age of the Tongfosi Formation is Albian but may extend upwards into Late Cretaceous and supports the interpretation of a lacustrine environment referred to this formation proposed by Matsukawa et al. (1995) and Yuan et al. (2015).

The ostracod fauna from the Dalazi Formation consists of *Mongolocypris yanjiensis*, *Cypridea concinaformis*, *Cyprois* sp., *Lycopterocypris* sp. and *Yumenella toorojensis*. This ostracod fauna indicates the age of the Dalazi Formation is not older than Albian probably an early Late Cretaceous age. The Dalazi Formation represents a shallow-littoral lacustrine environment that potentially included small ephemeral water bodies.

Palaeobiogeographically, the ostracod faunas of the Tongfosi and Dalazi formations show affinities to ostracod faunas from Eastern Mongolia and South Korea, providing evidence of potential faunal exchanges between Northeastern China, Eastern Mongolia and South Korea during the Albian to early Late Cretaceous times.

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Appendix A. Supplementary data

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