# LATE CAMBRIAN (POST-IDAMEAN) TRILOBITES FROM THE HIGGINS CREEK AREA, WESTERN TASMANIA

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Trilobites are described from nine localities on logging tracks between the Huskisson River and Burns Peak, NNE of Renison Bell, western Tasmania. The 18 taxa, 7 in open nomenclature, indicate an age in the pre-Payntonian Stage (Queensland scheme) or late Early to early Late Sunwaptan Stage (North American scheme). Seven new species are described as *Lotagnostus tullahensis, Rhaptagnostus mji, Cermatops thalasta, Asiocephalus latosuggrundus, Olenus apoxysomatus, Chekiangaspis concavus,* and *Wujiajiania distorta.* This fauna is important as it represents an off-shelf assemblage, possibly with some shelf inhabitants mixed in, that is contemporaneous with one of the carbonate shelf assemblages of western Queensland. ☐ *Late Cambrian, trilobites, Tasmania.*

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Tasmanian Late Cambrian trilobites have been recorded (Jago,1972, 1974, 1978, 1987; and references in Jago, 1979 and Banks, 1982) from several different parts of the State and from several different horizons. This paper presents a further discovery, in the Huskisson Group, in the Higgins Creek area between the Huskisson River and Burns Peak, 15 km NNE of Renison Bell, of a fauna of 18 trilobite taxa plus brachiopod and bradoriid elements; much of the fauna has not been previously described from Australia and has affinities with faunas from other parts of the world, in particular central China. The nearest occurrences of trilobites are those from the Huskisson River about 7 km NNE of Renison Bell (Jago, 1974) where the index fossil *Glyptagnostus reticulatus* indicates an early Idamean age.

A Late Cambrian fauna was described from the Climie Formation, Dundas Group (Jago, 1978) about 12 km south of Renison Bell. Jago (1978) favoured a post-Idamean age over the other possibility, latest Idamean. Jago's *Peltura* (?) sp. has a glabella with convex lateral margins and glabellar furrows that are almost straight in the two arms of the chevron and continuous across the axis; both are features of *Wujiajiania distorta* sp. nov. and we suggest that may be the more likely identity of Jago's specimen. His Ceratopygidae, gen. et sp. indet (Jago, 1978, pl.2, figs 16, 20) are indistinguishable from *Proceratopyge gordonensis* Jago, 1987, a close relative/descendant of which is found in our fauna. His Trilobita incertae sedis, specimen 3 (Jago, 1978, pl.2, fig. 18) is assignable to *Cermatops thalasta* sp. nov. as it has the same structure of furrows on the pleural areas as described for that species below. Moreover, we concur with Jago that his cranidial fragment (Jago, 1978, pl.2, fig.17) is conspecific with the pygidium but the possible assignment to *Briscoia* is revised. We suggest that both specimens belong to *C. thalasta*. *Lotagnostus* occurs in both faunas, with unavailability of features (through poor preservation) on Jago's (1978, pl.2, fig.1) specimen preventing specific comparison. *Olenus* occurs in both faunas, albeit as entirely different species; some importance is attached to its generic range in Europe, but in China *O. sinensis* occurs with taxonomic relatives of some of our Higgins Creek fauna in horizons younger than those yielding the genus in Europe (Lu and Lin, 1989). Based on this series of observations we deduce that Jago's Climie Formation fauna and our Higgins Creek fauna were approximately contemporaneous. Jago (in Shergold et al., 1985) reassessed the age of his Climie Formation fauna on the basis of the discovery of *Hedinaspis* in a correlative horizon in the Professor Range; on that basis he considered it late Late Cambrian but tabulated it (Shergold et al., 1985, chart 7, col. 53) as medial Late Cambrian with which we agree. We are unaware of this record of *Hedinaspis* being illustrated and suggest that it should be carefully scrutinized to determine

