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A *Glyptagnostus reticulatus* trilobite faunule from the Cambrian of the Northern Qilian Mountains, northwest China, and its paleogeographical implications

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Abstract.—A *Glyptagnostus reticulatus* (Angelin, 1851)–bearing trilobite assemblage has been found from an unnamed Cambrian formation in the Northern Qilian Mountains area, of which geographical placement in the Cambrian is contested. *Glyptagnostus reticulatus* is a biostratigraphic indicator of the Furongian Series and Paibian Stage, and three agnostoid and six polymerid taxa from the Changgou section, Daliang area are described herein, along with conspecific forms from the nearby Chuancigou section. This well-preserved assemblage shows strong taxonomic affinity with northwestern Queensland, Australia, and western Hunan–eastern Guizhou, China, and likely comes from deep outer-shelf to slope setting associated with the Northern Qilian arc. It is consistent with other arguments that during the Cambrian, the Northern Qilian arc, along with the Hexi Corridor of the Alxa terrane, were more closely allied to South China than to North China.

Introduction

Fossils can be of unique significance in areas with complex geological histories for the information they provide on age and geographical associations. The northwestern part of Tibet is one of Earth's most complex areas geologically, and its early Paleozoic history is particularly difficult to decipher. During the Cambrian, the Qilian Mountains comprised a series of island arc complexes that were later juxtaposed between the converging Qaidam and Alxa blocks (e.g., Xiao et al., 2009; Pan et al., 2012; Song et al., 2013; Yu et al., 2021). The region contains a Neoproterozoic to early Paleozoic ophiolite sequence, belts of high-pressure metamorphic rock, island-arc volcanic rocks and granitoid plutons, and a series of Silurian–Carboniferous sedimentary cover sequences (Song et al., 2013) that finally accreted to the North China block at the end of the early Paleozoic or possibly later (Zhang et al., 2015). In the Northern Qilian Mountains area, the Cambrian outcrops sporadically and is characterized by the development of a thick series of marine volcanic rocks that are commonly strongly tectonically deformed. The specimens in this study have not been strongly deformed and are preserved in limestone, offering the unique opportunity for more confident identification.

Traditionally, the Qilian Mountains area is divided into five tectonically defined regions: the Hexi Corridor area (assigned to the Alxa Block), the Northern, Central, and Southern Qilian Mountains areas, and the Lajishan Range area (Zhou et al., 1996) (Fig. 1.1). Terreneuvian–Series 2 trilobites have never been found in these areas, but Miaolingian–Furongian trilobites are quite frequently preserved. They are all from deep shelf to basinal environments. Miaolingian–Furongian trilobites of the Hexi Corridor area have been studied by Zhu et al. (1979) and Zhou et al. (1982). Lin et al. (2013, 2015) have respectively studied Miaolingian–Furongian agnostoid and polymerid trilobites collected from the Lajishan Range area. Before that, in the Central Qilian Mountains area, Miaolingian–Furongian Cambrian trilobites were studied by Zhu (1960a, 1965), Zhu et al. (1979), and Zhou et al. (1996). In the North Qilian Mountains area, some Miaolingian trilobites have been reported from Tianzhu, Gansu Province (Zhu, 1960b), and a Furongian trilobite fauna has been discovered from Chuancigou, Qilian County, Qinghai Province (Lin and Zhang in Zhu et al., 1979). Later, a similar Furongian trilobite faunule was discovered by Zhou and his colleagues from the Changgou section, Daliang area, Menyuan County, Qinghai Province, 170 km southeast of Chuancigou (Fig. 1.2), when they studied the early Paleozoic stratigraphy and sedimentary–tectonic evolution of the eastern Qilian Mountains. These authors listed some trilobite names along with some plates illustrating fossils (Zhou et al., 1996). Here the collections from the Changgou section, Daliang area, are formally described for the first time, *Glyptagnostus reticulatus* (Angelin, 1851) is recognized in the Qilian Mountains area for the first time, and some of the original identifications are revised. *Glyptagnostus reticulatus* is cosmopolitan and defines the conterminous base of the Furongian Series and Paibian Stage (Peng et al., 2004b). Its occurrence can help pinpoint the base of the Furongian Series in this region. Other regional Cambrian trilobites collected by Zhou and his colleagues (1996) will be the subject of forthcoming papers.

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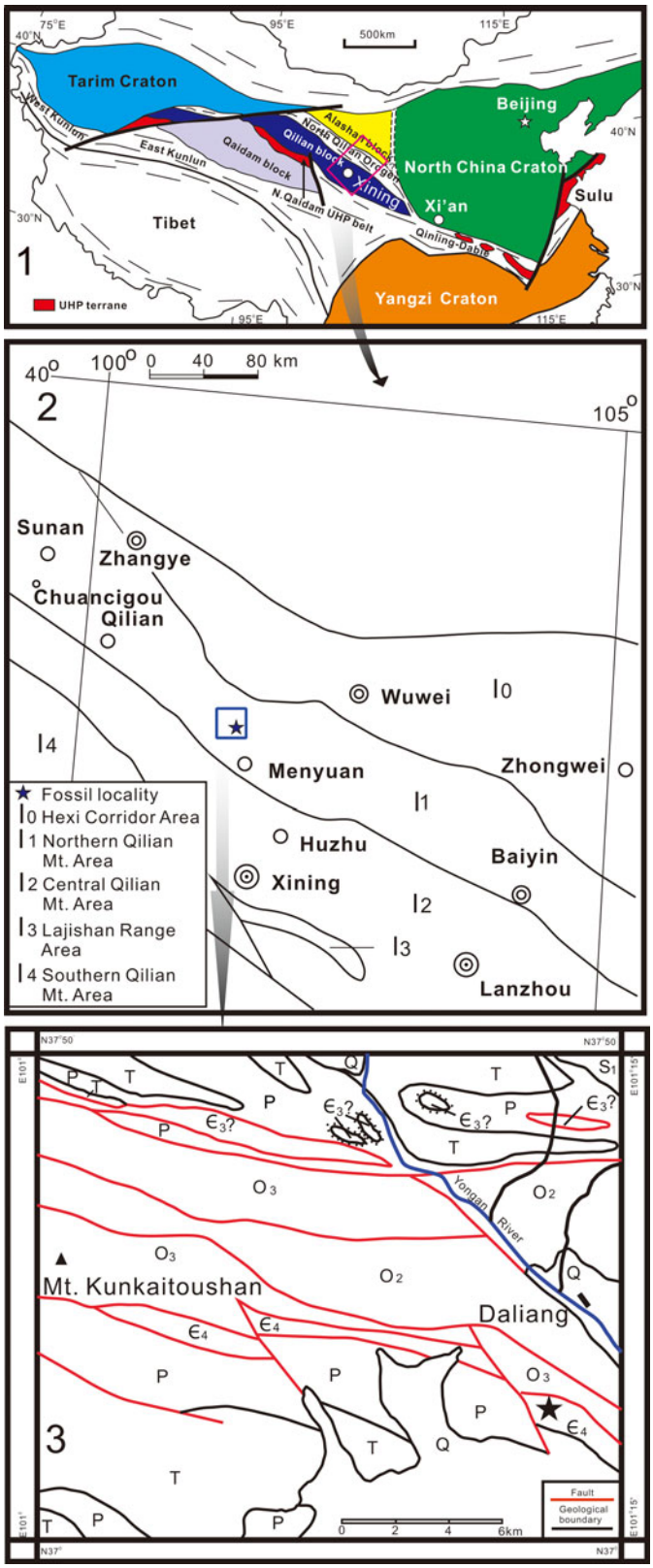

