Late Ordovician trilobites from the Xiazhen Formation in Zhuzhai, Jiangxi Province, China

DONG-CHAN LEE


Trilobites from mudstone of the Upper Ordovician Xiazhen Formation of South China are described. The reef-associated, unique fauna comprises 25 species, 14 genera, and ten families. Five new species are named: *Remopleurides xiazhenensis* sp. nov., *Hibbertia aodiensis* sp. nov., *Vietnamia yushanensis* sp. nov., *Ceraurinus zhuzhaiensis* sp. nov., and *Pliomerina tashanensis* sp. nov. The paucity of trilobites in reef-associated carbonates is interpreted that the trilobites diversified after the reef system decimated. Compared to the Late Ordovician trilobite faunas in other areas of South China, the Xiazhen mudstone fauna is unique in that the phacopids including *Vietnamia*, *Ceraurinus*, and *Pliomerina* account for 75% of the specimens collected. The occurrence of the same trilobite assemblage at different sampling localities along the dip direction of the formation suggests that the outcrops may be overlapped due to structural movement. The Xiazhen trilobite fauna is unique among the Late Ordovician fauna in that it is predominated by phacopids and associated with reef.

**Key words:** Trilobita, Ordovician, Xiazhen Formation, Zhuzhai, Jiangxi Province, China.

Dong-Chan Lee [dclee@chungbuk.ac.kr], Department of Earth Science Education, Chungbuk National University, 52, Naesudong-ro, Heungdeok-gu, Cheongju, South Korea, 361-763.

Received 9 April 2011, accepted 21 September 2011, available online 22 September 2011.

Copyright © 2013 D.-C. Lee. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

**Introduction**

The Upper Ordovician Xiazhen Formation in South China is well known for its reefs, mainly consisting of tabulate corals, stromatoporoids, and algae (Li et al. 2004; Zhang et al. 2007). The formation is also known to yield diverse other invertebrate fossils including brachiopods, cephalopods, gastropods, and trilobites. The brachiopod fauna has been well studied with focus on biostratigraphy and palaeobiogeography (e.g., Zhan and Cocks 1998; Zhan et al. 2002). In contrast, other invertebrates have received little attention and only their stratigraphical occurrences have been recorded. In the case of trilobites, the identification has been made at most to the genus level (see Chen et al. 1987; Zhang et al. 2007) and a proper systematic treatment has not been completed. Many trilobite specimens including several well-preserved articulated carapaces were collected from the mudstone rocks of the formation. This study systematically describes and illustrates this trilobite fauna.

**Institutional abbreviations.**—NIGP, Nanjing Institute of Geology and Palaeontology, Nanjing, China.

**Other abbreviations.**—exsag., exsagittally; L, glabellar lobe; S, glabellar furrow; sag., sagittally; tr., transversally.

**Material and methods**

The Xiazhen Formation consists of carbonates comprising tabulate coral/stromatoporoid reef and tidal/lagoonal limestone, and siliciclastics of mudstone/shale. The trilobites are known to occur in both mudstone and limestone beds (Chen et al. 1987; Zhang et al. 2007). Trilobite specimens were collected from the mudstone beds at five localities (Fig. 1). The mudstone is yellow brownish to olive greenish in colour, heavily weathered, and fractured at some localities (Fig. 2). The mudstone strata vary from a few decimetres (localities 1, 3, 4, and 5) to a few metres (locality 2) in thickness; it was not possible to accurately measure the thickness due to the deformation and weathering of the strata. Over 200 specimens were collected (Table 1); some are completely articulated. The specimens are mostly internal molds, but some have exoskeleton preserved. The specimens are moderately distorted in various directions. Latex casts were prepared for external molds to observe their external morphology.

**Geological setting**

The Xiazhen Formation is exposed at Zhuzhai in Yushan County, Jiangxi Province, China (Fig. 1). The formation is as-
signed to *Dicellograptus complexus* Graptolite Zone and is of late Katian (mid-Ashgill) age (Zhang et al. 2007: fig. 2-2); no biostratigraphical zones based on trilobites have been established for the stratigraphical interval in South China represented by the Xiazhen Formation. The formation is considered to be contemporaneous with the Sanqushan and Changwu formations; each formation is interpreted to represent co-existing sedimentary facies (lower-relief reef in shelf interior for the Xiazhen Formation, carbonate mudmound along shelf rim for the Sanqushan Formation, and fine detrital deposits in outer shelf for the Changwu Formation, respectively) in a rimmed shelf setting (Li et al. 2004: fig. 12).

Compared to the abundance and diversity of trilobites in the mudstone, fewer trilobites were found in reef-associated limestone in this study. Previous works have recorded trilobite occurrences in the limestone intervals (Zhang et al. 2007: 86–90); however, the abundance data was not compiled and only the taxon names are listed for each horizon. The occurrences documented in the previous works, but not in this study (units 3, and 13–15; see Table 2) are consistently associated with mudstone or shale lithology (see Zhang et al. 2007); even in these occurrences, only two genera were recorded (Table 2).

Only a few trilobite specimens were collected by this study (e.g., Fig. 6H) from the limestone layers where reef-building organisms are found. Considering abundant occurrence of well-preserved tabulate corals and stromatoporoids, the relative paucity of trilobites in reeval limestone, the paucity might be due to taphonomic control on taxonomic abundance (see Westrop 1986). Alternatively, the paucity suggests that the trilobites from the mudstone did not co-exist...
with reef-building organisms. A brachiopod lag deposit (Fig. 2D) underlies the mudstone at locality 1 and 2, although the direct contact was not detected, indicating that the mudstone is likely to have been deposited during a period of rapid relative sea-level rise. It seems that this sea-level rise played a crucial role in decimating the reef system, and the trilobites diversified afterwards.

Systematic palaeontology


Class Trilobita Walch, 1771
Order Asaphida Salter, 1864
Family Remopleuridae Hawle and Corda, 1847
Genus Remopleurides Portlock, 1843

Table 1. Occurrence and faunal composition of the trilobite fauna in the mudstones of the Xiazhen Formation.

<table>
<thead>
<tr>
<th>Order</th>
<th>Family</th>
<th>Faunal type</th>
<th>Species</th>
<th>Number of specimens per sample locality</th>
<th>Total</th>
<th>Proportion of the fauna (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asaphida</td>
<td>Remopleuridae</td>
<td>Ibex I</td>
<td>Remopleurides xiazhenensis sp. nov.</td>
<td>2 11 2 3 18</td>
<td>8.8</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Remopleurides aff. nasutus</td>
<td>2 2 4</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td>Nileida</td>
<td>Ibex II</td>
<td></td>
<td>Nileus sp.</td>
<td>1</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>Asaphida</td>
<td>Ibex II</td>
<td></td>
<td>Asaphidae ined.</td>
<td>1 9</td>
<td>4.9</td>
<td></td>
</tr>
<tr>
<td>Corynexochida</td>
<td>Styginidae</td>
<td>White rock</td>
<td>Metanillaenus? sp.</td>
<td>7</td>
<td>3.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Ekoosovopeltis cf. currajongensis</td>
<td>1</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Styginidae ined. sp. A</td>
<td>2</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Styginidae ined. sp. B</td>
<td>2</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>Harpetida</td>
<td>Harpetidae</td>
<td>White rock</td>
<td>Hibbertia aodiensis sp. nov.</td>
<td>5</td>
<td>2.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Scotoharpes sp.</td>
<td>1</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>Lichida</td>
<td>Lichidae</td>
<td>White rock</td>
<td>Amphilibas sp.</td>
<td>1</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>Phacopida</td>
<td>Calymenidae</td>
<td>White rock</td>
<td>Vietnamia yushanensis sp. nov.</td>
<td>6 39 12 8 4 69</td>
<td>33.7</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Vietnamia sp. A</td>
<td>1</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Vietnamia sp. B</td>
<td>3 3</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Vietnamia sp. C</td>
<td>1</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Vietnamia sp. D</td>
<td>2 1 3</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Vietnamia sp. E</td>
<td>1 1</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Vietnamia? sp.</td>
<td>1</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>cf. Reedoclymene sp.</td>
<td>1</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Neseuretinus? sp.</td>
<td>6</td>
<td>2.9</td>
<td></td>
</tr>
<tr>
<td>Cheiruridae</td>
<td>White rock</td>
<td></td>
<td>Ceraurinus zhuaiaensis sp. nov.</td>
<td>24</td>
<td>14.1</td>
<td></td>
</tr>
<tr>
<td>Encrinurida</td>
<td>White rock</td>
<td></td>
<td>Erratencrinurus aff. trippi</td>
<td>10</td>
<td>4.9</td>
<td></td>
</tr>
<tr>
<td>Pliomerida</td>
<td>Ibex II</td>
<td></td>
<td>Pliomerina ashanensis sp. nov.</td>
<td>22</td>
<td>10.7</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pliomerina sp.</td>
<td>4</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td>20 87 67 20 11 205</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* This specimen is collected from a limestone layer above the mudstone at Locality 1.

Type species: Remopleurides colbii Portlock, 1843; middle Caradoc of Ireland; by subsequent designation of Miller (1889); re-described and illustrated by Whittington (1950).

Remopleurides xiazhenensis sp. nov.
Figs. 3A, 4, 5A, B, F–K, M.

Etymology: After the Xiazhen Formation where the species occurs.

Holotype: NIGP-151979, an articulated specimen from locality 5.

Type locality: Locality 5, about 800 m south of Zhuzhai, Yushan County. GPS coordinate is 28°33′57.97″ N and 118°20′25.87″ E.

Type horizon: Xiazhen Formation, Upper Ordovician, Dicellograptus complexus Graptolite Zone.

Material.—Four articulated exoskeletons, ten thoraco-pygidia, two thoraces, and two cranidia (repository numbers: NIGP-151978, 151979, 151981–151983, 151985–151990)

Diagnosis.—Species of Remopleurides with non-spinose, entire pygidial margin and longitudinal ridges on occipital ring and thoracic axial rings.

Description.—Dorsal exoskeleton elliptical in outline, gently tapers backwards, and moderately convex. Cephalon semi-circular in outline. Axial furrow extremely narrow and deep. Glabella sub-circular in outline with maximum (tr.) width at
mid-palpebral point; postero-most part waisted and defined by axial furrows that are straight and run moderately convergent backwards; most glabellar area nearly flat. Glabellar tongue rapidly bends downwards and gently tapers forwards. Glabellar surface covered with fine, sub-parallel terrace lines arranged in concentric fashion that become indistinct toward center of glabella (more clearly seen in external mold). Occipital ring elongated (tr.) spindle-shaped; lateral profile mushroom-shaped (nearly flat, laterally expanded dorsal part and constricted middle part); base protruded outwards in triangular shape beyond dorsal outline of occipital ring; about 20 longitudinal ridges developed that are slightly curved outwards and become indistinct adaxially. Occipital furrow straight and deep. Palpebral lobe narrow. Preocular and palpebral area of fixigenae absent; postocular area narrow and triangular in outline. Posterior branch of facial suture sinusoidal. Librigena with moderately long, stout genal spine; librigenal field gently slope downwards and ornamented with moderately raised terrace-ridges. Eye large and crescentic in outline with exsagittal length being 80% of glabellar sagittal

---

### Table 2. Stratigraphical position of the sampling localities with reference to the lithological column by Chen et al. (1987: fig. 1) and Zhang et al. (2007: fig. 4-2).