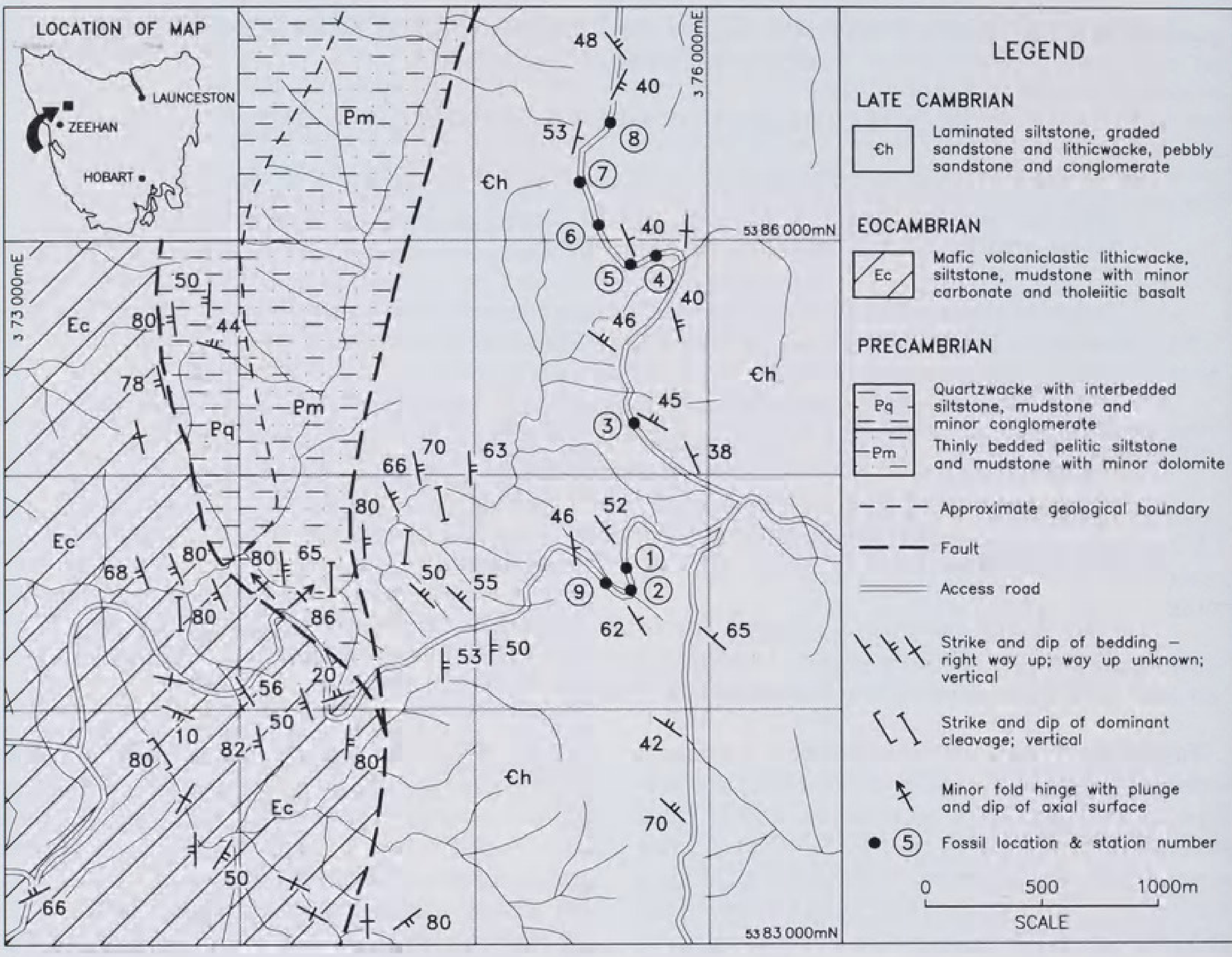



FIG. 1. Locality map for fossil localities mentioned in text. Area is situated between the Huskisson River and Burns Peak NNE of Renison Bell.

whether it may be the similar *Asiocephalus* or not. Similarly the record of *Hedinaspis* from western New South Wales (Webby et al., 1988) could represent *Asiocephalus*; distinctive features are unavailable on specimens illustrated.

The fauna from the Singing Creek Formation of the Denison Range, southwestern Tasmania (Jago,1987) has in common with faunas described below *Micragnostus, Pseudagnostus, Aphelaspis, Proceratopyge,* but this does not indicate contemporaneity in itself. However, note that Jago (1987) compared his Leiostegiacean gen. et sp. indet. to families that are normally post-Idamean in China and described a species of *Pseudoyuepingia*, that genus being post-Idamean in China and interpreted as such in western New South Wales (Webby et al., 1988). Moreover, Jago (in Shergold et al., 1985) attributed a post-Idamean to pre-Payntonian age to this fauna. Comparison of elements of this fauna with the one described below also suggest a post-Idamean age with possible close proximity of the ages of both faunas. We accept Jago's (in Shergold et al., 1985) assessment of its age.

Geological setting and age of the Higgins Creek fauna indicate that it is buried in a turbidite sequence probably deposited on or at the base of the continental slope. Some of the taxa found in only one of the three faunas (Higgins Creek, Climie Formation, Denison Range) may have been shelf benthos, having been incorporated into the off shelf deposits by slump or flow at the shelf margin. Those taxa common to the faunas may have been off shelf benthos or inhabitants of the water column. We suggest that these three faunas were essentially contemporaneous, post-Idamean in age; discussion of this age is presented below.

## LOCALITY AND GEOLOGICAL SETTING

During mapping for the Corinna 1:50,000

Geological Atlas Map Sheet (Turner et al. 1991), a small area containing a sequence of interbedded pebble to granule conglomerate, with dominantly siliceous clasts and matrix, graded sandstone and lithicwacke and siltstone was encountered along the poorly accessible southeastern margin of the map sheet in the Higgins Creek area (Fig.1). In March 1990, during a reconnaissance traverse into this area, nine localities with fossiliferous lithicwacke and siltstone were found in cuttings along a new road west from the Murchison Highway towards the Huskisson River; the area is about 15 km NNE of Renison Bell and 12 km NW of Tullah, both towns being on the Murchison Highway.