Figure 1. (**1**) Schematic map showing major tectonic units of China (modified from Song et al., 2013). (**2**) Geological sketch of Qilian Mountain area, northwest China (modified from Lin et al., 2013). (**3**) Geological map of Changgou section, Daliang area (modified from unpublished data, Qinghai Geological Bureau, 1969). C3 - Miaolingian, C4 - Furongian, O2 - Middle Ordovician, O3 - Late Ordovician, S1 - Llandovery, P - Permian, T - Triassic, Q - Quaternary.

Stratigraphy, age, and affinity

This trilobite faunule has been collected from Changgou, Daliang, Menyuan County, Qinghai Province (Fig. 1.3). The Cambrian strata of this area are traditionally ascribed to the Heicigou Group (Zhou et al., 1996) because their lithological features are similar to those of the eponymous section of the group, which lies in Heicigou, Tianzhu County, Gansu Province. The Heicigou Group in the type section belongs to the Wuliuan to Drumian Stages, Miaolingian Series, but the so-called Heicigou Group in the Changgou section is within the Furongian Series, and thus these two groups are not chronostratigraphically congruent. Therefore, the Cambrian strata of Changgou section likely merits a new lithostratigraphic unit name. Full discussion of the lithostratigraphy is beyond the scope of this paper, and in this paper the rocks from which our specimens were collected are referred to simply as an unnamed formation. It comprises thick spilitic basalts extruded subaqueously with one limestone interval (Fig. 2). Underlying rocks are not exposed, and the formation is overlain by the limestone of the Late Ordovician Koumenzi Formation. The contact between these two formations is mapped as a normal fault (unpublished data, Qinghai Geological Bureau, 1969).

Trilobites were collected from the limestone interval near the base of this unnamed formation (Fig. 2). The occurrence of *Glyptagnostus reticulatus* indicates this faunule is from the lower part of the Paibian Stage. Other agnostoid trilobites include *Pseudagnostus idalis* Öpik, 1967 and *Innitagnostus inexpectans* (Kobayashi, 1938). The polymerid trilobites include *Baikadamaspis sinensis* (Yang in Zhou et al., 1977), *Aphelaspis granulata* Kuo in Egorova et al., 1963, *Eugonocare* (*Olenaspella*) *transversa* Lin and Zhang in Zhu et al., 1979, *Paraacidaspis hunanica* Egorova in Poletaeva, 1960, *Shengia shergoldi* Peng, Babcock, and Lin, 2004c, and *Corynexochus plumula* Whitehouse, 1939.

The Changgou fauna is similar to that of Chuancigou. The latter comprises *Pseudagnostus communis* (Hall and Whitfield, 1877), *Corynexochus plumula*, *Aphelaspis qilianensis* Lin and Zhang in Zhu et al., 1979, *Eugonocare* (*Olenaspella*) *transversa*, *Shengia shergoldi*, *Dunderbergia elongata* Lin and Zhang in Zhu et al., 1979, *Proceratopyge chuancigouensis* Lin and Zhang in Zhu et al., 1979, and *Baikadamaspis sinensis*. These two faunas share four species, *Baikadamaspis sinensis*, *Shengia shergoldi*, *Corynexochus plumula*, and *Eugonocare* (*Olenaspella*) *transversa*, and two genera, *Pseudagnostus* and *Aphelaspis*. They are almost coeval, although *Glyptagnostus reticulatus* is not found in the Chuancigou section.

This trilobite association reveals strong affinities with western Hunan–eastern Guizhou, China, as described by Peng (1992), with all the genera and most of the species being found in both areas. Affinities with northwestern Queensland, Australia, are shown by the presence of all the agnostid species, *Corynexochus plumula*, and *Eugonocare* (Öpik, 1967). These associations are of interest considering the markedly different paleogeographic positions and associations proposed for North Qilian and associated regions during the early Paleozoic (e.g., compare Gehrels et al., 2011, fig. 10; Pan et al., 2012, fig. 5; Hu et al., 2015, fig. 12a; Zhang et al., 2015, fig. 12;

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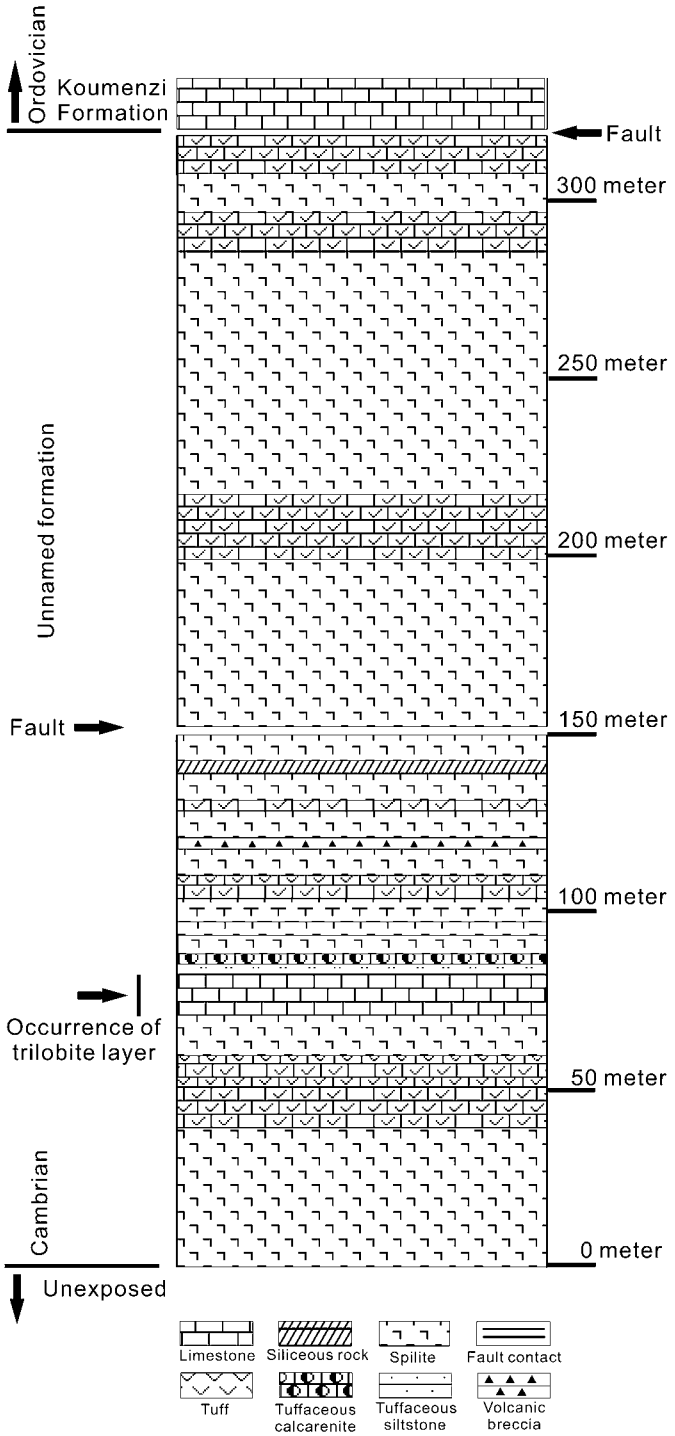