<table>
<thead>
<tr>
<th>Stratigraphical unit</th>
<th>Collection number</th>
<th>Brachiopods</th>
<th>Trilobites</th>
<th>Locality in this study</th>
</tr>
</thead>
<tbody>
<tr>
<td>19</td>
<td>Yz’18-89</td>
<td>Antizygospira liquanensis Sowerbyella sinensis</td>
<td></td>
<td>locality 4/5</td>
</tr>
<tr>
<td>18</td>
<td>Yz’18</td>
<td>Oxoplecia Sowerbyella sinensis Strophomena Antizygospira liquanensis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Yz’17</td>
<td>Tcherskidium jiangshanensis Antizygospira liquanensis Ovalospira dichotoma Triplesia zhejiangensis Eospirifer praecursor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>covered</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Yz’15, Yz37-44</td>
<td>Tcherskidium jiangshanensis</td>
<td>Remopleurides sp.</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Yz’14, Yz35</td>
<td>Tcherskidium jiangshanensis</td>
<td>Remopleurides sp.</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Yz’13, Yz33-34</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Yz’12, Yz32</td>
<td>Eospirifer praecursor Ovalospira dichotoma Plectoglossa sp.</td>
<td></td>
<td>Dulanaspis</td>
</tr>
<tr>
<td>11</td>
<td>Yz’11, Yz29-31</td>
<td>Eospirifer praecursor Ovalospira dichotoma Plectoglossa sp.</td>
<td>Dulanaspis? Pliomerina Lichas</td>
<td>locality 3</td>
</tr>
<tr>
<td>10</td>
<td>Yz’10, Yz24-28</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>no collection</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>no collection</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Yz’7, Yz23</td>
<td>Sowerbyella Strophomena Antizygospira</td>
<td>Cheirusus Remopleurides Calymenesun Dulanaspis Eoharpes Ilaenus Eobronteus</td>
<td>locality 1/2</td>
</tr>
<tr>
<td>6</td>
<td>no collection</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>YZ 4-3’, Yz’5, Yz21-20</td>
<td>Altuethyrella zhejiangensis Ovalospira dichotoma Sowerbyella sinensis Antizygospira liquanensis Eospirigerina yulangensis Exostrophina anitlicipa</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Yz’4</td>
<td>Tcherskidium jiangshanensis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Yz’3, Yz19</td>
<td></td>
<td>Remopleurides</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>YZ3(1-3), Yz’2, Yz18</td>
<td>Eospirifer praecursor Antizygospira liquanensis Plectoglossa sp.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Yz’1, Yz16</td>
<td>Tcherskidium jiangshanensis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A1</td>
<td>FZ3</td>
<td>Eospirifer praecursor Tcherskidium jiangshanensis</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
length; eye socle narrow and eye socle furrow moderately deep and wide. Posterior librigenal border narrow and disappear distally. Presence of lateral librigenal border and furrow not observed.

Thorax of 11 segments. Axis gently tapers backwards; maximum width (located between second to fourth segment) about 60% of maximum thoracic width. Axial ring strongly convex and lateral profile identical to occipital ring; up to about 20 longitudinal ridges present; number of ridges progressively reduced towards posterior segments. Articulating furrow wide, steep-sided, and deep but become shallow adaxially. Articulating half ring with a pair of elongated pits; each pit located at adaxial one-quarter of axial ring; anterior margin appears to be broadly notched medially, forming dish-shaped outline. Axial spine on the eighth (from the anterior) segment projected posteriorly and narrow-based; exact length not known. Pleura rhomboidal in outline. Pleural furrow arrowhead-shaped in outline, obliquely directed, and separates pleura into two bands of unequal size. Anterior pleural band much larger than posterior one; anterior band convex, gently slopes forwards and steeply backwards; posterior band convex with equal steepness; dorsal surface of anterior band ornamented with fine terrace lines parallel to outer pleural margin, whereas no distinct lines on posterior band. Fulcral process large, strongly raised, moderately curved distally, and located adaxial one-third of pleura; fulcral socket follows outline of fulcral process. Pleural doublure ornamented with fine terrace lines that run parallel to outer pleural margin; crescentic articulating facet present on posterior half of doublure; dorsal surface of articulating facet smooth.

Pygidium small and sub-elliptical in outline. One axial ring present and divided into two strongly convex lobes by sagittal furrow. Fulcral process narrow and elongated. No pleural region present. Pleural border slightly concave. Pygidial margin non-spinose. Pygidial doublure ornamented with fine terrace lines that are parallel to pygidial margin.

Remarks.—Morphological features that distinguish *Remopleurides xiazhenensis* sp. nov. from other *Remopleurides* species are: (i) non-spinose, entire pygidial margin (see Figs. 4C2, 5B2, G), (ii) longitudinal ridges on the occipital ring and thoracic axial rings (see Fig. 4A1, C3), and (iii) a pair of elongated pits on thoracic articulating half ring (see Fig. 4A1).


Of these, the presence of a small pygidium with non-spinose margin is confirmed for *R. mukatchensis fastigatus* Koroleva (1982: pl. 7: 4, 5) and *R. cf. cinghizus* (Koroleva 1982: pl. 14: 4a). The pygidia of both species, however, dif-
fer from those of Remopleurides xiazhenensis sp. nov. in having concentric terrace lines (for the first) and straight ridges (for the second species) on the doublure of marginal border; R. xiazhenensis has terrace lines that are parallel to the border (Figs. 4C2, 5B2). Although the specimens of other species apparently have a small pygidium, they are too poorly preserved to compare their posterior margin in detail.

(ii) Longitudinal ridges on occipital ring and thoracic axial rings: Remopleurides species show various ornaments on occipital ring and thoracic axial rings; for example, transverse terrace lines and tubercules are developed in Remopleurides perspicax Nikolaisen (1983: see pl. 6: 6, 8) and R. eximius Whittington (1959: pl. 15: 7), concentric terrace lines in R. amphitryonoides Lu, 1975 (see Zhou et al. 2005: pl. 2: 13, 17) and R. cf. exallos (Edgecombe and Webby 2007: fig. 12G, H), and tubercules in R. pattersoni Chatterton and Ludvigsen (1976: pl. 1: 49). The longitudinal ridges are present in such Kazakhstan Remopleurides species as R. pisiformis (see Weber 1948: pl. 2: 29a, b; Koroleva 1982: pl. 9: 3a, b), R. cinghizus Koroleva (1982: pl. 14: 1, 2), and R. akdombackensis Koroleva (1982: pl. 15: 2). In regard to glabellar morphology, R. pisiformis (Weber 1948: pl. 2: 27–29; see also Koroleva 1982: pl. 8: 3a, pl. 9: 1) is most similar to R. xiazhenensis sp. nov.; R. cinghizus differs in having tuberculated glabellar surface (Koroleva 1982: pl. 13: 9) and R. akdombackensis in having more elongated (sag.) glabellar tongue (Koroleva 1982: pl. 15: 1). Cranidia of R. pisiformis differs in having terrace lines that cover the entire glabellar surface and are arranged in fingerprint-like fashion (terrace lines in R. xiazhenensis are strongly developed on anterior and lateral glabellar area and become indistinct toward the glabellar central area; see Fig. 4A3), and three pairs of glabellar furrows (no glabellar furrows are recognized in R. xiazhenensis). It cannot be determined whether or not R. pisiformis has a non-spinose, entire pygidial margin from the illustrations. However, Koroleva (1982: 71) mentioned the presence of a notch along pygidial margin as a coaptative device that is well observed in Remopleurides perspicax (Nikolaesin 1983: pl. 5: 2, 4), which suggests the presence of a spinose posterior pygidial margin.

The two Remopleurides species which have a non-spinose pygidial margin, R. mukatchensis fastigatus Koroleva (1982) and R. cf. cinghizus (Koroleva 1982) have transverse terrace lines (in the first species, see Koroleva 1982: pl. 7: 5) and tubercules (in the second, see Koroleva 1982: pl. 14: 4a).

(iii) A pair of elongated (tr.) pits on articulating half rings: The paired pits are observed where dorsal exoskeleton and doublure of the thoracic axial rings is partially exfoliated (see Fig. 4A1, C3). Since the ventral surface of the axial rings is not available, it cannot be determined whether the paired pit has a corresponding protruded structure on the doublure of axial rings. Silicified specimens of Remopleurides do not have a comparable ventral projection from the thoracic axial rings (see Whittington 1959: pl. 12: 17, pl. 14: 2; Chatterton and Ludvigsen 1976: pl. 1: 17, 31). The function of this paired pit is yet to be understood.

The ventral surface of the silicified specimens shows that the anterior margin of the articulating half rings is broadly notched posteriorly. In Remopleurides xiazhenensis sp. nov., the preserved portion of the doublure of axial rings shows a sharp, dish-shaped posterior margin (see eighth thoracic segment of Fig. 4A1 and third thoracic segment of Fig. 4C1), which has a similar outline as in the silicified specimens. The paired pits are located right at the boundary of the posterior margin (see Fig. 4C3), indicating that the margin may not truly reflect the notched anterior margin of the articulating half ring. However, such sharpness of the posterior margin implies that the anterior margin of the articulating half rings is notched (the exact extent is not known) but post-mortem deformation has slightly displaced the thoracic segments, resulting in the configuration as it is.

Except for the last feature which is only discernible where the specimen is properly exfoliated, none of Remopleurides species bear both non-spinose pygidial margin and longitudinal ridges on thoracic axial rings.

Stratigraphic and geographic range.—Late Ordovician and Jiangxi Province, South China.

Remopleurides aff. nasutus (Lu, 1957) Fig. 5C–E, L.

Material.—Three cephalo-thoraces and one cranidium (repository numbers: NIGP-151991–151994).

Remarks.—This species is readily distinguished from the coeval Remopleurides xiazhenensis sp. nov. by its sub-hexagonal glabella. Due to the poor preservation, the presence of the longitudinal ridges on occipital ring and thoracic axial rings diagnostic of R. xiazhenensis cannot be determined. The sub-hexagonal glabella and occipital and thoracic axial ring width are comparable to those of Remopleurides nasutus Lu, 1957 (see Lu 1975: pl. 4: 1, 2) from Shaanxi and Hubei, China.

Family Nileidae Angelin, 1854

Genus Nileus Dalman, 1827

Type species: Asaphus (Nileus) armadillo Dalman, 1827, probably from the Arenig (the Expansus Limestone) of Sweden.
Nileus sp.