Lithologically, the sequence is dominated by interbedded siltstone and well bedded lithicwacke, with lenses and channel infillings of conglomerate. The conglomerate units are of both clast and matrix supported varieties. The open framework conglomerate units have dominantly chert clasts whereas the closed framework units are dominated by rounded quartzite clasts. The thicker sand grade beds and conglomerate units have scour bases and, in places, contain rip-up siltstone clasts in the basal section. Sand grade beds are usually graded and consistently give an east facing (easterly dip). Some sand grade beds contain intraformational soft sediment deformation and small cross-bedded channel infills. Siltstone beds are usually laminar but cross-bedded units are also present. Sedimentological features within this succession suggest a submarine fan environment of deposition.

The rock sequence is considered to belong to the upper part of the Huskisson Group and a correlate of the upper part of the Dundas Group (as described by Brown, 1986). Rock sequences lithologically similar to those containing the fossil sites occur to the north and south of the area. To the north, the succession contains mudstone, quartzite, greywacke, and tuffaceous greywacke-mudstone with conglomerate and crystal-vitric tuff units (Collins et al., 1981).

To the south, exposures were available in two locations during the early to mid 1980s. The first of these were in roadside quarries made during the construction of the Lower Pieman Dam Road; however, these exposures have since been re-vegetated. The second location was in the Pieman River Gorge to the south of the road, but flooding the river to form Lake Pieman drowned these localities. Decription of the sequences in these areas can be found in Green (1983) and Brown (1986).

The Higgins Creek sequence containing the fossils belongs to a belt of rocks formed during the latest Idamean, which is now thrust against Precambrian successions to the west and has Middle(?) Cambrian volcano-sedimentary successions thrust against it on the east. Due to discontinuous structures to the north and south of the Higgins Creek area and the unresolved structural complexity of the rocks to the east, it is not possible to give a structural relationship of this east facing sequence with the Middle(?) Cambrian volcano-sedmentary sequences.

The implication of structural complexity of the Higgins Creek area, the discontinuous structures both to the north and south of the Higgins Creek area, and the lack of knowledge as to the boundary relationship of this area with the sequences containing, the as yet undescribed, late Middle(?) Cambrian faunas within the volcaniclastic sequences to the east of Burns Peak (Corbett and McNeil, 1986; Corbett and Solomon, 1988: 101), and the tectonic significance of the new fauna, will be discussed within the forthcoming Explanatory Notes to the Corinna 1:50,000 Map Sheet (in prep.).

## FAUNA AND AGE

We describe 18 trilobite taxa, with 7 of those in open nomenclature (Table 1). *Proceratopyge gordonensis* has been found in Australia in strata we consider approximately coeval with the collections described below but considered by Jago (1987) to be Idamean. *Pseudagnostus* sp. is compared with *P. idalis* Öpik, 1967, although that is a dubious comparison; *P. idalis* is restricted to the Idamean in the rest of Australia. Apart from its record in the Climie Formation (Jago, 1978) mentioned above, *Olenus* has been recorded in the Idamean of western Queensland (Öpik, 1963), and the *Olenus* Zones of Europe are correlated with the Australian Idamean. *Aphelaspis* is now widely known in Australia, but its greatest development is in North America; the *Aphelaspis* Zone of that continent is correlated with the early half of the Australian Idamean Stage. However, the range of this taxon is not certain and depends to large extent on better definition of this and related taxa currently assigned to separate but undifferentiated genera, as discussed in the sysyematics below. *Olentella* for example ranges into the post-Idamean. These taxa could be used to suggest correlation with the latest Idamean (Shergold et al., 1990).

However, the rest of the fauna is not obviously

| TRILOBITES \ LOCALITIES | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| *Acmarhachis*? sp. | X | | | | | | | | |
| *Micragnostus* sp. cf. *M. intermedius* Palmer, 1968 | X | | | | | | | | |
| Pseudagnostids | X | | | | X | | | | |
| *Lotagnostus tullahensis* sp. nov. | | | | | | | | | X |
| *Pseudagnostus* sp. | | X | X | | | | | | |
| *Pseudagnostus (Sulcatagnostus)* sp. | | | | | | | X | | |
| *Neoagnostus clavus* Shergold, 1972 | | | | | | | | X | |
| *Rhaptagnostus convergens* Palmer, 1955 | | | | | | | | X | |
| *Rhaptagnostus mji* sp. nov. | | | | | | | | | |
| *Proceratopyge* sp. cf. *P. gordonensis* Jago, 1987 | X | | | | X | X | | X | X |
| *Cermatops thalasta* sp. nov. | | | | X | | | | X | X |
| *Asiocephalus latosuggrundus* sp. nov. | X | X | | | | | | | |
| *Olenus apoxysomatus* sp. nov. | X | X | X | | X | | X | | |
| *Chekiangaspis concavus* sp. nov. | | | | | X | | | | |
| *Wujiajiania distortus* sp. nov. | | X | X | | | | X | | X |
| *Aphelaspis* sp. | | | | | X | | | | X |
| Conokephalinidae indet. | | | | | | | | | X |
| *Aposolenopleura* sp. | | | | | | | | | X |