Figure 2. Stratigraphic column of the unnamed formation at Changgou section, Daliang area, Menyuan County, Qinghai Province, showing fossiliferous limestone layer occurring within a thick sequence of spilitic basalts and other volcanogenic rocks.

Han et al., 2016, fig. 4; Li et al., 2018, fig. 20B; Yu et al., 2021, fig. 11). Given the slope setting that these forms inhabited, high endemism for the fauna is unlikely. Nevertheless, the presence of species shared with South China and Australia supports a low-latitude peri-Gondwanan affinity for this fauna and is thus consistent with locating North Qilian in that region at the time.

The paleogeographical implications of this result are consistent with recent results based on integrated geological data that suggest that during the Cambrian, the Qaidam–Qilian–Alxa region was in the process of amalgamation (Xiao et al., 2009, fig. 12; Pan et al., 2012, fig. 5; Song et al., 2013, fig. 22) and sufficiently close to share fauna and sediment sources common to the South Chinese and Indian sectors of the Gondwana margin. Our results are thus in accord with those of Zhang et al. (2015), who pointed out that during the early Paleozoic provenance, data support a closer association of the Alxa block with South China than with North China. Accordingly, if recent reconstructions that link South China to western India in the Cambrian are correct (e.g., Burrett et al., 2014; Xu et al., 2014; Yao et al., 2014; Hughes, 2016; Zhou et al., 2019), the Qaidam–Qilian–Alxa regions were likely associated with it. Although some authors (Li et al., 2018, fig. 20B; Zhao et al., 2021, fig. 3) isolate North China from equatorial Gondwana during the Cambrian, detrital zircon and faunal evidence for its continuity with Gondwana at the time remains strong (McKenzie et al., 2011; Wernette et al., 2021). Our results need not suggest great geographic distance between the Northern Qilian Mountains area and the North China block during the Furongian, but rather highlight the paleoenvironmental contrast between the platform environment of the North Chinese late Cambrian deposits and the deeper water setting of the fauna described herein.

Repository and institutional abbreviation.—Illustrated materials are housed in the Nanjing Institute of Geology and Paleontology, Chinese Academy of Sciences (NIGP). We appreciate ongoing debates about the taxonomic affinity of Agnostina (e.g., Legg et al., 2013; Moysiuk and Caron, 2019), but as this study throws no further light on the higher-level affinity of the group, we treat them alongside Trilobita.

Systematic paleontology

Family Glyptagnostidae Whitehouse, 1936
Genus *Glyptagnostus* Whitehouse, 1936

Type species.—*Glyptagnostus toreuma* Whitehouse, 1936 (=*Agnostus reticulatus* Angelin, 1851; Öpik, 1961), from the Georgina Limestone of Queensland, Australia, by original designation.

Glyptagnostus reticulatus (Angelin, 1851)
Figure 3.1

2000 *Glyptagnostus reticulatus*; Peng and Robison, p. 87, fig. 71 (see for synonymy to date).
2000 *Glyptagnostus reticulatus*; Peng, Lin, and Zhu, fig.1.
2001 *Glyptagnostus reticulatus*; Peng et al., pl. 4.1–4.4, 5.1–5.3, 6.1, 6.6, 6.14.
2003 *Glyptagnostus reticulatus*; Ahlberg, fig. 3E–G.
2004a *Glyptagnostus reticulatus*; Peng et al., pl. 1.5–1.9.
2004b *Glyptagnostus reticulatus*; Peng et al., fig. 8C–E.
2005 *Glyptagnostus reticulatus*; Peng et al., fig.10.1, 10.2.