Fig. 6L.

Material.—One articulated specimen minus free cheeks (repository number NIGP-152007).

Remarks.—This species resembles Nileus petilus Xia, 1978 from Hubei, China (see Zhou et al. 2005: pl. 3: 9, 15, 17, 21) and Nileus hunxianensis Zhou in Zhou et al., 1982 from Gansu, China (see Zhou and Dean 1986: pl. 60: 1–6, 8, 11) in sharing a gently curved anterior branch of facial suture and similar location of palpebral lobe. This species, however, differs in having a sagittally longer cranidial portion anterior to palpebral lobe, smaller palpebral lobe, and semi-circular pygidial outline with a slightly convex forward anterior margin. In particular, the presence of shallow anterior cranidial border and ventrally-curving anterior craniocates that this might be a new species of Nileus; the absence of anterior cranidial border and ventrally-curving anterior cranium are typical of Nileus (see Tjernvik 1956: pl. 2: 13 for N. limbatis Brügger. 1882) including N. petilus and N. huanxianensis. However, more specimens are required to officially erect it as a new species.

Family Asaphidae Burmeister, 1843

Asaphidae indet.

Fig. 6K, M.

Material.—Four free cheeks and six pygidia (repository numbers: NIGP-152005, 152006).

Remarks.—These free cheeks and pygidia are of generalized asaphid type. No corresponding cranidial materials were found.

Order Corynexochida Kobayashi, 1935

Family Styginidae Vogdes, 1890

Genus Meitanillaenus Chang, 1974

Type species: Meitanillaenus binodosus Chang, 1974, from the Lower Silurian Lungmachi Formation of Meitan, Guizhou, China; by original designation.

Meitanillaenus? sp.

Fig. 6A–E.

Material.—Seven cranidia (repository numbers: NIGP-151995–151999).

Remarks.—This species, only known from cranidial material, bears morphological features that are comparable to those of Meitanillaenus Chang, 1974, Failleana Chatterton and Ludvigsen, 1976, Sanghiscutellum Lin, 1987, and Ciliscutellum Lin, 1987. Zhou and Zhen (2008: 271) transferred all the Chinese species that had been previously assigned to Meitanillaenus into Lamproscutellum Yin, 1980, confining the stratigraphical occurrence of the former to the Silurian and the latter to the Ordovician. Cranidial morphology of Lamproscutellum is, however, readily distinguishable from that of Meitanillaenus by the presence of a paradoublural line, rounded antero-lateral corner of glabella, three distinct pairs of glabellar furrows, distinct fixigenal impression, and eye ridge (see Yin 1980: pl. 1: 4–6). The following species transferred to Lamproscutellum do not bear these features; Meitanillaenus luerkouensis Liu in Zhou et al. (1977: pl. 72: 1, 2; see also Liu 1982: pl. 229: 2, 7 and Tripp et al. 1989: fig. 8i); Meitanillaenus flabelliforme Liu (1982: pl. 230: 5, 6); and Scutellum (Planiscutellum) wuxiensis Lee (1978: pl. 107: 1, 2). From Meitanillaenus? sp., differs M. luerkouensis in having an anterior cranidial border along the entire anterior margin and lacking a glabellar crest; M. flabelliforme in having a longer anterior branch of facial suture and more posteriorly located palpebral lobe; S. (P.) wuxiensis in having a transversely wider occipital ring and more strongly divergent axial furrows.

Tripp et al. (1989) questionably transferred Meitanillaenus luerkouensis into Failleana. Lane and Siveter (1991) treated Failleana as a junior synonym of Meitanillaenus without an explanation. Chatterton and Ludvigsen (2004, see also Adrain et al. 1995) disagreed to this synonymy because Failleana has a wider axis, distinct ventral projection of axial furrows (called “omphalus”), and a backwardly convex posterior margin of the rostral plate. Comparison of cranidia of Meitanillaenus-allied species and Failleana (Table 3) shows that (i) Meitanillaenus has a narrower occipital ring (maximum transverse width 47% of width across cranidial antero-lateral corner versus 64% in Failleana), (ii) an exsagittally longer palpebral lobe (31% of cranidial length versus 23% in Failleana), and (iii) a transversely narrower glabellar constriction (39% of width across cranidial antero-lateral corner versus 50% in Failleana). Therefore Meitanillaenus should be treated as a separate genus from Failleana.

From cranidium of Meitanillaenus binodosus Chang, 1974, the type species from the Silurian of Guizhou (see Chang 1974: pl. 82: 12), all the Ordovician Chinese Mei
**Table 3. Comparison of *Meitanillaenus* and *Failleana*-allied taxa.**

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Specimen</th>
<th>Glabellar construction relative to cranidial width across antero-lateral corner</th>
<th>Palpebral lobe length (exsag.) relative to cranidial (sag.) length</th>
<th>Occipital ring width relative to cranidial width across antero-lateral corner</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Meitanillaenus?</em> sp.</td>
<td>NIGP-151995</td>
<td>39%</td>
<td>29%</td>
<td>46%</td>
<td>Fig. 6A</td>
</tr>
<tr>
<td></td>
<td>NIGP-151998</td>
<td>41%</td>
<td>32%</td>
<td>44%</td>
<td>Fig. 6D</td>
</tr>
<tr>
<td></td>
<td>NIGP-151996</td>
<td>38%</td>
<td>28%</td>
<td>45%</td>
<td>Fig. 6B</td>
</tr>
<tr>
<td></td>
<td>NIGP-151999</td>
<td>41%</td>
<td>36%</td>
<td>45%</td>
<td>Fig. 6E</td>
</tr>
<tr>
<td></td>
<td>NIGP-151997</td>
<td>41%</td>
<td>35%</td>
<td>42%</td>
<td>Fig. 6C</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td></td>
<td>40%</td>
<td>32%</td>
<td>44%</td>
<td></td>
</tr>
<tr>
<td><em>Meitanillaenus</em> ? <em>huekoensis</em></td>
<td></td>
<td>31%</td>
<td>30%</td>
<td>38%</td>
<td>Tripp et al. (1989: fig. 8i)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>35%</td>
<td>31%</td>
<td>46%</td>
<td>Zhou et al. (1977: pl. 72: 1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>37%</td>
<td>31%</td>
<td>46%</td>
<td>Liu (1982: pl. 229: 7)</td>
</tr>
<tr>
<td><em>Meitanillaenus</em> binodus</td>
<td></td>
<td>42%</td>
<td>30%</td>
<td>54%</td>
<td>Yin and Lee (1978: pl. 181: 12)</td>
</tr>
<tr>
<td><em>Sangzhiscutellum</em> flabelliformes</td>
<td></td>
<td>40%</td>
<td>29%</td>
<td>45%</td>
<td>Liu (1982: pl. 230: 5)</td>
</tr>
<tr>
<td><em>Scutellum</em> (Planiscutellum) <em>wuxiensis</em></td>
<td></td>
<td>38%</td>
<td>33%</td>
<td>52%</td>
<td>Lee (1978: pl. 107: 1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>40%</td>
<td>N/A</td>
<td>59%</td>
<td>Lee (1978: pl. 107: 2)</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td></td>
<td>39%</td>
<td>31%</td>
<td>47%</td>
<td></td>
</tr>
<tr>
<td><em>Failleana</em> <em>calva</em></td>
<td></td>
<td>41%</td>
<td>24%</td>
<td>61%</td>
<td>Chatterton and Ludvigsen (1976: pl. 6: 39)</td>
</tr>
<tr>
<td><em>Failleana</em> <em>magnifica</em></td>
<td></td>
<td>52%</td>
<td>21%</td>
<td>61%</td>
<td>Chatterton and Ludvigsen (2004: pl. 6: 3)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>52%</td>
<td>22%</td>
<td>69%</td>
<td>Chatterton and Ludvigsen (2004: pl. 6: 11)</td>
</tr>
<tr>
<td><em>Failleana</em> <em>wangi</em></td>
<td></td>
<td>57%</td>
<td>26%</td>
<td>65%</td>
<td>Chatterton and Ludvigsen (2004: pl. 84: 9)</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td></td>
<td>50%</td>
<td>23%</td>
<td>64%</td>
<td></td>
</tr>
<tr>
<td><em>Ciliscutellum</em> <em>ciliensis</em></td>
<td></td>
<td>32%</td>
<td>27%</td>
<td>43%</td>
<td>Lin (1987: pl. 1: 2)</td>
</tr>
</tbody>
</table>

**Genus Eokosovopeltis** Přibyl and Vaněk, 1971

*Type species:* *Bronteus romanovskii* Weber, 1948, from the Anderken Horizon (late Sandbian to early Katian of Ordovician), southern Kazakhstan; by original designation.

**Eokosovopeltis** sp.

Fig. 6G.

**Material.**—One pygidium (repository number NIGP-152001).

**Remarks.**—This pygidium bears morphologic features of *Eokosovopeltis*. Compared with pygidia of other Late Ordovician *Eokosovopeltis* species such as *E. romanovskii* (= *Bronteus romanovskii*) (Weber 1948: pl. 7: 20–23), *E. atavus* (= *Heptabronteus atavus*) (Webby 1974: pl. 28: 15–18), *E. grandicurvatus* (Edgecombe et al. 2004: fig. 5A–F), *E. currajongensis* (Edgecombe and Webby 2007: fig. 4C, D, F–I), the pygidium differs in having an inverted trapezoidal axis with a pair of longitudinal furrows, concave anterior part of the postaxial region, and slightly convex posterior part of the postaxial region with faintly impressed longitudinal furrow. Of the species, the pygidial morphology of *E. currajongensis* is most similar to this pygidium, but the former differs in having a sagittally much wider articulating half ring, faintly-defined anterior limit of postaxial region, and obliquely-directed anterior margin. To confidently erect a new *Eokosovopeltis* species to which this pygidium is assigned requires discovery of cranidial materials.

This pygidium might be associated with the styginid cranidia assigned to *Meitanillaenus?* sp. (Fig. 6A–E). However, the pygidium occurs in locality 2, whereas the cranidia occur in locality 3. Since the mudstone of each locality is not stratigraphically contemporaneous (see above), the association is considered less likely.

**Eokosovopeltis** cf. *currajongensis* (Edgecombe and Webby, 2007)

Fig. 6H.