TABLE 1. Distribution of fauna at the nine collecting localities marked on the locality map (Fig. 1).

in accord with this date. *Aposolenopleura* and the nearest specific comparison of *Lotagnostus tullahensis* are to be found in the *Hungaia magnifica* Faunule which was originally thought to be of late Trempealeau age (Rasetti, 1944); subsequently, Lochman and Wilson (1958) correlated it with the late Franconian (Sunwaptan) *Ptychaspis–Prosaukia* and *Saukia* Zones. Palmer (1968) accepted correlation with the late Franconian (late Early Sunwaptan)and erected *Asiocephalus* for trilobites from the same faunule. This genus is represented in our Higgins Creek fauna. In Kazakhstan, *Hedinaspis (Asiocephalus) sulcata* is the nominal species of a zone correlated with the *Trisulcatagnostus trisulcus* and *Eolotagnostus scrobicularis* Zones; Shergold et al. (1990) correlated these zones with the *Saukia* Zone (*Saukiella junia* Subzone)of North America even though *Saukiella* does not appear in the Kazakh sequence until two zones later in the *Harpidioides-Platypeltoides* Zone (Apollonov and Chugaeva, 1983); Shergold (pers. comm. June, 1991) would now correlate those Kazakh zones with older horizons in the rest of the world thus coming closer to the suggestion made here . We suggest that horizon should be correlated with pre-*Saukiella* horizons in North America, i.e. with the late Early Sunwaptan (=late Franconian). *Cermatops* occurs in western Queensland in the post-Idamean *Wentsuia iota–Rhaptagnostus apsis* Zone (Shergold,1980), and the Welsh species of Hughes and Rushton (1990) is from the contemporaneous *Parabolina spinulosa* Zone, two zones younger than the Idamean. The Chinese *Wujiajiania* and *Chekiangaspis* occur together in the *Lotagnostus punctatus* Zone of western Zhejiang; this zone is numbered 14 in the scheme of Lu and Lin (1989) with *Pseudagnostus idalis* occurring in the*Proceratopyge fenghuangensis* and *Erixanum* Zones (Zones 11 and 12 of Lu and Lin's scheme) those zones being correlated with the third and second last zones of the Australian Idamean, respectively (Lu and Lin, 1989, table 8). Therefore, if Lu and Lin's zone 13 (*Pseudoglyptagnostus clavatus–Sinoproceratopyge kiangshanensis* Zone) is equated with the last Idamean or an immediately post-Idamean Zone (J.H. Shergold (pers. comm. June, 1991) suggested equivalence with the *Irvingella* Zone) then the *Lotagnostus punctatus* Zone (14) is post-Idamean. In so far as the base of the *L.*

*punctatus* Zone of western Zhejiang is aligned with the base of the *Maladioidella* Zone of the North China Province and that Zone is shown by Shergold et al. (1990, fig.7)to be equivalent to the post-*Irvingella* Zone of Queensland, we correlate the *L. punctatus* Zone, with the late Early Sunwaptan (=late Franconian). Therefore, 6 members of the Higgins Creek fauna suggest correlation with this North American horizon.

*Neoagnostus clavus* is found in western Queensland in the penultimate and prepenultimate zones of the pre-Payntonian. Shergold et al. (1990) also correlated this horizon with the *Saukiella junia* Subzone of North America but that correlation was based on conodont work which has been revised providing a different picture (Nicoll and Shergold, 1991). Its contemporaneous horizons in the North American sequence may be near the Early /Late Sunwaptan boundary (Ludvigsen and Westrop, 1985). Similarly, *Rhaptagnostus convergens* is ascribed an age (Shergold, 1977) in the *Saukiella pyrene* Subzone of Nevada; that horizon, immediately on top of the *Ellipsocephaloides* Zone (Longacre, 1970, text-fig.5) indicates the Early to Late Sunwaptan boundary. These two species may therefore be added to those that suggest a Sunwaptan age for our fauna even if the suggestion is for a zone younger than suggested by the previous six species.

The Higgins Creek fauna, therefore, contains 8 species that suggest correlation with horizons just below or above the Early/Late Sunwaptan (=late Franconian) boundary (3 or 4 zones post-Idamean) and 4 that suggest latest Idamean but much less strongly. In discussions of *Wujiajiania distorta* and *Asiocephalus latosuggrundus* we point out that they are probably ancestral to members of the respective genera found elsewhere in the world. Therefore, they may be interpreted as indicating a slightly older horizon in Tasmania. We initially considered that among the 9 localities, which could not be placed in stratigraphic sequence, some may have been late Idamean and others several zones post-Idamean. However, careful examination of the collections show the reported associations to be valid with some of the unexpected co-occurrences on one piece of rock.