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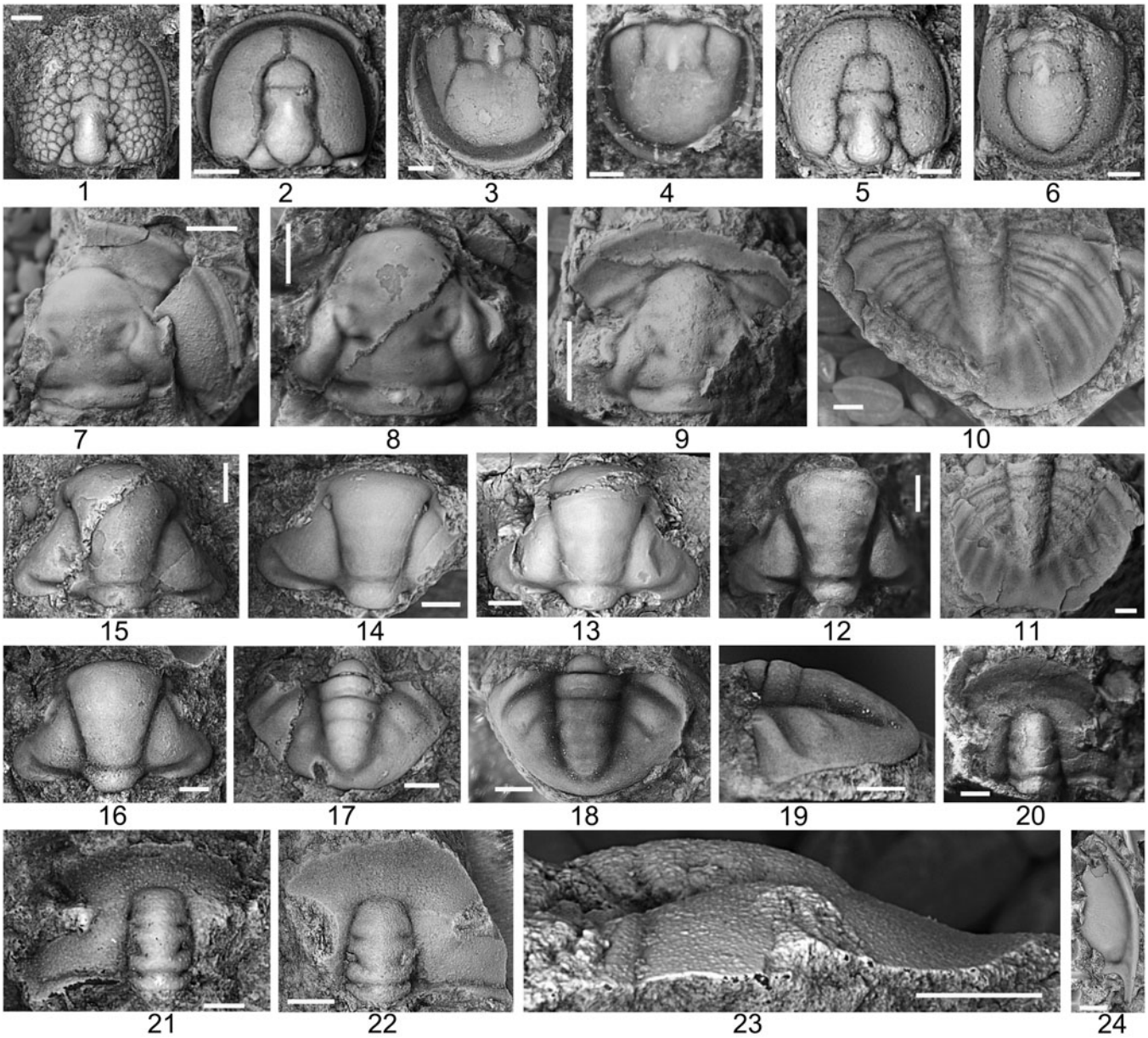

Figure 3. Trilobites from Changgou section, Daliang area, Menyuan County, Qinghai Province, except the holotype of *Pterocephalops granulus* Lin and Zhang in Zhu et al., 1979 (=*Baikadamaspis sinensis* [Yang in Zhou et al., 1977]) (**20**) and the holotype of *Corynexochus chinensis* Lin and Zhang in Zhu et al., 1979 (**12**) from Chuancigou, Qilian County, Qinghai Province. (**1**) *Glyptagnostus reticulatus* (Angelin, 1851), cephalon, scale bar = 1 mm, NIGPAS174370. (**2–4**) *Pseudagnostus idalis* Öpik, 1967: (**2**) cephalon, scale bar = 0.5 mm, NIGPAS174371; (**3**) pygidium, scale bar = 1 mm, NIGPAS174372; (**4**) pygidium, scale bar = 0.5 mm; NIGPAS174373. (**5, 6**) *Innitagnostus inexpectans* (Kobayashi, 1938): (**5**) cephalon, scale bar = 1 mm, NIGPAS174374; (**6**) pygidia, scale bar = 1 mm, NIGPAS174375. (**7–11**) *Paraacidaspis hunanica* Egorova in Poletaeva, 1960: (**7**) cranidium, scale bar = 5 mm, NIGPAS174376; (**8**) cranidium, scale bar = 5 mm, NIGPAS174377; (**9**) cranidium, scale bar = 5 mm, NIGPAS174378; (**10**) pygidium, scale bar = 2 mm, NIGPAS174379; (**11**) pygidium, scale bar = 2 mm, NIGPAS174380. (**12–19**) *Corynexochus plumula* Whitehouse, 1939: (**12**) cranidium, scale bar = 1 mm, NIGPAS44654 (the holotype of *Corynexochus chinensis* Lin and Zhang in Zhu et al., 1979, transferred to *C. plumula* in this paper); (**13**) cranidium, scale bar = 1 mm, NIGPAS174381; (**14**) cranidium, scale bar = 1 mm, NIGPAS174382; (**15**) cranidium, scale bar = 1 mm, NIGPAS174383; (**16**) cranidium, scale bar = 1 mm, NIGPAS174384; (**17**) pygidium, scale bar = 1 mm, NIGPAS174385; (**18, 19**) dorsal and left lateral view of pygidium, scale bar = 1 mm, NIGPAS174386. (**20–23**) *Baikadamaspis sinensis* (Yang in Zhou et al., 1977): (**20**) cranidium, scale bar = 1 mm, NIGPAS44665 (the holotype of *Pterocephalops granulus* Lin and Zhang in Zhu et al., 1979, transferred to *Baikadamaspis sinensis* in this paper); (**21**) cranidium, scale bar = 1 mm, NIGPAS174387; (**22, 23**) dorsal and right lateral view of cranidium, scale bar = 2 mm, NIGPAS174388. (**24**) Librigena of *Shengia shergoldi* Peng, Babcock, and Lin, 2004c, scale bar = 2 mm, NIGPAS174389.

2006 *Glyptagnostus reticulatus*; Varlamov, Pak, and Rosova, p. S29, pl. 1, figs. 1–3.

2008 *Glyptagnostus reticulatus*; Ergaliev and Ergaliev, p. 88, pl. 28, figs. 1, 4, 6.

2008 *Glyptagnostus angelini* Resser, 1938; Ergaliev and Ergaliev, p. 89, pl. 28, figs. 5, 7.

2012 *Glyptagnostus reticulatus*; Westrop and Eoff, p. 235, fig. 22.9–22.15.

2012 *Glyptagnostus reticulatus*; Ahlberg and Terfelt, fig. 3a, b.

2012 *Glyptagnostus reticulatus*; Schwimmer and Montante, p. 34, fig. 2.5–2.8.

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2013 *Glyptagnostus reticulatus*; Makarova, p. 13, fig. 1a.
2013 *Glyptagnostus reticulatus*; Peng et al., fig. 2.7c–g.
2014 *Glyptagnostus reticulatus*; Danukalova, Kuzmichev, and Korovnikov, pl. 3, figs. 4, 5.
2016 *Glyptagnostus reticulatus*; Peng, Hou, and Wang, fig. 4.45.

Lectotype.—Cephalon (Westergård, 1947, pl. 1, fig. 2, RM, no. Ar. 9794), Scania, Andrarum, Sweden, Furongian, *Olenus* Zone.

North Qilian material.—One cephalon.