**Material.**—One pygidium from a limestone layer above the mudstone at locality 1 (repository number NIGP-152002).

**Remarks.**—This pygidium differs from *Eokosovopeltis* sp. in having much narrower pleural furrows and a narrower (tr.) axial region. It is similar to pygidia of *Eokosovopeltis curra-
Fig. 6. Late Ordovician trilobites from Xiazhen Formation near Zhuzhai, Yushan County, China. **A–E.** _Meitanillaenus_? sp. A. NIGP−151995, cranidium from locality 3; dorsal (_A_1) and anterior (_A_2) views. B. NIGP-151996, cranidium from locality 3; dorsal (_B_1) and lateral (_B_2) views. C. NIGP-151997, cranidium from locality 3, dorsal view. D. NIGP-151998, cranidium from locality 3, dorsal view. E. NIGP-151999, cranidium from locality 3, dorsal view. **F.** _Amphilichas_ sp., NIGP-152000, cranidium from locality 3; dorsal (_F_1), oblique posterior (_F_2), anterior (_F_3), and lateral (_F_4) views. **G.** _Eokosovopeltis_ sp., NIGP-152001, pygidium from locality 2, dorsal view. **H.** _Eokosovopeltis cf. currajongensis_ (Edgecombe and Webby, 2007), NIGP-152002, pygidium from a limestone layer overlying the mudstone at locality 1, dorsal view. **I.** Styginidae indet. sp. A, NIGP-152003, hypostome from locality 3, ventral view. **J.** Styginidae indet. sp. A, NIGP-152004, incomplete thoraco-pygidium with four thoracic segments from locality 3, dorsal view. **K, M.** Asaphidae indet. **K.** NIGP-152005, free cheek from locality 2, dorsal view. **M.** NIGP-152006, pygidium from locality 3, dorsal view. **L.** _Nileus_ sp., NIGP-152007, articulated specimen minus free cheeks from locality 2; posterior (_L_1), anterior (_L_2), lateral (_L_3), and dorsal (_L_4) views. Scale bars 2.5 mm, except E, F, I 1 mm; G, H, K 5 mm.
**Hibbertia aodiensis** Edgecombe and Webby (2007: fig. 4C, D, F–I); both have seven pairs of pleural ribs. Due to poor preservation, the specific identification as *E. currajongensis* is provisional.

Styginidae indet. sp. A

Fig. 6f

**Material.**—Two thoraco-pygidia (repository number NIGP-152004).

**Remarks.**—The sub-circular outline and absence of pygidial pleural furrows resemble *Bumastus* (see Chatterton and Ludvigsen 1976: pl. 5: 12, 37). However, the presence of distinct ridge along inner margin of marginal border is not present in *Bumastus*. These specimens may be associated with co-occurring *Meitanillaenus* sp., since they resemble the thoraco-pygidium of *Meitanillaenus binodosus* Chang (1974: pl. 81: 6). However, they have much less distinct axial furrows and lack the antero-most pair of pleural furrows.

Styginidae indet. sp. B

Fig. 6f

**Material.**—Two hypostomes (repository number NIGP-152003).

**Remarks.**—The hypostomes are of styginid (e.g., see Whittington 1988: fig. 9 for *Bumastus*). They are characterized by a more pentagonal outline and a pair of short, closely-spaced spines along posterior margin. The hypostomes may be associated with co-occurring *Meitanillaenus* sp.

Order Harpetida Whittington, 1959

Family Harpetidae Hawle and Corda, 1847

Genus *Hibbertia* Jones and Woodward, 1898

**Type species:** *Harpes flanaganni* Portlock, 1843 from the Caradocian (Late Ordovician) Bardahessiagh Formation of Pomeroy, Tryone County, Northern Ireland.

*Hibbertia aodiensis* sp. nov.

Figs. 3B, 7A–D, F, G.

**Etymology.**—After Aodi, a small village next to Zhuzhai.

**Holotype:** NIGP-152011, incomplete cephalon from locality 2.

**Type locality:** Locality 2, about 60 m northwest of Zhuzhai, Yushan County. GPS coordinate is 28°34′23.27″ N and 118°20′16.50″ E.

**Type horizon:** Xiazhen Formation, Upper Ordovician, *Dicellograptus complexus* Graptolite Zone.

**Material.**—Four cephalons and one hypostome (repository numbers: NIGP-152008–152013).

**Diagnosis.**—Species of *Hibbertia* with a longer (sag.) glabella, brim that is narrow, deep, flat-bottomed, and lower-leveled ala, and lacking interalar furrow.

**Description.**—Cephalon minus prolongation semi-circular in outline; cephalic and prolongation length nearly equal. External rim strongly vaulted. Brim narrow, deep and nearly flat-bottomed; sagittal length about one-fifth of cephalic length. Genal roll slightly convex outwards and steeply down-sloping. Girder deeply impressed and extends to mid-point of prolongation. Girder kink weakly developed. Inner margin of fringe runs parallel to genal roll and then strongly curved inwards to merge into internal rim; the margin expressed by moderately raised ridge which corresponds to distal limit of caeca on genal area. Anterior boss and pre-glabellar depression absent. Transverse preglabellar ridge weakly developed. Glabella strongly vaulted and bullet-shaped, with maximal sagittal length being 54% of cephalic length. Axial furrow deep and moderately wide, narrowing forwards. Three pairs of glabellar furrows present: S1 straight, deeply incised and obliquely directed backwards; S2 short and anteriorly directed; S3 short (but longer than S2) and anteriorly directed. L1 convex and sub-triangular in outline. S0 wide and shallow, with deeply impressed distal end; L0 strongly convex, and anterior margin curved forwards; small sagittal node present. Palpebral lobe highly raised. Eye small and located at anterior 35% of glabellar sagittal length; distal end located at the same exsagittal line as that of ala. Eye ridge moderately developed and slightly obliquely directed backwards. Ala semi-circular in outline, moderately convex, and much lower than genal area; maximum width 75% and maximum length 40% of corresponding glabellar dimension. Alar ridge weakly developed, follows axial furrow, and ends immediately posterior to adaxial end of eye ridge. Alar furrow steep-sided, deep and wide, becoming shallower and narrower forwards. Interalar furrow and alar depression absent. Internal rim strongly raised, becomes narrow adaxially, and extends posteriorly to meet external rim.

Brim ornamented with one or two rows of large pits along distal extremity and girder, and Anastomosing caeca at bottom; pits along distal extremity larger than those along girder; genal roll with smaller pits (pits become larger towards girder); genal area with anastomosing caeca; glabella with weakly developed caeca along crest (only observed in external mold); pits on brim and genal roll become larger posteriorly; caeca on genal area form distinct ridge that runs anteriorly from proximal end of eye ridge, gently convex outwards, and abruptly stops at inner margin of fringe, and runs posteriorly from palpebral lobe, gently convex outwards, and then smoothly merged into inner margin of fringe.

**Fig. 7.** Late Ordovician trilobites from Xiazhen Formation near Zhuzhai, Yushan County, China. A–D, F, G. *Hibbertia aodiensis* sp. nov. A. NIGP-152008, incomplete cephalon from locality 2; dorsal (A1), anterior (A2), lateral (A3) views. B. NIGP-152009, incomplete cephalon from locality 2, dorsal view. C. NIGP-152010, incomplete cephalon from locality 2; dorsal (C1) and lateral (C2) views of cast of external mould, and ventral view (C3). D. NIGP-152011, holotype, incomplete cephalon from locality 2; dorsal (D1), lateral (D2), and anterior (D3) views of internal mould, dorsal (D4), lateral (D5), and anterior (D6) views of cast of external mould, and ventral view of external mould (D7). E. NIGP-152012, hypostome from locality 2; lateral (F1) and ventral (F2) views. G. NIGP-152013, incomplete thoracic segments from locality 2, dorsal view. E. *Scotoharpes* sp., NIGP-152014, incomplete cephalon from locality 4; lateral (E1) and dorsal (E2) views of cast of external mould, and lateral (E3) and dorsal (E4) views of internal mould. Scale bars 5 mm, except F, G 2.5 mm.
Hypostome as wide as long. Anterior lobe of middle body convex and sub-circular in outline; posterior lobe small and crescentic in outline; sagittal length of posterior lobe 20% of hypostomal sagittal length. Anterior margin gently convex forwards; lateral margin straight at antero-lateral portion, gently curved inwards at mid-point of hypostomal length, projected outwards opposite anterior end of posterior lobe, and then runs straight and obliquely posteriorly; posterior margin slightly curved forwards. Anterior border widens abaxially and narrows to disappear adaxially; lateral border rimmed, and of consistent thickness; lateral border furrow moderately deep, but shallows out posteriorly. Middle furrow shallows out adaxially. Macula indistinct.

Remarks

furrow that continues into pleural spine.

Hibbertia aodiensis

furrow moderately deep, but shallows out posteriorly. Mid−margin slightly curved forwards. Anterior border widens and then runs straight and obliquely posteriorly; posterior projected outwards opposite anterior end of posterior lobe, gently curved inwards at mid−point of hypostomal length, forwards; lateral margin straight at antero−lateral portion, hypostomal sagittal length. Anterior margin gently convex crescentic in outline; sagittal length of posterior lobe 20% of convex and sub−circular in outline; posterior lobe small and rim, much distinct inner margin of fringe, taller genal roll, longer (sag.) glabella, narrower (sag.) brim, taller external and genal area. However, this new species differs in having a and the same ornamentation pattern in the brim, genal roll ridge and the other that runs diagonally from palpebral lobe), genal area (one that runs anteriorly from proximal end of eye ridge and the other that runs diagonally from palpebral lobe), and the same ornamentation pattern in the brim, genal roll and genal area. However, this new species differs in having a longer (sag.) glabella, narrower (sag.) brim, taller external rim, much distinct inner margin of fringe, taller genal roll, and less elevated ala, and lacking an interalar furrow. Hibbertia ottawaensis (Billings, 1865) from Canada (see Shaw 1968: pl. 6: 18) bears the similar glabellar morphology with regard to its sagittal length. However, it shares such features as elevated ala and interalar furrow with other Hibbertia spe−cies, which are not present in H. aodiensis.

Stratigraphic and geographic range.—Late Ordovician and Jiangxi Province, South China.

Genus Scotoharpes Lamont, 1948

Type species: Scotoharpes domina Lamont, 1948 from the Llandovery (Early Silurian) of Scotland.

Scotoharpes sp.

Fig. 7E.

Material.—One cephalon (repository number NIGP−152014).

Remarks.—This incomplete cephalon is distinguished from the co−occurring Hibbertia aodiensis sp. nov. in having a wider cephalon, shorter (sag.), smaller, sub-rectangular glabella, longer (sag.) area of genal roll plus genal area, strongly obliquely-directed eye ridge (posteriorly located eye accordingly), wider (tr.) ala, and triangular area with faintly-developed caeca located postero-laterally diagonal to the ala. The larger ala, oblique eye ridge and posteriorly located eye indicate that this cranium is associated with Scotoharpes; compare with Scotoharpes domina Lamont (1948: pl. 1: 2 and see also Norford 1973: pl. 1: 1–3).

Order Lichida Moore, 1959

Family Lichidae Hawle and Corda, 1847

Genus Amphilichas Raymond, 1905

Type species: Platyrometus lineatus Angelin, 1854 from the Ashgillian Boda Limestone of Sweden; by monotypy.

Amphilichas sp.