We suggest that the age of the fauna may be post-Idamean within the Early Sunwaptan Stage, with which its constituents have been compared above; no zonal correlation may be substantiated with any other part of the world, not even with Queensland or other parts of Australia. As discussed above approximate contemporaneity with Jago's (1978, 1987) Climie and Singing Creek faunas is suggested as the only speculation at a more specific level. The lower fauna in the Watties Bore section (Webby et al., 1988) resembles the Tasmanian faunas in containing *Pseudoyuepingia, Proceratopyge, Pareuloma* (close to *Chekiangaspis* as discussed by Webby et al. (1988, p.914)), and *Hedinaspis* sp. (may be *Asiocephalus* as discussed above); however, these similarities may be due to their occurring in the same off shelf environment where a number of genera are beginning to appear to have quite long ranges as well as to proximity of age, if any. The significance of the fauna is its further revealing the oceanic fauna of eastern Australia in the Late Cambrian and providing more information for correlation within Australia and the Asian region.

## SYSTEMATIC PALAEONTOLOGY

The fossils described herein are housed in the Geological Survey of Tasmania (prefix GST). Descriptive terminology follows Moore (1959), where possible, with the notation for glabellar lobes and furrows following Henningsmoen (1957) (i.e. lobes termed L0, L1, L2, L3 etc. and furrows S0, S1, S2 etc from the occipital forward).

Class TRILOBITA
Order MIOMERA Jaekel, 1909
Superfamily AGNOSTOIDEA McCoy, 1849
Family AGNOSTIDAE McCoy, 1849

### **Lotagnostus** Whitehouse, 1936

Type Species

*Agnostus trisectus* Salter, 1864 from the Late Cambrian of Britain and Sweden.

### **Lotagnostus tullahensis** sp. nov.
(Fig. 3G–I)

Etymology

Near the town of Tullah, western Tasmania.

Material

Holotype GST14375 and paratypes GST14373 and 14374 from Loc. 9.

Diagnosis

Cephalon with well-impressed preglabellar median furrow reaching border furrow, scrobiculate cheek areas; anterior glabellar lobe large, subquadrate with slight anteromedial projection and rounded anterolaterally; S2 well-impressed, chevron-shaped over axis; glabellar node just behind S2; basal lobes large, triangular, extending well forward. Pygidium with wide, straight-sided axis finishing well forward of border furrow; first axial ring of two lateral lobes; second axial ring with high-rounded median node descending forward to articulating furrow and dividing first ring; cheek areas weakly scrobiculate; border flat but not wide, with pair of marginal spines posterior of widest point.

REMARKS

Generic assignment is made using the diagnosis of Ludvigsen et al. (1989) wherein the only point of possible disagreement could be the indication that the pygidial axis extends close to the posterior border furrow. In this Tasmanian species the axis does not appear to extend as far posteriorly (Fig. 3I) as in cogeners. Variation in this feature is evident in other species.

The Tasmanian cephalon is virtually indistinguishable from that of *L. americanus* (cf. Rasetti, 1944, pl. 36, fig. 1; Ludvigsen et al. 1989, pl. 1, fig.25–upper right). Anterior glabellar shape and strongly divided posterior glabellar lobe are distinctive. However, the pygidium of that North American species has a wide border constricted acrolobes, axis reaching close to border furrow and differently shaped first and second pygidial axial rings and tubercle thereon. In this last feature, the furrow between the first and second pygidial axial rings is usually transverse and continuous in previously described species of the genus but in *L. americanus* as in our Tasmanian species (Ludvigsen et al. 1989, pl.1, fig.15; Rasetti, 1944, pl.36, fig. 2) the tubercle interrupts that furrow, extending over the length of 2 segments. Nevertheless, shape of the lateral parts of the first ring and shape of the tubercle distinguish these 2 species. *Lotagnostus* sp. of Palmer (1968, pl.12, figs 3,4) has a pygidium almost identical with the Tasmanian (axial ring is longer, axis narrower, border narrower) but the associated cephalon is distinct (nonscrobiculate, wide border furrow, poorly divided posterior glabellar lobe, posteriorly placed glabellar node).

### **Acmarhachis** Resser, 1938

TYPE SPECIES

*Acmarhachis typicalis* Resser, 1938, from the Dresbachian of Alabama, by original designation.

### **Acmarhachis** ? sp.
(Fig. 2A,B)

MATERIAL

GST14355 from Loc. 1

DISCUSSION

This specimen is too poorly preserved for taxonomic treatment but it is assigned to *Acmarhachis* on the basis of glabellar shape with broadly rounded anterior and long anterior lobe, on lack of preglabellar median furrow and on shape of the pygidial axis which reaches to the posterior border furrow. This may be slim evidence but Shergold (1980) showed that the genus ranges higher into the Late Cambrian in Australia and the features outlined are sufficient for tentative assignment of this poor specimen.

### **Micragnostus** Howell, 1935

TYPE SPECIES

*Agnostus clavus* Lake, 1906 from the Tremadocian of Wales, by original designation.