Remarks.—Albeit slightly broken, the cephalon is assigned to *Glyptagnostus reticulatus* with certainty. The reticulate pattern on the genae and pleural fields of *Glyptagnostus reticulatus* varies ontogenetically and stratigraphically (Peng and Robison, 2000). The new material, with dense reticulate sculpture, is similar to those commonly occurring in younger strata within the zone. The anteroglabella in our specimen is sagittally bipartite. This feature is also found in the material of Bennett Island (Danukalova et al., 2014).

Family Agnostidae M'Coy, 1849
Genus *Pseudagnostus* Jaekel, 1909

Type species.—*Agnostus cyclopyge* Tullberg, 1880, from the Furongian of Sweden, by original designation.

Pseudagnostus idalis Öpik, 1967
Figure 3.2–3.4

1967 *Pseudagnostus idalis* Öpik, p. 153, pl. 62, figs. 8, 9, pl. 63, figs.1, 3.
1971 *Pseudagnostus idalis*; Hill, Playford, and Woods, pl. 12, figs. 1, 2.
1980 *Pseudagnostus (Pseudagnostus) idalis* Öpik, 1967; Ergaliev, p. 107, pl. 11, fig. 9.
1982 *Pseudagnostus (Pseudagnostus) idalis*; Shergold, p. 26, pl. 2, figs. 1–5, pl. 3, figs. 1–8.
1982 *Pseudagnostus (Pseudagnostus) idalis sagittus*; Shergold, p. 27, pl. 3, figs. 1–8.
1985 *Pseudagnostus idalis*; Xiang and Zhang, p. 84, pl. 12, figs. 1–7.
1987 *Pseudagnostus (Pseudagnostus) idalis denisonensis*; Jago, p. 210, pl. 24, figs. 4–12.
1989 *Pseudagnostus (Pseudagnostus) vigilax*; Lu and Lin, p. 116 (233), pl. 14, figs. 5–11.
1992 *Pseudagnostus* (*Pseudagnostus*) *idalis huskissonensis*; Jago and Brown, p. 63, pl. 1, figs. U–W, pl. 2, figs. A–O.
1992 *Pseudagnostus* (*Pseudagnostus*) *idalis transversus*; Peng, p. 26, figs. 11M–Q.
1992 *Pseudagnostus* (*Pseudagnostus*) *ampullatus* Öpik, 1967; Peng, p. 26, figs. 11I–L.
1995 *Pseudagnostus* (*Pseudagnostus*) *idalis* Öpik, 1967; Shergold, Bordonaro, and Liñán, p. 251, pl. 3, figs. 1–6.
1995 *Pseudagnostus* (*Pseudagnostus*) sp. cf. *P. idalis* Öpik, 1967 sensu lato; Shergold, Bordonaro, and Liñán, p. 251, pl. 3, figs. 7–12.
2000 *Pseudagnostus josepha* (Hall, 1863); Peng and Robison, p. 16, figs. 10.1–10.10.
2004 *Pseudagnostus idalis*; Paterson and Laurie, p. 93, figs. 6B–D, F–N.
2006 *Pseudagnostus (Pseudagnostus) idalis*; Varlamov, Pak, and Rosova, p. s31, pl. 1, figs. 5–10.
2008 *Pseudagnostus (Pseudagnostus) idalis*; Ergaliev and Ergaliev, p. 168, pl. 29, figs. 5–13, pl. 31, figs. 1–3, 8–14, pl. 34, figs. 6–25, pl. 35, figs. 1, 2, 4–13, 15, pl. 39, figs. 5–7.

Holotype.—Pygidium (Öpik, 1967, pl. 62, fig. 8, CPC5908), Glenormiston, Queensland, Australia, Furongian, Idamean, *Corynexochus plumula* Zone.

Description.—Cephalon subcircular with deliquiate border furrow, axial furrow and median preglabellar furrow deep, gena smooth. Glabella rounded at front, slightly constricted at F2; F3 slightly bowed rearward. Basal lobes prominent, triangular. Pygidia suboval with deliquiate border furrow, acrolobe weakly constricted, pleural fields smooth; axial furrow behind F2 becoming shallower or entirely effaced when reaching to border furrow; posterolateral spines small; axis constricted at M2, F1 short and weak, and F2 deep to weak and interrupted by median tubercle.

North Qilian material.—One cephalon and two pygidia.

Remarks.—This species is commonly confused with *Pseudagnostus josepha* (Hall, 1863), and their relationship has been fully discussed (Peng and Robison, 2000; Laurie in Paterson and Laurie, 2004; Varlamov et al., 2006; Westrop and Eoff, 2012). The type specimens of *Pseudagnostus josepha*, collected from the Sunwaptan Lone Rock Formation of Wisconsin, are poorly preserved (Shergold, 1977, pl. 15, figs. 9, 10). Westrop (1986) assigned better material, collected from the coeval Bison Creek Formation, Alberta, to this species. Until new topotypes of *Pseudagnostus josepha* prove it to be synonymous with *Pseudagnostus idalis*, we prefer to treat them as separate species.

Genus *Innitagnostus* Öpik, 1967

Type species.—*Innitagnostus innitens* Öpik, 1967 from the Pomegranate Limestone, Willis Creek, northwestern Queensland, Australia, by original designation.

Remarks.—This genus is controversial currently. Some workers regarded it as a junior synonym of *Agnostus* or *Micragnostus* (e.g., Robison, 1994; Peng and Robison, 2000; Høyberget and Bruton, 2008), whereas others treated it as a separate genus (e.g., Shergold and Laurie, 1997; Laurie in Paterson and Laurie, 2004; Westrop and Eoff, 2012). In *Innitagnostus*, the glabella has an angulate recess at the base to accommodate the basal lobes, and lateral portions of glabellar M2 are commonly separated from the midmost glabella by weak longitudinal (exsag.) furrows. These two characters differentiate *Innitagnostus* from *Agnostus* and *Micragnostus*. At present, we regard them as three valid genera.

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Innitagnostus inexpectans (Kobayashi, 1938)
Figure 3.5, 3.6

2000 *Agnostus inexpectans*; Peng and Robison, p. 12, fig. 7 (see for synonymy).
2004 *Innitagnostus inexpectans*; Paterson and Laurie, p. 93, figs. 6O–Q.
2008 *Innitagnostus inexpectans*; Ergaliev and Ergaliev, p. 43, pl. 30, figs. 1–10.
2012 *Agnostus inexpectans*; Schwimmer and Montante, p. 34, fig. 2.1.
2012 "*Innitagnostus" inexpectans*; Westrop and Eoff, p. 231, figs. 21, 22.1–22.8.