Fig. 6F.

Material.—One cranidium (repository number NIGP−152000).

Remarks.—Amphilichas from Tasmania (Edgecombe et al. 2004: fig. 11A−C; Edgecombe and Webb 2007: fig. 5B−D) shows resemblance to this cranium. This incomplete glabella however differs in having an anterior margin that is slightly curved backwards sagittally and sharply curved longitudinal furrows. The specific identification cannot be completed, because of incomplete preservation as well as paucity of specimens.

Order Phacopida Salter, 1864

Family Calymenidae Milne Edwards, 1840

Subfamily Reedocalymeninae Hupé, 1955

Genus Vietnamia Kobayashi, 1960

Type species: Calymene douvillei Mansuy, 1908, from the Na Mo Formation (Middle to Upper Ordovician), Thai Nguyen, Vietnam; by original designation.

Vietnamia yushanensis sp. nov.

Figs. 3C, 8A−G, I–N, P, 9B, E, H, I, N.

Etymology: After Yushan county where the sampling localities are located.

Holotype: NIGP−152032, articulated specimen from locality 2, 2 cephalon, 21 cranidia, 14 thoraces, six pygidia, five free cheeks, and one hypostome.

Type locality: Locality 2, about 60 m northwest of Zhuzhai, Yushan County. GPS coordinate is 28°34′23.27″ N and 118°20′16.50″ E.
Type horizon: Xiazhen Formation, Upper Ordovician, Dicellograptus complexus Graptolite Zone.

Material.—Seven articulated exoskeletons, four cephalo-thoraces, 12 thoraco-pygidia, two cephalia, 21 cranidia, 14 thoraces, six pygidia, five free cheeks, and one hypostome (repository numbers: NIGP-152032–152045, 152050, 152052–152054, 152056).

Diagnosis.—Species of *Vietnamia* with distinct pygidial lateral and posterior edge anterior to cincture, seven pygidial axial rings, anterior node in fossula, and lower-leveled area between L1.

Description.—Dorsal exoskeleton elliptical in outline. Cephalon semi-circular in outline with pointed (sag.) anterior margin, and sagittal length 60% of transverse width. Anterior cranidial border nearly flat and weakly arched dorsally; anterior cranidial border furrow shallow and broad, and moderately deepens distally. Prelabellar area moderately convex; anterior furrow shallow and wide, and divergent forwards at about 30° from sagittal line; prelabellar furrow deeper than anterior furrow. Fossula distinctly depressed, and located diagonal to S3, immediately outside axial and anterior furrows, and immediately anterior to eye ridge; anterior node small but distinct and positioned at adaxial slope of fossula. Eye ridge moderately developed, and abruptly narrows as crossing axial furrows. Axial furrow wide and deep, and progressively wider and deeper posteriorly, with maximum width and depth opposite L1; axial furrow opposite L1 steep-sided and flat-bottomed. Glabella trapezoidal in outline, anterior margin straight to slightly convex forwards, and sagittal length 63% of maximum transverse width across L1. Three pairs of glabellar furrows present; abaxial end of all three pairs positioned within palpebral area of fixigenae. S3 obliquely directed backwards, weakly incised, and shortest. S2 slightly more oblique and weakly bifurcated. S1 deeply impressed, strongly obliquely directed posteriorly, and shortest. S2 slightly more oblique and weakly bifurcated. S1 deeply impressed, strongly obliquely directed posteriorly, and bifurcated at mid-length adaxially; anterior branch shorter and more weakly impressed, and proximal one-quarter of posterior branch shallow and gently curved forwards. L1 elongated (tr.), moderately convex, strongly inflated abaxially, tabs adaxially, abaxial edge overlaps axial furrows, and posterior margin weakly sinuous; adaxial one-third gently slopes down and then slightly raised sagitally, and node weakly developed at adaxial one-third. L2 and L3 sub-rectangular and raised as pointed node in central area. Intermediate lobe sub-circular in outline, weakly convex, well delineated posteriorly and abaxially by posterior branch of S1, and remaining boundaries poorly defined by weakly impressed furrows. Palpebral lobe crescentic in outline and mid-point located opposite S2. Occipital furrow moderately curved forwards following posterior margin of L1 and abruptly becomes shallower sagitally from adaxial two-thirds of its course. Occipital ring progressively widens adaxially; distal end protruded as distinct node. Preocular area of fixigenae gently slopes downwards; palpebral area steeply slopes; postocular area triangular in outline and gently slopes distally. Posterior cranidial border furrow shallow and broad, and slightly curved forwards at its mid-length. Anterior branch of facial suture slightly convex laterally and moderately convergent forwards in posterior half; anterior half runs straight and parallel-sided, and then sharply curved inwards; posterior branch runs transversely and then gently curved backwards, and cuts postero-lateral cephalic corner, forming gonatoparian suture.

Librigena with blunted postero-lateral end. Eye socle weakly developed and eye socle furrow shallow. Librigena field gently slopes downwards in adaxial two-thirds and then steeply slopes. Librigena lateral border furrow moderately deep and continues into anterior furrow and anterior cranidial border furrow; librigena lateral border sharply inturned.

Hyposome elliptical in outline. Anterior margin strongly convex forwards. Posterior and lateral borders moderately convex; posterior and lateral border furrows deep but shallow out at anterior end of posterior lobe; posterior border projected as spine of moderate length. Anterior lobe sub-circular in outline; posterior lobe crescentic in outline and larger than anterior lobe. Middle furrow deep and shallows adaxially.

Thorax of 13 segments. Axis gently tapers backwards and occupies about 45% of thoracic width. Axial furrow relatively wide and deep, deepening as pit at posterior end in each segment. Axial ring slightly curved forwards medially; distal end moderately curved forwards and protruded as distal node. Articulating furrow deep and wide in distal half and shallows and narrows in proximal half. Anterior and posterior pleural band of equal width, and strongly convex; small fulcrum process located at proximal one-third (or mid-length at dorsal view) of posterior band; the processes be...
Pygidium triangular in outline. Axis occupies about 54% of maximum transverse pygidial width; axial furrow straight or slightly convex laterally; axis moderately tapers posteriorly; inter-ring furrow progressively shallower posteriorly; postaxial ridge moderately convex and laterally delineated by shallow furrow which is apparently continuous into axial furrows. Five pairs of pleural furrows moderately impressed; posteriormost furrow separates terminal piece and posteromost pleur; pleural rib abruptly bends downwards along lateral and posterior edge of triangular pleural field; the edge moderately protruded outwards, and the lower limit represents cincture; pleural field distal to the edge nearly vertical.

Dorsal exoskeleton covered with fine granules. Some specimens enrolled.

Remarks.—The concept of Vietnamia has recently been revised by Turvey (2005); most features listed in the emended diagnosis are observed in this species. Vietnamia yushanensis sp. nov. is characterized by a distally protruding lateral and posterior pygidial edge that is immediately anterior to the cincture, seven pygidial axial rings, an anterior node in the fossula, and the absence of pygidial interpleural furrows. The presence of small morphologic features such as the anterior node cannot be confirmed from the illustrations of other species. However, the pygidial features ensure that it is a new species of Vietnamia.

Zhou and Zhen (2008: 241) transferred a few species from China previously assigned to Neseuretus into Vietnamia. Neseuretus abnormis Li, 1988 (Li 1988: pl. 1: 8, pl. 2: 4–7) from Tibet was erected based on a poorly preserved cranidium and four pygidia; Turvey (2005) concluded that it is a probable junior synonym of Vietnamia nivalis (Salter, 1865); the pygidial morphology does accord with that of V. nivalis (see Turvey 2005: pl. 4: 6, 10). Liu et al. (1991: pl. 17: 6) illustrated Neseuretus (Neseuretus) henanensis Chang from Henan. The poorly-preserved cranidium exhibits more resemblance to Vietnamia than to Neseuretus in having a truncated anterior glabellar margin and laterally inflated L1. Assignment of Neseuretus (Neseuretus) sp. from Xinjiang (Lin et al. 1990: pl. 6: 1, 2) to Vietnamia appears questionable, because the pygidium is of Calymenes or Reedocalymene in having a distinct cincture and narrower (tr.), posteriorly-tapering post-axial region, although the cranidium resembles that of V. nivalis.

Like many calymenid taxa, Vietnamia yushanensis sp. nov. has 13 thoracic segments, which is the first documentation for the genus. V. yushanensis has an anterior node in the fossula (see Fig. 8A1, B1, P) which is also observed in Reedocalymene and Calymenes (Peng et al. 2000); the node is smaller than that of other taxa. Vietnamia douvillei (Mansuy, 1908), the type species appears to have the node (see Turvey 2005: pl. 3: 5; a small node appears to be present on the left fossula).

Stratigraphic and geographic range.—Late Ordovician and Jiangxi Province, South China.

Vietnamia sp. A Fig. 8Q.

Material.—One incomplete cephalon (repository number NIGP-152031).

Remarks.—This species differs from co-occurring Vietnamia yushanensis sp. nov. in having a strongly dorsally arched anterior cephalic margin, posterior cranidial border furrow that is smoothly curved forwards distally, moderately convex sagittal area between L1, more weakly developed intermediare lobe, and truncated anterior glabellar margin. The dorsal flexure of the anterior cephalic margin of this species is the strongest of the Vietnamia species described herein.

Turvey (2005: pl. 4: 2) illustrated a rostral plate of Vietnamia douvillei (Mansuy, 1908). The impression of the rostral plate of Vietnamia yushanensis sp. nov. (Fig. 8Q1, Q2) accords with the morphology of V. douvillei; a fissure in the middle of left half (Fig. 8Q2) represents a connective suture. The upside down anvil-shaped rostral plate of Vietnamia differs from Neseuretus (see Whittington 1966: pl. 5: 5, 6, 8, 10; Hammann 1983: pl. 4: 39b) in being laterally bounded by less divergent connective sutures, and from Calymenes and Reedocalymene (see Peng et al. 2000: text-fig. 1A–E, pl. 3: 1–3) in having a doubling sector that is much wider (tr.) than the border sector.