### **Micragnostus** sp. cf. **M. intermedius**
(Palmer, 1968)
(Fig. 2G–I, K(right only)

MATERIAL

Three cranidia GST14359-14361 and one pygidium, GST14366 all from Loc. 1.

DISCUSSION

These cephala are tiny and the pygidium is only a little larger. It is, therefore, difficult to compare them with material of the long-ranging *M. intermedius* (assigned to *Micragnostus* by Fortey (1980:21)) from Alaska (Palmer, 1968), Mexico (Robison and Pantoja-Alor, 1968) and Newfoundland (Ludvigsen et al., 1989). However, the pygidium is distinctive with its axis finishing well forward of the border furrow, and markedly narrow border for the genus or for agnostoids of this age. The latter feature in particular, is distinctive of *M. intermedius* among its contemporaries, but is shared with Tremadocian forms described by Fortey (1980, pl.1). The cranidia are less distinctive but comparison with the smaller cranidia from Mexico (Robison and Pantoja-Alor, 1968, pl.97, figs 4,5) shows the anteriorly tapering glabella with well rounded

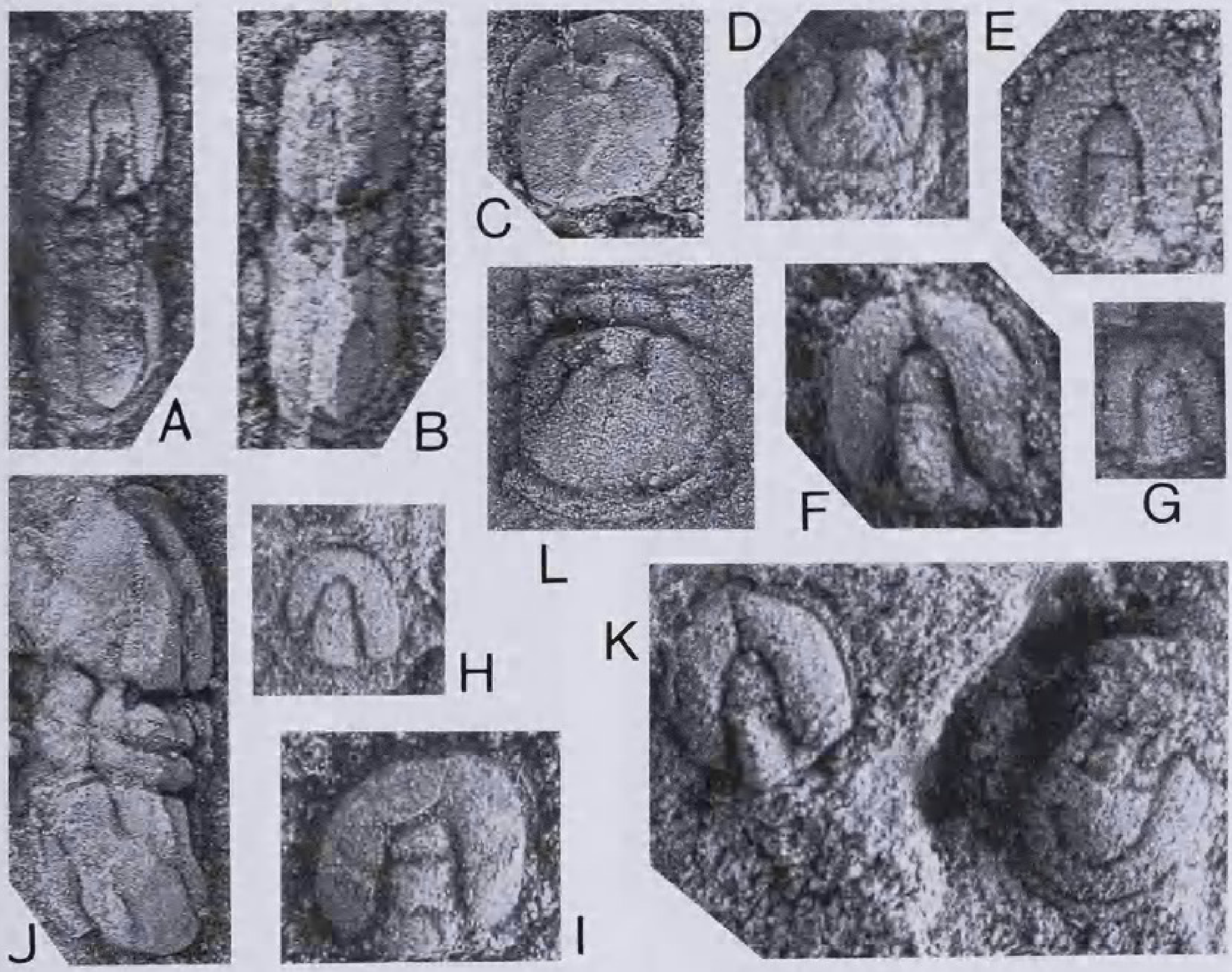



FIG. 2. All from Loc. 1 except L from Loc. 5. A,B, *Acmarhachis*? sp. internal mould and latex cast, respectively, of complete specimen GST14355, x8. C, Effaced pseudagnostid GST14356, x7. D–F, K (left), *Rhaptagnostus