Lectotype.—Cephalon (Westrop and Eoff, 2012, fig. 22.1–22.3, GSC12006), locality P6/6, British Columbia, Furongian, "*Taenicephalus*"- (=*Taenicephalites*) bearing black limestone.

Description.—Cephalon subcircular with moderate convexity, clearly furrowed, and smooth. Border narrow, slightly wider anteriorly; border furrow narrow. Preglabellar median furrow narrow, moderately deep. Glabella tapering forward; anterior glabellar subquadrate with a short frontal sulcus. F3 deep, narrow, and nearly straight; F2 and F1 fairly well defined and connected by weak longitudinal (exsag.) furrows. Glabellar node obscure. Basal lobes trapezoid with moderate size.

Pygidium subcircular, smooth with moderate convexity. Axial furrow deep, narrow. Axis constricted across M2. M1 trilobate; F1 shallow with moderate width, arching forward; F2 narrow and shallow, bent rearward by strong axial node. Posteroaxis ogival, terminal node obscure. Border narrow, slightly wider posteriorly. Posterolateral border spine small.

North Qilian material.—One cephalon and one pygidium.

Remarks.—Our new material is very similar to that described by Westrop and Eoff (2012) and is regarded as conspecific.

?Family Harpididae Whittington, 1950
Genus *Baikadamaspis* Ergaliev, 1980

Type species.—*Baikadamaspis proprius* Ergaliev, 1980, from the *Glyptagnostus reticulatus* Zone and *Homagnostus longiformis* Zone, Malyi, Karatau, Kazakhstan, by original designation.

Baikadamaspis sinensis (Yang in Zhou et al., 1977)
Figure 3.20–3.23

1977 *Loganopeltoides sinensis* Yang in Zhou et al., p. 244, pl. 73, fig. 18.
1978 *Loganopeltoides sinensis*; Yang, p. 70, pl. 13, figs. 11, 12.
1979 *Pterocephalops granulus*; Lin and Zhang in Zhu, Lin, and Zhang, p. 92, pl. 38, fig. 2.
1982 *Loganopeltoides sinensis*; Liu, pl. 230, fig. 18.
1996 *Loganopeltoides sinensis*; Zhou et al., p. 46, pl. 7, figs. 9, 10.
2004c *Baikadamaspis sinensis*; Peng, Babcock, and Lin, p. 159, pl. 74, figs. 6–12; text-fig. 21.

Holotype.—Cranidium (Zhou et al., 1977, pl. 73, fig. 18; also Yang, 1978, pl. 13, fig. 12, CUGB [China University of Geosciences] 0308001), Tingziguan, Chatian Town, Fenghuang County, Hunan Province, southwest China, Furongian, *Chuangia–Prochuangia* Zone.

North Qilian material.—Two cranidia.

Remarks.—Our material was assigned originally to *Loganopeltoides* by Zhou et al. (1996) and later transferred to *Baikadamaspis* by Peng et al. (2004c). This transfer is accepted. *Pterocephalops granulus* Lin and Zhang in Zhu et al., 1979 was transferred to *Pterocephalopsinus* by Jell in Jell and Adrain, 2003, as its genus name is preoccupied. It was later transferred to *Baikadamaspis* by Peng et al., 2004c. The holotype has been refigured herein (Fig. 3.20). It is similar to the holotype of *Baikadamaspis sinensis* (Peng et al., 2004c, p. 160, text-fig. 21) and our material and is regarded as a junior synonym of *Baikadamaspis sinensis*.

Family Pterocephalidae Kobayashi, 1935
Genus *Aphelaspis* Resser, 1935

Type species.—*Aphelaspis walcotti* Resser, 1938, from the Furongian of Virginia, subsequently designated by Palmer (1953).

Aphelaspis granulata Kuo in Egorova et al., 1963
Figure 4.14–4.25

1963 *Aphelaspis granulata* Kuo in Egorova et al., p. 59, pl. 14, figs. 7–11.
1965 *Aphelaspis granulata*; Lu et al., p. 177, pl. 30, figs. 1–4.
1992 *Aphelaspis granulata*; Peng, p. 57, figs. 27D–G.

Holotype.—Cranidium (Egorova et al., 1963, pl. 14, fig. 11, GMC (Geological Museum of China) F281, Chuandong Town, Tongren County, Guizhou Province, southwest China, Furongian.

Description.—Cranidium subquadrate with high convexity. Glabellar tapering forward, obtusely round or truncate anteriorly. Four pairs of lateral glabellar furrows shallow. Eye ridges prominent, extending backward slightly; palpebral lobe moderately large, located at the mid-length of glabella. Anterior branch of facial sutures divergent, and posterior branch of facial sutures diagonally extending outward and backward. Preglabellar field long (sag.), anterior border furrow shallower medially, and anterior border narrower abaxially. Occipital furrow arching backward, shallower medially; occipital ring wider proximally, occipital tubercle small. Posterior border furrow deep and wide. Exoskeleton covered with small granules.