Fig. 10. Cheirurid trilobite Remopleurides xiazenensis sp. nov. from the Late Ordovician Xiazhen Formation near Zhuzhai, Yushan County, China. A. NIGP-152015, incomplete articulated specimen minus two thoracic segments and pygidium from locality 2; dorsal (A1), lateral (A2), and anterior (A3) views; note the presence of pits on fixigenal and librigenal field. B. NIGP-152016, holotype, articulated specimen from locality 2; ventral view of external mould (B1), dorsal view (B2), and dorsal view of cast of external mould (B3); note the presence of densely-distributed granules and the arrow in B1 and B3 points the boundary between thorax and pygidium. C. NIGP-152017, cranidium from locality 2; dorsal view; note the presence of a pair of small pits on L4 (see also Fig. 10M and I). D. NIGP-152018, incomplete articulated specimen from locality 2, dorsal view. E. NIGP-152019, cranidium from locality 2; lateral (E1) and dorsal (E2) views. F. NIGP-152020, provisionally associated hypostome from locality 4; ventral (F1) and lateral (F2) views. G. NIGP-152021, cranidium from locality 2; anterior (G1) and dorsal (G2) views. H. NIGP-152022, thoraco-pygidium with four thoracic segments from locality 2, dorsal view; the arrow indicates the boundary between thorax and pygidium. I. NIGP-152023, cranidium from locality 2, dorsal view. J. NIGP-152024, articulated specimen minus pygidium from locality 4, dorsal view. K. NIGP-152025, cranidium from locality 4, dorsal view. L. NIGP-152026, cranidium from locality 4, dorsal view. M. NIGP-152027, disarticulated cephalon and four thoracic segments from locality 2, dorsal view. N. NIGP-152028, external mould of incomplete thoraco-pygidium from locality 2, ventral view; note the absence of articulating ring that confirms the boundary between thorax and pygidium indicated by the arrow. Scale bars 2.5 mm, except A, B, D, J 5 mm.
Vietnamia sp. B
Fig. 9A, D, J.

Material.—One cranidium, thoraco-pygidium, and free cheek (repository numbers: NIGP-152046, 152051, 152055).

Remarks.—The cranidium differs from other co-occurring Vietnamia species in having a very strongly developed intermediate lobe, more strongly depressed sagittal area between most strongly elongated (tr.) L1, relatively longer (sag.) preglabellar area, and more laterally convex posterior half of anterior branch of facial suture. The pygidium also differs in having shallower inter-ring furrows and pleural furrows.

Vietnamia sp. C
Fig. 9F.

Material.—One incomplete cephalon (repository number NIGP-152048).

Remarks.—This incomplete cephalon, although seemingly compressed laterally, differs from other Vietnamia species in having a rounded anterior cranidial margin, anterior glabellar margin that is indented medially, and weakly developed intermediate lobe.

Vietnamia sp. D
Figs. 9G, 11V.

Material.—One articulated specimen and two pygidia (repository numbers: NIGP-152049, 152083).

Remarks.—This species is distinguished by its rounded anterior glabellar margin, anterior glabellar margin that is not pointed, cincture expressed as a margin that is indented medially, and weakly developed inter-ring furrows, having shallower inter-ring furrows and pleural furrows. Scale bars 2.5 mm, except C, K–N, R–V 1 mm.

Vietnamia sp. E
Figs. 8H, 9C.

Material.—One disarticulated specimen and two pygidia (repository numbers: NIGP-152029, 152047).

Remarks.—This species is distinguished by its anterior cranidial margin that is not pointed, cincture expressed as a narrow furrow, pygidial pleural furrows which maintain their depth as crossing cincture (become shallower and obscure in Vietnamia yushanensis sp. nov.; see Fig. 8F), and less distinct lateral and posterior edge anterior to cincture.

Vietnamia? sp.
Fig. 8O.

Material.—One incomplete cephalon (repository number NIGP-152030).

Remarks.—The morphology of L1, intermediate lobe, course of facial suture of this species resemble those of Calymenesun tingi (Sun, 1931) (see Lu 1975: pl. 46: 13; Peng et al. 2000: text-fig. 1A). This species has a longer (exsag.) palpebral lobe and wider (tr.) preglabellar area. It cannot be confirmed whether it has a pre-cranidial spine as does Calymenesun. It is the rostral plate that evidently differentiates this species from Calymenesun. The rostral plate is wide (tr.) and strongly arched dorsally (Fig. 8O1), whereas that of Calymenesun (see Peng et al. 2000: text-fig. 1B–E) is much smaller and not arched dorsally. In addition, the rostral plate is located more anteriorly and dorsally than that of Calymenesun which is entirely ventral. With regard to the morphology and position, the rostral plate of this species is similar to that of Neseuretus (see Hammann 1983: pl. 4: 39b; Rabano 1990: pl. 14: 6; pl. 15: 2, 10) and Calymene (see Chatterton and Ludvigsen 2004: pl. 54: 1–4).

Compared to Vietnamia sp. A (compare Fig. 8O2 and Q2), this species has a more flattened cephalon, and more strongly laterally inflated L1. The rostral plate morphology is much different. Vietnamia sp. A has a doublure sector that is wider (tr.) than border sector. Calymene (see Chatterton and Ludvigsen 2004: pl. 54: 4) and Flexicalymene (see Evitt and Whittington 1953: pl. 9: 4–6) whose overall morphology of rostral plate is similar to this species, have a doublure sector that is narrower (tr.) than border sector. Such mixture of characters prevents the author from confidently placing this species in any of the above-mentioned genera, but the glabellar configuration leads to questionably associate it with Vietnamia.

Genus Neseuretus Dean, 1967
Type species: Neseuretus (Neseuretus) turcicus Dean, 1967, from the Caradoc of Turkey; by original designation.

Neseuretus? sp.
Fig. 11S–U.

Fig. 11. Late Ordovician trilobites from Xiazhen Formation near Zhuzhai, Yushan County, China. All specimens are collected from locality 3, except for NIGP-152079 (R) from locality S. A–L, O, Q. Plomerina tashanensis sp. nov. A. NIGP-152062, cranidium; dorsal (A1) and lateral (A2) views. B. NIGP-152063, holotype, cranidium, dorsal view. C. NIGP-152064, cranidium, dorsal view. D. NIGP-152065, thoraco-pygidium with nine thoracic segments (thoracic axis was inadvertently broken off while being photographed); dorsal (D1), posterior (D2), oblique left posterior (D3), and oblique right posterior (D4) views. E. NIGP-152066, cranidium; dorsal (E1) and anterior (E2) views. F. NIGP-152067, cranidium, dorsal view. G. NIGP-152068, cranidium, dorsal view. H. NIGP-152069, pygidium; dorsal (H1) and posterior (H2) views. I. NIGP-152070, pygidium; dorsal (I1) and lateral (I2) views. J. NIGP-152071, cranidium, dorsal view. K. NIGP-152072, pygidium, dorsal view. L. NIGP-152073, two pygidia, dorsal view. O. NIGP-152077, pygidium, cast of external mould, dorsal view. Q. NIGP-152074, thoraco-pygidium with nine thoracic segments, dorsal view; note that the presence of distal part of left posterior cranidial border, indicating that the number of thoracic segments is nine. M, N, P. Plomerina sp. M. NIGP-152075, cranidium, cast of external mould, dorsal view. N. NIGP-152076, cranidium, cast of external mould, dorsal view. P. NIGP-152078, cranidium, cast of external mould, dorsal view. R. cf. Redocalymene sp., NIGP-152079, pygidium with two thoracic segments, dorsal view. S–U. Neseuretus? sp. S. NIGP-152080, pygidium; lateral (S1) and dorsal (S2) views. T. NIGP-152081, pygidium, dorsal view. U. NIGP-152082, pygidium, dorsal view. V. Vietnamia sp. D. NIGP-152083, pygidium; lateral (V1) and dorsal (V2) views. Scale bars 2.5 mm, except C, K–N, R–V 1 mm.
Material.—Four pygidia (repository numbers: NIGP-152080–152082).

Remarks.—These poorly preserved pygidia exhibit morphology similar to that of Neseuretinus (see Turvey 2005: pl. 2: 8) in sharing a sharply turning anterior margin and relatively distinct terminal piece. The rimmed nature of marginal border in some specimens (Fig. 11T, U) is unusual for reedocalymenines; Reedocalymene has the border that is rather flat than rimmed (see Peng et al. 2000: pl. 1: 1). No Neseuretinus-like cranidium with a pre-cranidial spine was found in the entire collection. It cannot be ruled out that the pygidium may be a dorso-ventrally compressed specimen of Vietnamia species (compare Figs. 8E2, 9D1, and 11S1). The assignment to Neseuretinus is uncertain.

Genus Reedocalymene Kobayashi, 1951
Type species: Reedocalymene unicornis (Reed, 1917), from the Middle Ordovician Shidian Formation of Yunnan, China.

cf. Reedocalymene sp.

Discussion.—The pygidium is greatly similar to that of Reedocalymene expansa Yi, 1957 (see Peng et al. 2000: pl. 1: 1), but differs in lacking interpleural furrows posterior to cincture. Peng et al. (2000) noted the shorter (sag.) pygidial cincture which are absent in this species. The absence of have interpleural furrows in the pleural field posterior to pygidium of Reedocalymene. Calymenesun tingi (see Zhou et al. 1984: fig. 7e for Calymenesun tingi [Sun, 1931]) as the sole difference from pygidium of Reedocalymene. The pygidia of both genera have interpleural furrows in the pleural field posterior to cincture which are absent in this species. The absence of associable cranidial materials renders this species left in open nomenclature.

Family Cheiruridae Hawle and Corda, 1847
Genus Ceraurinus Barton, 1913
Type species: Ceraurinus marginatus Barton, 1913, probably from Upper Ordovician Cobourg Formation of Ontario, Canada (see Ludvigsen 1977).

Ceraurinus zhuzhaiensis sp. nov.

Figs. 3D, 10.

Etymology: After Zhuzhai village where the sampling quarries are located.

Holotype: NIGP-152016, articulated specimen from locality 2.

Type locality: Locality 2, about 60 m northwest of Zhuzhai, Yushan County. GPS coordinate is 28°34′23.27″ N and 118°20′16.50″ E.

Type horizon: Xiazhen Formation, Upper Ordovician, Dicellograptus complexus Graptolite Zone.

Material.—Three articulated exoskeletons, five cephalo-thoraces, four thoraco-pygidia, one cephalon, 12 cranidia, one thorax, one free cheek, and one hyposome (repository numbers: NIGP-152015–152028).

Diagnosis.—Species of Ceraurinus possessing three pairs of pygidial pleural ribs with free, blade-shaped antero-most pair and posterior two pairs expressed by smoothly saw-toothed pygidial margin, and pair of weakly-impressed pits on L4.