mji* sp. nov. D, internal mould of small pygidium GST14357, x14. E,F, latex cast and internal mould of small cephalon GST14358, x14. K (left), internal mould of small cephalon GST14365, x14. G–I, K(right), *Micragnostus* sp. cf. *M. intermedius* (Palmer, 1968). G–I, internal moulds ofsmall cephala GST14359–14361, x15, x15, and x11, respectively. K(right), internal mould of pygidium GST14366, x14. J, Pseudagnostid indet.internal mould of complete deformed specimen GST14362, x6. L, Pseudagnostidindet. GST14363, x5.

anterior, narrow border, and short but distinct basal lobes to be shared by both sets of material. Identification with this American species is necessarily tentative because cranidia of comparable size to the larger Amer-ican specimens are not available from Tasmania as yet and because the Tasmanian specimens are all internal moulds and therefore may prove to have different external morphology.

Family DIPLAGNOSTIDAE Whitehouse, 1936

Subfamily PSEUDAGNOSTINAE Whitehouse, 1936

**Neoagnostus** Kobayashi, 1955

TYPE SPECIES

*Neoagnostus aspidoides* Kobayashi, 1955 from British Columbia, by original designation.

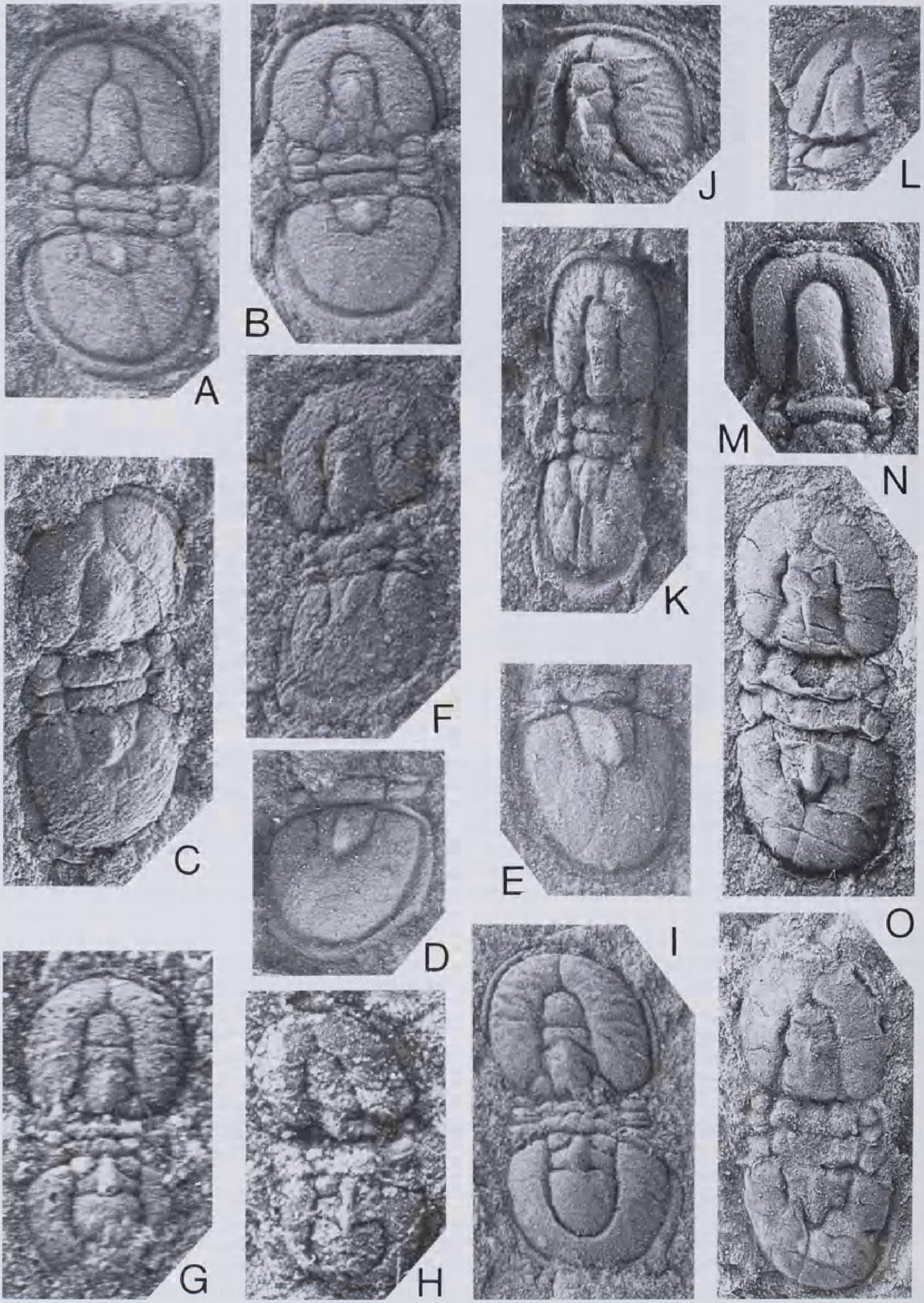
**Neoagnostus clavus** (Shergold, 1972)
(Fig. 3M)

MATERIAL

GST14379, cephalon with first thoracic segment articulated from Loc. 8.