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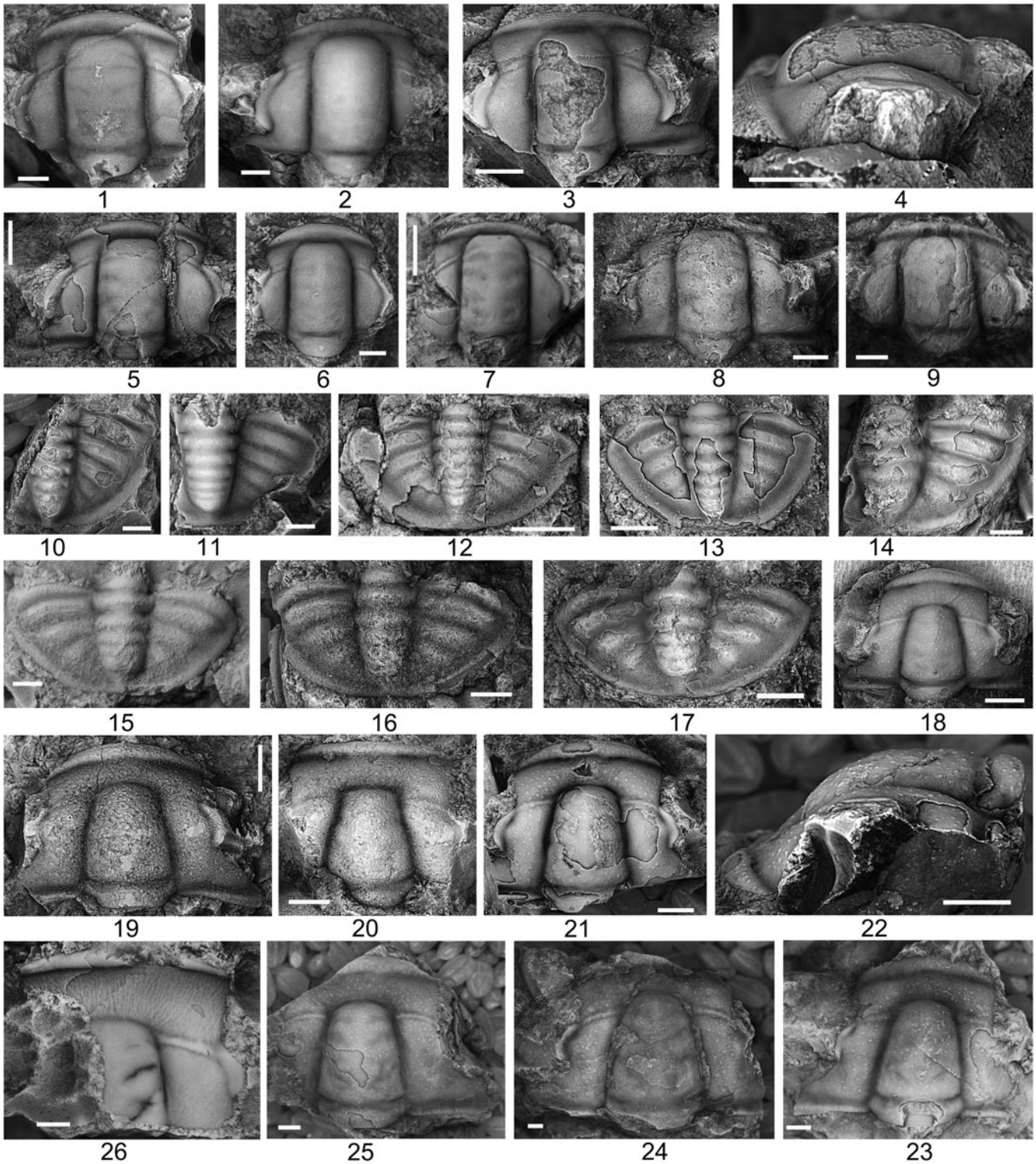

Figure 4. Trilobites from Changgou section, Daliang area, Menyuan County, Qinghai Province except the holotype of *Shengia intermedia* Lin and Zhang in Zhu et al., 1979 (=*Shengia shergoldi* Peng, Babcock, and Lin, 2004c) (**9**) from Chuancigou, Qilian County, Qinghai Province. (**1–13**) *Shengia shergoldi* Peng, Babcock, and Lin, 2004c: (**1**) cranidium, scale bar = 1 mm, NIGPAS174390; (**2**) cranidium, scale bar = 1 mm, NIGPAS174391; (**3, 4**) dorsal and left lateral view of cranidium, scale bar = 2 mm, NIGPAS174392; (**5**) cranidium, scale bar = 2 mm, NIGPAS174393; (**6**) cranidium, scale bar = 1 mm, NIGPAS174394; (**7**) cranidium, scale bar = 1 mm, NIGPAS174395; (**8**) cranidium, scale bar = 2 mm, NIGPAS174396; (**9**) cranidium, scale bar = 2 mm, NIGPAS44701 (the holotype of *Shengia intermedia* Lin and Zhang in Zhu et al., 1979, transferred to *S. shergoldi* in this paper); (**10**) pygidium, scale bar = 1 mm, NIGPAS174397; (**11**) pygidium, scale bar = 1 mm, NIGPAS174398; (**12**) pygidium, scale bar = 2 mm, NIGPAS174399; (**13**) pygidium, scale bar = 2 mm, NIGPAS174400. (**14–25**) *Aphelaspis granulata* Kuo in Egorova et al., 1963: (**14**) pygidium, scale bar = 2 mm, NIGPAS174401; (**15**) pygidium, scale bar = 2 mm, NIGPAS174402; (**16**) pygidium, scale bar = 2 mm, NIGPAS174403; (**17**) pygidium, scale bar = 2 mm, NIGPAS174404; (**18**) cranidium, scale bar = 2 mm, NIGPAS174405; (**19**) cranidium, scale bar = 2 mm, NIGPAS174406; (**20**) cranidium, scale bar = 2 mm, NIGPAS174407; (**21, 22**) dorsal and left lateral views of cranidium, scale bar = 2 mm, NIGPAS174408; (**23**) cranidium, scale bar = 2 mm, NIGPAS174409; (**24**) cranidium, scale bar = 2 mm, NIGPAS174410; (**25**) cranidium, scale bar = 2 mm, NIGPAS174411. (**26**) *Eugonocare (Olenaspella) transversa* Lin and Zhang in Zhu et al., 1979, cranidium, scale bar = 2 mm, NIGPAS174412.

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Pygidia inverted trapezoid in outline with small granules. Axis as wide as half of pleural region, tapering backward gently, composed of three axial rings and terminal axial piece; terminal axial piece divided by a shallow transverse furrow. Postaxial ridge narrow. Four pairs of pleural furrows deep and wide, interpleural furrow undeveloped. Border furrow shallow. Border narrow, wider posteriorly, and gently arching forward medially.

North Qilian material.—Abundant cranidia and pygidia.

Remarks.—This is the first time that a pygidium associated with this species has been found. The species is easily differentiated from *Aphelaspis qilianensis* Lin and Zhang in Zhu et al., 1979 by its granulose cranidia and relatively narrow pygidial axis.

Genus *Eugonocare* (*Olenaspella*) Wilson, 1956

Type species.—*Parabolinella*? *evansi* Kobayashi, 1938, from McKay Group, British Columbia, Canada, by original designation.

Eugonocare (*Olenaspella*) *transversa* Lin and Zhang in Zhu, Lin, and Zhang, 1979
Figure 4.26

1979 *Olenaspella transversa* Lin and Zhang in Zhu, Lin, and Zhang, p. 93, pl. 38, figs. 9, 10.

Holotype.—Cranidium (Zhu et al., 1979, pl. 38, fig. 9, NIGPAS44672), eastern branch of Chuancigou, Qilian County, Qinghai Province, northwest China, Furongian.

North Qilian material.—One cranidium.

Remarks.—Although our specimen is broken, its wide (tr.) cranidium, short (sag.) and wide (tr.) glabella, long (exs.) eye ridge, and wide (tr.) fixigena warrant its assignment to this species. The diagnosis of *Eugonocare* has been revised by Peng (1992, p. 59) and included three subgenera, *Eugonocare*, *Olenaspella*, and *Pseudeugonocare*, distinguished by their pygidial marginal spines, which are not represented in our collection. The latter two genera have been found in China. *Eugonocare* (*Olenaspella*) usually occurs in the Jiangshanian Stage, and *Eugonocare* (*Pseudeugonocare*) occurs earlier in the Paibian Stage in China. Given this, our specimens are more likely *Eugonocare* (*Pseudeugonocare*). As the pygidium of this species has not been found at this locality, and Zhu in Zhou and Zhen (2008) has already ascribed this species to *Eugonocare* (*Olenaspella*), at present we follow Zhu in Zhou and Zhen's (2008) assignment and tentatively assign it to *Eugonocare* (*Olenaspella*).