Description.—Dorsal exoskeleton elliptical in outline and covered with irregularly-distributed granules. Cephalon semi-circular in outline; transverse width 49% of sagittal length. Anterior cranidial border narrow, rimmed, and slightly indented sagittally. Anterior cranidial border furrow and preglabellar furrow merged, moderately impressed but shallower than axial furrow. Axial furrow deep and wide. Glabella sub-rectangular in outline, and slightly expands laterally or forwards in some specimens; maximum transverse width 86% of sagittal length. Central area of glabella moderately crested, which become more raised posteriorly, ending as if a large lobe is developed at posterior end; central area occupies 34% of maximum glabellar width. Three pairs of glabellar furrows present; S1, S2 and S3 equally spaced; S1 runs slightly obliquely backwards, then sharply turns posteriorly, and then merged with occipital furrow; S1 moderately deep and become shallower after turning posteriorly; S2 runs moderately obliquely and then sharply turns posteriorly, and moderately deep and become shallower after turning posteriorly; part of S2 which turns posteriorly much shallower than that of S1; S3 more obliquely directed backwards and become shallower to disappear adaxially; S3 longer than the obliquely-running part of S1 and S2. L1 and L2 sub-quadrate; pair of small pits present middle of L4. Occipital furrow curved forwards sagittally; adaxial two-thirds of the course much shallower than abaxial course. Palpebral lobe crescentic in outline and mid-point located opposite mid-point of L3; palpebral furrow moderately impressed. Preocular area of fixigenae very narrow (tr.) or nearly absent; palpebral area triangular in outline; postocular area sub-rectangular in outline, with relatively short spine at postero-lateral corner; fixigenal field covered with irregularly-dispersed pits. Posterior cranidial border straight, rimmed and obliquely directed forwards; posterior margin broadly indented at mid-length; posterior cranidial border furrow moderately deep, wide, and straight to slightly sinuous; articulating flange narrow and disappears adaxially. Anterior branch of facial suture gently curved forwards; posterior branch runs nearly transverse, and then gently turns posteriorly; facial suture of proparian type.

Librigena small, triangular in outline; librigenal lateral border furrow moderately impressed and merged with axial furrow opposite S1; librigenal field covered with irregularly-dispersed pits.

Hyposome shield-shaped. Anterior lobe of middle body sub-rectangular in outline; posterior lobe small and crescentic in outline. Anterior margin gently rounded; lateral margin strongly curved inwards at mid-point of anterior lobe, strongly projected outwards as shoulder, and then run obliquely straight backwards. Anterior border widens distally and narrows to be absent proximally; lateral border rimmed; lateral border furrows moderately deep and wide. Middle furrow shallow and disappears adaxially.
Thorax of 11 segments. Axis occupies 33% of thoracic width; axial furrow parallel-sided and then gently tapers backwards from the eighth or ninth thoracic segment. Axial ring slightly convex forwards sagittally and distal end curved forwards; axial ring furrow shallows adaxially with distinct elongated (tr.) apodemal pit at distal end. Pleura divided into anterior and posterior pleural band which are strongly convex and elongated triangular in shape, and separated from each other by deep, oblique pleural furrow; band width 37% of pleural transverse width; fulcral node moderately convex and sub-quadrate in outline. Anterior and posterior flange narrowing, becoming narrower at half-way of pleura, and delineated by deep furrow. Pleural spine blade-shaped, and gently curved backwards distally; posterior spines progressively more strongly curved backwards; spine half as long as pleura.

Pygidium sub-elliptical in outline. Three axial rings and terminal piece present; axial ring curved forwards sagittally. Three pleural ribs present; first (from the anterior) pleural rib with pleural bands and fulcral node as in thoracic segments, distally ending with free, strongly curved, blade-shaped spine; second pleural rib with pleural bands but without distinct fulcral node; third rib lacks pleural bands and fulcral node. Lateral and posterior pygidial margin smoothly saw-toothed, corresponding the second and third pleural spines.

Discussion.—The genera of the subfamily Cheirurinae are distinguished from one another chiefly upon the basis of pygidial morphology (Ludvigsen 1977). Pygidial morphology of Ceraurinus is characterized by a pair of long, curved, carinated first pleural spines, and two pairs of relatively short posterior spines (see Ludvigsen 1977: text-fig. 1). The pygidium of Ceraurinus zhuzhaiensis sp. nov., however, has a non-carinated first spine and saw-toothed pleural margin corresponding the posterior two pleural spines (Fig. 10B, B', H, N). The carination of other Ceraurinus species is also observed in genal and thoracic pleural spines as well as pygidal pleural spines (see Ludvigsen 1977: pl. 1: 7 for Ceraurinus marginatus Barton, 1913), while C. zhuzhaiensis lacks the feature in any of these spines. In addition, C. zhuzhaiensis is characterized by having a pair of small pits on L4. A provisionally associated hypostome (Fig. 11F) has a shoulder that is narrower and located more posteriorly, and a border that is more narrowly rimmed, compared to those of other Ceraurinus species (see Ludvigsen 1977: text-fig. 3).

Following Ludvigsen’s (1977) treatment of Remipyga as a junior synonym of Ceraurinus, Zhou and Zhen (2008: 242; misspelled as C. sinensis) transferred Remipyga chinensis Ju in Qiu et al. (1983) into Ceraurinus. It is the only Ceraurinus species listed in Zhou and Zhen, 2008 where other Chinese species previously assigned to Ceraurinus are transferred to other cheirurid genera. The sagittally-compressed, poorly-preserved cranium (Qiu et al. 1983: pl. 81: 9) exhibits a comparable glabellar morphology of Ceraurinus zhuzhaiensis sp. nov., but it appears to be rather oval than sub-rectangular; the more poorly-preserved pygidium (Qiu et al. 1983: pl. 81: 10), which has three axial rings and first pleural rib with free blade-shaped spine, appears to have a much wider (tr.) pleural field posterior to the first pleura than C. zhuzhaiensis. Furthermore, C. chinensis occurs in the Wen chang Formation of the Hirnantian age, which is younger than the Xiazheng Formation. 

Stratigraphic and geographic range.—Late Ordovician and Jiangxi Province, South China.

Family Encrinuridae Angelin, 1854

Genus Erratencrinurus Krueger, 1971

Type species: Erratencrinurus capricornus Krueger, 1971, from the Caradoc of Germany; by subsequent designation of Krueger (1972).

Erratencrinurus aff. trippi (Edgecombe, Banks, and Banks, 1999a)

Fig. 9K–M. O. P.

Material.—One thoraco-pygidium, three cranidia, three pygidia, one free cheek, and one thorax (repository numbers: NIGP-152057–152061).

Remarks.—This species resembles Erratencrinurus trippi Edgecombe, Banks, and Banks, 1999a (Edgecombe et al. 1999a: figs. 7A–E, G, H, 9L) from Tasmania. This species differs in having a straight fixigenal spine (directed moderately outwards in E. trippi) and less densely-distributed smaller tubercles on cranidium. In Zhou and Zhen (2008: 247) which summarizes trilobite records of China, listed is only a single occurrence of Erratencrinurus, which is from Inner Mongolia and has recently been described by Zhou and Zhou (2006). Erratencrinurus (Erratencrinurus) ejinensis Zhou and Zhou (2006: figs. 5E, G, I, J, M, 6A, D–F) differs from this species in having larger and more denser tubercles on cranidium; the cranidial tubercle formula of this species 1L-0, 2L-2, 1, 0, and 3L-3, 2, 1, 0, with large 3L-0 and that of E. (E.) ejinensis 1L-1, 2L-3, 2, 1, and 3L-3, 2, 1. The pygidia of E. (E.) ejinensis have 16 pleural ribs (see Zhou and Zhou 2006: fig. 6A, D–F), while those of this species have 11; the pygidia of both species lack tubercles on axial rings.

North American Erratencrinurus species differ in having much coarser tubercles on cranidium (see Lespérance and Desbiens 1995: figs. 3–14 for Erratencrinurus spicatus [Tripp, 1974]), and a sagittal tubercle on pygidial axial rings (see Lespérance and Tripp 1985: fig. 5f, i, j for Erratencrinurus perceensis [Cooper in Schuchert and Cooper, 1930]). This species would be a new Erratencrinurus species that is first recorded from South China region (see Zhou and Zhou 2006: 386 for geographic distribution of Erratencrinurus species), but better preserved material is needed to officially name it.

Family Pliomeridae Raymond, 1913

Genus Pliomerina Chugaeva, 1958

Type species: Pliomerina martelli (Reed, 1917), from the Shihtien Formation (Llanvirn) of Pupiao, western Yunnan Province, China.

Pliomerina tashanensis sp. nov.

Figs. 3E, 11A–L, O, Q.

Etymology: After the Tashan village where the type section of the Xiazheng Formation is located.
Holotype: NIGP-152063, cranidium from locality 3.

Type locality: Locality 3, about 400 m southeast of Zhuzhai, Yushan County. GPS coordinate is 28°34′14.33″ N and 118°20′22.41″ E.

Type horizon: Xizhen Formation, Upper Ordovician, Dicellograptus complexus Graptolite Zone.

Material.—Two thoraco-pygidia, nine cranidia, and eleven pygidia (repository numbers: NIGP-152062−152074, 152077).

Diagnosis.—Species of Pliomerina with abaxial end of S3 located posterior to antero-lateral glabellar corner, and more strongly backwardly curved posterior margin of pygidial axial rings.

Description.—Cranidium sub-triangular in outline. Anterior cranidial border narrow and rimmed; anterior cranidial border furrow moderately deep and concave; preglabellar field absent. Axial furrow deep and wide, steep-sided. Glabella elongated (sag.) pentagonal in outline; central area moderately carinated. Four pairs of glabellar furrows present; S1 elongated (tr.) triangular in outline and slightly curved backwards medially; S2 slit-like, straight, and transversely; S3 longest, obliquely directed posteriorly; adaxial end of S1/S2/S3 connected into shallow furrow to abaxially delineate carinated central area; abaxial end of S1/S2/S3 located within palpebral area of fixigenae; abaxial end of S3 posterior to antero-lateral glabellar corner; S4 weakly impressed, straight, obliquely directed, and isolated from axial furrow. L1 elongated (tr.) triangular in outline, protruded posteriorly to overhang occipital furrow, and distal end sharply curved forwards; L2 sub-rounded; L3 sub-triangular in outline and moderately convex; L4 paper fan-shaped in outline and covered with randomly-distributed tubercles while other lobes smooth. Palpebral lobe large, crescentic in outline, exsagittal length 41% of sagittal glabellar length, and posterior end overhangs posterior area of fixigenae. Palpebral furrow triangular in outline and shallow. Palpebral area of fixigenae narrow, elongated, and moderately carinated. Occipital furrow wide and gently curving forwards and shallows sagittally. Occipital ring spindle-shaped and distal end sharply curving forwards; occipital node weakly developed. Posterior cranidial border narrow and rimmed in adaxial two-thirds, and broad with rounded postero-lateral margin in abaxial one-third; posterior cranidial border furrow moderately deep and wide, becoming shallow to disappear distally. Postocular sulcus runs transverse and then sharply curved posteriorly.

More than 10 thoracic segments present. Axis slightly tapers backwards; axial ring narrows and curved forwards distally; axial furrow deep and wide. Pleura divided into adaxial and abaxial region by fulcral line; elongated (tr.) strongly raised ridge with slightly bulbous ends present in adaxial region; shallow furrow developed anterior and posterior to the ridge; abaxial region slightly obliquely directed backwards and diagonally divided into raised, flat band and depressed, flat articulating facet.