Family Eoacidaspidae Poletaeva, 1957
Genus *Paraacidaspis* Poletaeva, 1960

Type species.—*Paraacidaspis hunanica* Egorova in Poletaeva, 1960 from the *Chuangia–Prochuangia* Zone, Huaqiao Formation, Tingziguan, Chatian, Fenghuang, northwestern Hunan, China, by original designation.

Paraacidaspis hunanica Egorova in Poletaeva, 1960
Figure 3.7–3.11

2004c *Paraacidaspis hunanica*; Peng, Babcock, and Lin, p. 147, pl. 46, figs. 1–16, text-fig. 24 (see for synonymy).

Holotype.—Cranidium (Poletaeva, 1960, pl. 3, fig. 1; GMC [Geological Museum of China] 2604), Huaqiao Formation, Tingziguan, Chatian, northwestern Hunan, China, Furongian.

North Qilian material.—Three cranidia and two pygidia.

Remarks.—Peng et al. (2004c) have discussed the morphological variation of this species, and our material falls within the range of it.

Family Lisaniidae Zhang, 1963
Genus *Shengia* Xiang in Egorova et al., 1963

Type species.—*Shengia quadrata* Xiang in Egorova et al., 1963, from the *Glyptagnostus reticulatus* Zone, Huaqiao Formation, northwestern Hunan, by original designation.

Shengia shergoldi Peng, Babcock, and Lin, 2004c
Figures 3.24, 4.1–4.13

1979 *Shengia intermedia* Lin and Zhang in Zhu, Lin, and Zhang, p. 102, pl. 40, fig. 13.

Holotype.—Cranidium (Zhu et al., 1979, pl. 40, fig. 13, NIGPAS44701), eastern branch of Chuancigou, Qilian County, Qinghai Province, China; Furongian.

Description.—Cranidium subquadrate in outline with high convex. Glabella long (sag.), almost parallel-sided to slightly tapering forward, obtusely rounded to truncated anteriorly, with four pairs of weakly incised lateral furrows. S1 bifurcated; S2 extending inward and backward; S3 transversely or slightly backward extending; S4 short and narrow, extending inward and upward. Occipital furrow wide medially, narrowing abaxially, and almost indiscernible laterally. Occipital ring broad (sag.) and narrowing distally; occipital tubercle small. Fixigena narrow (tr.), evenly convex. Eye ridge narrow and short (tr.); palpebral lobe long, arcuate, opposite to cranidial midpoint. Anterior border narrow and longer adaxially, gently arching forward, covered with terrace ridges. Posterior border furrow deep and wide; posterolateral projection long and wide. Librigena broad (tr.); lateral border generally tapering posteriorly and extending into a strong genal spine.

Pygidium semicircular; length (sag.) half of width (tr.). Axis strongly convex, with six rings and a terminal piece. Postaxial ridge weak. Pleural region evenly divided by five pairs of wide pleural furrows. Interpleural furrows indiscernible. Border wide and slightly arching forward medially, covered with weak terrace ridges.

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North Qilian material.—Abundant cranidia and pygidia and one librigena.

Remarks.—This species is originally named *Shengia intermedia* Lin and Zhang in Zhu et al., 1979. It is homonymous with *S. intermedia* (Resser and Endo, 1937), and Peng et al. (2004c) renamed it *S. shergoldi*. The holotype of this species is refigured (Fig. 4.9), and larger Changgou materials (Fig. 4.3, 4.8) are closely similar to it. The meraspid is differentiated by its relatively narrower fixigena and more curved anterior border. These differences are regarded as ontogenetic variations.

Family Corynexochidae Angelin, 1854
Genus *Corynexochus* Angelin, 1854

Type species.—*Corynexochus spinulosus* Angelin, 1854 from the middle Cambrian of Sweden, by original designation.

Corynexochus plumula Whitehouse, 1939
Figure 3.12–3.19

1979 *Corynexochus chinensis* Lin and Zhang in Zhu, Lin, and Zhang, p. 88, pl. 37, fig. 5.
1992 *Corynexochus chinensis*; Peng, p. 34, fig. 16J, non-fig. 16K.
1992 *Corynexochus plumula*; Peng, p. 34, figs. 16B–I, P (see for synonymy).
1992 *Corynexochus plumula*; Pratt, p. 45, pl. 9, figs. 17–21.
1996 *Corynexochus plumula*; Zhou et al., pl. 7, figs. 13, 14.
1999 *Corynexochus plumula*; Duan, Yang, and Shi, p. 164, figs. 12A, 13F.
2004 *Corynexochus plumula*; Paterson and Laurie, p. 96, fig. 7A–C.

Holotype.—Cranidium (Whitehouse, 1939, pl. 24, fig. 8), Georgina Limestone, Queensland, Australia, Miaolingian.

North Qilian material.—Four cephala and two pygidia.

Remarks.—This widespread and well-known species has been fully discussed by Whitehouse (1939) and Öpik (1967). The posterior branch of the facial suture extends backward and straightly outward in small cranidia (pl. 3, fig. 15) but is gently curved in larger cranidia (pl. 3, fig. 16) and curved in the largest cranidium (pl. 3, figs. 12, 14). This ontogenetically related variation can also be observed in northwestern Queensland material (Öpik, 1967, pl. 3, figs. 1, 2, 4).

Corynexochus chinensis Lin and Zhang in Zhu et al., 1979 and *C. pulcher* Zhou in Zhou et al., 1982, the other two late Cambrian species, are reminiscent of this species. Lin and Zhang in Zhu et al. (1979) separated *C. chinensis* from *C. plumula* by the former's nearly straight cranidial axial furrow, relatively less expanding glabella, longer palpebral lobe, and narrower fixigena. The holotype of *C. chinensis* is a cranidium and refigured herein (Zhu et al., 1979, pl. 3, fig. 12). As seen herein, all cranidial features of these two species are similar, and it is hard to differentiate them. Therefore, *C. chinensis* is regarded as a junior synonym of *C. plumula*. The pygidium of *C. chinensis*, ascribed to this species by Peng (1992), is easily differentiated from that of *C. plumula* by its relatively larger width/length ratio. It may belong to another species of this genus. As mentioned by Peng (1992), because *C. pulcher* is based on meraspid materials, it may also be a junior synonym of *C. plumula*.

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