Pygidium semi-circular in outline. Axis gently tapers backwards with five axial rings and terminal piece; interring furrow moderately deep and become shallow and narrow adaxially, and gently curved backwards sagittally; terminal piece elongated (tr.) triangular in outline; postaxial ridge narrow (more distinct in internal moulds). Five pleural ribs present; each widens distally, and gently curved backwards and downwards distally; postero-most pair fused posteriorly and adaxially. Pleural furrow moderately deep and wide. Pygidial margin sawtooth-shaped due to distal projection of pleural ribs. No marginal border present.

Remarks.—From co-occurring Pliomerina tashanensis sp. nov., this species is discriminated by having the abaxial end of S3 located posterior to antero-lateral glabellar corner. Other species including P. trisulcata have the end anterior to the corner; see P. trisulcata Edgecombe et al. (1999a: fig. 10D), Pliomerina peripata Edgecombe et al. (1999b: figs. 1.1−1.5) from Argentina, Pliomerina martelli (Reed, 1917) (see Sheng 1974: pl. 7: 5a−c) from Yunnan, and Pliomerina serrata Zhou and Zhou (2006: fig. 4A, B) from Inner Mongolia. Posterior margins of pygidial axial rings of P. tashanensis are more strongly curved backwards (see Fig. 11O for cast of external mould), compared with P. trisulcata (see Edgecombe et al. 1999a: fig. 9F). Other species have a straight posterior margin; for example, see Pliomerina australis Webby (1971: pl. 114: 8), P. peripata Edgecombe et al. (1999b: figs. 1.15−1.18).

Stratigraphic and geographic range.—Late Ordovician and Jiangxi Province, South China.

Pliomerina sp.

Fig. 11M, N, P.

Material.—Three cranidia (repository numbers: NIGP-152075, 152076, 152078).

Remarks.—From co-occurring Pliomerina tashanensis sp. nov., this species is discriminated by having the abaxial end of S3 at antero-lateral glabellar corner, shorter (sag.) glabella, and non-carinated palpebral area of fixigenae. Of Pliomerina species: P. australis Webby, 1971 and P. prima Webby, 1971 from New South Wales, Australia; P. dukhanensis Chugaeva, 1958 from Kazakhstan; P. serratia Zhou and Zhou, 2006 and P. rigida Kolobova, 1972 from Inner Mongolia exhibits comparable cranidial architecture. The cranidia however differ in having a more rounded anterior margin, less deeply impressed glabellar furrows, larger palpebral lobe that is located more posteriorly, and longer (tr.) posterior border.

Discussion

Characteristics of the fauna.—The trilobite fauna from the mudstone beds of the Xizhen Formation comprises 25 species, 14 genera, and ten families (Table 1). Of these, five species are new: Remopleurides xiazhaiensis sp. nov., Hibbertia aodiensis sp. nov., Vietnamia yushanensis sp. nov., Ceraurinus zhuzhaiensis sp. nov., and Pliomerina tashanensis sp. nov. These new species represent about 70% of the speci-
mens collected; other species, which are all described in open nomenclature, each represent 1.7% in average. Of the ten families, six belong to those of Whiterock and four to those of Ibex fauna (Adrain et al. 1998, 2004); those belonging to the Whiterock fauna families account for 71% of the total specimens.

Zhou et al. (2004: fig. 2.5.1) recognised three trilobite associations during the mid-Ashgill of South China, and the *Pliomerina–Vietnamia* association is recognized in carbonate buildups in Changshan area which includes the Zhuhai area. Although the fauna from the Xiazheng Formation consisting of ten genera of nine families was mentioned, the recognition is mainly based on the trilobite assemblages from Huishandi and Jitoushan section of the Sanqushan Formation (see Zhan and Cocks 1998: text-fig. 1 for location of the sections); the fauna has not received a proper systematic treatment either. *Pliomerina* (56%) and *Vietnamia* (20%) are said to be the major components of the assemblage, so that the association is named after these two genera. Unlike the Sanqushan fauna associated with carbonate mudmounds, the Xiazheng fauna associated with mudstone is predominated by *Vietnamia* (39%); *Pliomerina* accounts for only 13% (see Table 1). The difference from the Sanqushan fauna can be attributed to a lateral biofacies change in relation to co-existing sedimentary facies in a rimmed shelf setting (Li et al. 2004: fig. 12).

Seventy five percent of the specimens are assigned to the four phacopid families (Table 1); the Calymenidae (43%; all belongs to the subfamily Reedocalymeninae), Cephalura (14%), Pliomeridae (13%), and Encrinuridae (5%). These phacopids seem to be rare in other Ordovician biostratigraphic regions of China than South China region (see Zhou and Zhen 2008: figs. 1–4) for the Ordovician palaeogeographical units of China). In Zhou and Zhen (2008) which has summarised trilobite records of China, listed are two occurrences of *Vietnamia* from Xinjiang and Xizang (Tibet) (Zhou and Zhen 2008: 241), a single occurrence of *Erratencrinurus* from Inner Mongolia (Zhou and Zhen 2008: 247; this has been described by Zhou and Zhou 2006), and no occurrence of *Ceraurinus*, *Plomerina*, the third dominant taxon of the Xiazheng fauna, occur in nearly all biogeographical units of China; a total of nine occurrences are listed (Zhou and Zhen 2008: 263).

Outside China, *Vietnamia* has been reported from Sar-dinia, Vietnam, Himalayas, Tasmania, Uzbekistan and Tadzhikistan (Turvey 2005 and see references therein); *Ceraurinus* from North America (Ludvigsen 1977 and see references therein) and Kazakhstan (Chugaeva 1958); *Plomerina* from South Korea, Kazakhstan, Turkey, Australia (New South Wales and Tasmania), and Argentina (Zhou and Zhou 2006 and see references therein); and *Erratencrinurus* from England, Norway, Germany, Estonia, North America and Taiwan (Zhou and Zhou 2006 and see references therein). There is no region where all four genera occur together. *Vietnamia*, *Plomerina*, and *Erratencrinurus* occur together in Tasmania (Edgecombe et al. 1999a), which is the sole occurrence of *Vietnamia* with other taxa; *Vietnamia*, however, appears to be a minor component in this fauna. *Ceraurinus* and *Erratencrinurus* occur together in North America and *Ceraurinus* and *Plomerina* in Kazakhstan. This indicates that the phacopid-dominant Xiazheng mudstone fauna is unique during the Late Ordovician, even in the global scale. The fact that the major elements of the fauna are new to science further supports that the faunal affinity to any biogeographical regions cannot be inferred. It seems that the association of the fauna with a localized reef system, probably within an isolated platform in South China Plate (Zhang et al. 2007: figs. 2–21) is the reason for this faunal uniqueness.

**Stratigraphical implication of trilobite occurrences.**—Comparison of the trilobite occurrences in present study with the previous occurrence data bears an interesting implication for stratigraphy of the Xiazheng Formation (Table 2); the mudstone strata of locality 2 in this study correspond to those of stratigraphical unit 7 in Chen et al. (1987: fig. 1; see also Zhang et al. 2007: figs. 4–2), those of locality 3 to unit 11, and those of locality 4 and 5 both to unit 18. The mudstone strata of locality 1 are not recognized in the stratigraphical column by Chen et al. (1987: fig. 1). Considering the average dip angle of 19° SE and the trilobite composition (Table 1), the mudstone strata of locality 1 are considered to be contemporaneous with those at locality 2. The mudstone strata of locality 4 are contemporaneous with those of locality 5, since the same trilobite fauna occur in both localities. The trilobite composition of locality 3 is unique in that *Plomerina* and *Meitanillaenus*, the dominant elements do not occur in other localities (see Table 1). This indicates that the mudstone layers at locality 3 are a stratigraphically different unit from those at other localities.

The stratigraphical column by Zhang et al. (2007: figs. 4–2) shows that the Xiazheng Formation exposed at Zhuhai is conformable across three exposures in Fig. 1, with the one at northwest being oldest. This suggests that the mudstone at locality 4 and 5 is stratigraphically younger than that at locality 1 and 2, with that at locality 3 being placed in the middle; the localities 1 and 2 and localities 4 and 5 are separated more than 200 m apart in vertical thickness. However, the trilobite assemblages from localities 1, 2, 4, and 5 are greatly similar to each other (Table 1), indicating that the mudstone strata of these localities are likely to be stratigraphically contemporaneous. Other fossils including brachiopods, cephalopods, and crinoids also show a similar occurrence pattern (see Table 2 for brachiopod occurrence). Such repeated occurrence of the identical trilobite assemblage along the dip direction suggests that the outcrops of the Xiazheng Formation are overlapped. This may be due to structural movement caused by large-scale tectonic movements of South China Plate and Cathaysian Land (e.g., see Guo et al. 2009 and references therein). Alternatively, but less likely, the same fauna comprising benthic mobile, sessile, and nektic animals might have re-colonized the environment where the mudstone at Locality 4/5 was depos-
Conclusions

A newly described trilobite fauna from the mudstone beds of the Upper Ordovician Xiazhen Formation includes five new species and 20 species in open nomenclature. The fauna predominated by phacopids appears to have inhabited the muddy substrate after decimation of the reef system. The fauna is unique among the Late Ordovician trilobite fauna, most of which are not associated with reef and not dominated by the phacopids.

Acknowledgements

The author is grateful to Dong-Jin Lee (Andong National University, Andong, South Korea), Jeong-Gu Lee (Gwacheon National Sciences Museum, Gwacheon, South Korea), and Jusun Woo (Korea Polar Research Institute, Incheon, South Korea) for their assistance in collecting specimens. Jino Park (Korea University, Seoul, Andong, South Korea), Jeong-Gu Lee (Gwacheon National Sciences Museum, Gwancheon, South Korea), and Jusun Woo (Korea Polar Research Institute, Incheon, South Korea), and Jusun Woo (Korea University, Seoul, Andong, South Korea) for their assistance in collecting specimens. Jino Park (Korea University, Seoul, South Korea) is thanked for his generous help for the field trip and logistical arrangement of specimen shipment. This research is financially supported by a grant from Korea Research Foundation (Grant No. KRF-21A4007−2010−0011026) to the author. The author thanks Brian D.E. Chatterton (University of Alberta, Edmonton, Canada) and anonymous person: Barton, D.C. 1913. A new genus of the Cheirurinae, with descriptions of some new species. Bulletin of the Museum of Comparative Zoology 54: 723–736.


References

Note: Translation of Chinese literature follows Zhou and Zhen (2008).


Kobayashi, T. 1935. The Cambro-Ordovician formations and faunas of South Chosen. Palaeontologia part 3: Cambrian faunas of South Chosen with special study on the Cambrian trilobite genera and families. Journal of the Faculty of Science, Imperial University of Tokyo (Section II: Geology) 4: 49–344.
LEE—ORDOVICIAN TRILOBITES FROM CHINA

Kobayashi, T. 1951. On the Ordovician trilobites in central China. Journal of the Faculty of Science, Imperial University of Tokyo (Section II: Geology) 8: 1–87.