DISCUSSION

This cephalon resembles the western Queensland paratype figured by Shergold (1977, pl.16, fig.14), particularly in outline, glabellar lobes and node arrangement, and waisted glabel-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la. Only the preglabellar median furrow on the Tasmanian specimen could be used to distinguish it from the Queensland species but that is not sufficient in view of the other close similarities exhibited. This Tasmanian specimen has been tectonically compressed in the transverse direction so the glabella, border furrow (laterally) and basal lobes appear narrower than in the undistorted Queensland specimens but the specific identity is not in doubt, although a pygidium will be necessary to make certain identification.

### **Pseudagnostus** Jaekel, 1909

Type Species

*Agnostus cyclopyge* Tullberg, 1880 from the Late Cambrian of Sweden.

### **Pseudagnostus sp.**
(Figs 4,5)

Material

GST14381–14388 from Loc. 2, GST14390–14401 from Loc. 3.

Discussion

Agnostids are common in collections from Localities 2 and 3 but they are invariably distorted to some degree and cannot be identified with confidence because the parietal structures of the glabella, which are so important to taxonomy in this group cannot be observed. It is not even certain how many species are represented (e.g. are Fig. 5J,I,L with blunter glabellar anterior and effaced accessory furrows conspecific with the rest of the material?). They are apparently spectaculate agnostids, with a well-impressed preglabellar median furrow, wide deliquiate border furrows, subquadrate pygidium, accessory furrows in most specimens, accessory furrows not reaching border furrow, marginal spines situated posteriorly level with or behind the rear of the acrolobe. These features are consistent with the morphology of *Pseudagnostus idalis* Öpik, 1967 but we are reluctant to suggest such an assignment on the available material. Further discussion of these specimens seems fruitless because the features of the glabella are uncertain.

### **Pseudagnostus** (**Sulcatagnostus**) sp.
(Fig. 3J,K)

Material

GST14376, 14377 from Loc. 7.

Discussion

The internal mould of a whole specimen is laterally compressed and damaged in some parts. Likewise the cranidium (Fig.3K) is strongly distorted. Therefore, features of the subgenus are the scrobiculate cranidium, long straight-sided glabella with poorly impressed transverse furrow, well impressed preglabellar median furrow, small triangular basal lobes, truncated glabellar rear, elongate pygidial medial node, accessory furrows not meeting posteriorly, wide border furrow, and distinct marginal spines.

Features not fully in accord with *Ps.* (*Sulcatagnostus*) are the apparent lack (it is not clear if the border is entire at this point and the mid posterior spine might be an external feature anyway) of the third pygidial (mid posterior) spine and posterior position of marginal spines. *Ps.* (*Sulcatagnostus*) *rugosus* Ergaliev, 1980 also lacks the third pygidial marginal spine. As Shergold (1977) pointed out this form is closely allied to the *Ps. cyclopyge* Group of *Pseudagnostus* and Ergaliev's Kazakh species and this Tasmanian form could well belong to *Ps. idalis* if the mid posterior spine is considered subgenerically critical. However, the scrobiculate cranidium seems a distinctive feature of these 3 forms giving a basis for distinction.

### **Rhaptagnostus** Whitehouse, 1936

Type Species

*Agnostus cyclopygeformis* Sun, 1924 from the

FIG. 3. A–F, *Rhaptagnostus mji* sp. nov. from Loc. 9. A,B, internal moulds of complete specimens (A is holotype) GST14367, 14368, x8 and x5, respectively. C, latex cast of complete specimen GST14369, x9. D,E, internal moulds of pygidia GST14370, 14371, x9. F, latex cast of small complete specimen GST14372, x12. G–I, *Lotagnostus tullahensis* sp. nov. from Loc. 9. G,H, latex casts of small complete specimens GST14373, 14374, x12. I, latex cast of larger articulated holotype GST14375, x10. J,K, *Pseudagnostus (Sulcatagnostus)* sp. from Loc. 7. J, internal mould of cranidium GST14376, x9. K, internal mould of articulated specimen GST14377, x9. L, Pseudagnostid indet. interna l mould of cranidium and first thoracic segment from Loc. 7, GST14378, x5. M, *Neoagnostus clavus* Shergold internal mould of cephalon and first thoracic segment from Loc. 8, GST14379, x8. N,O, *Rhaptagnostus convergens* Palmer, latex cast and internal mould of articulated specimen from Loc. 8, GST14380, x7.

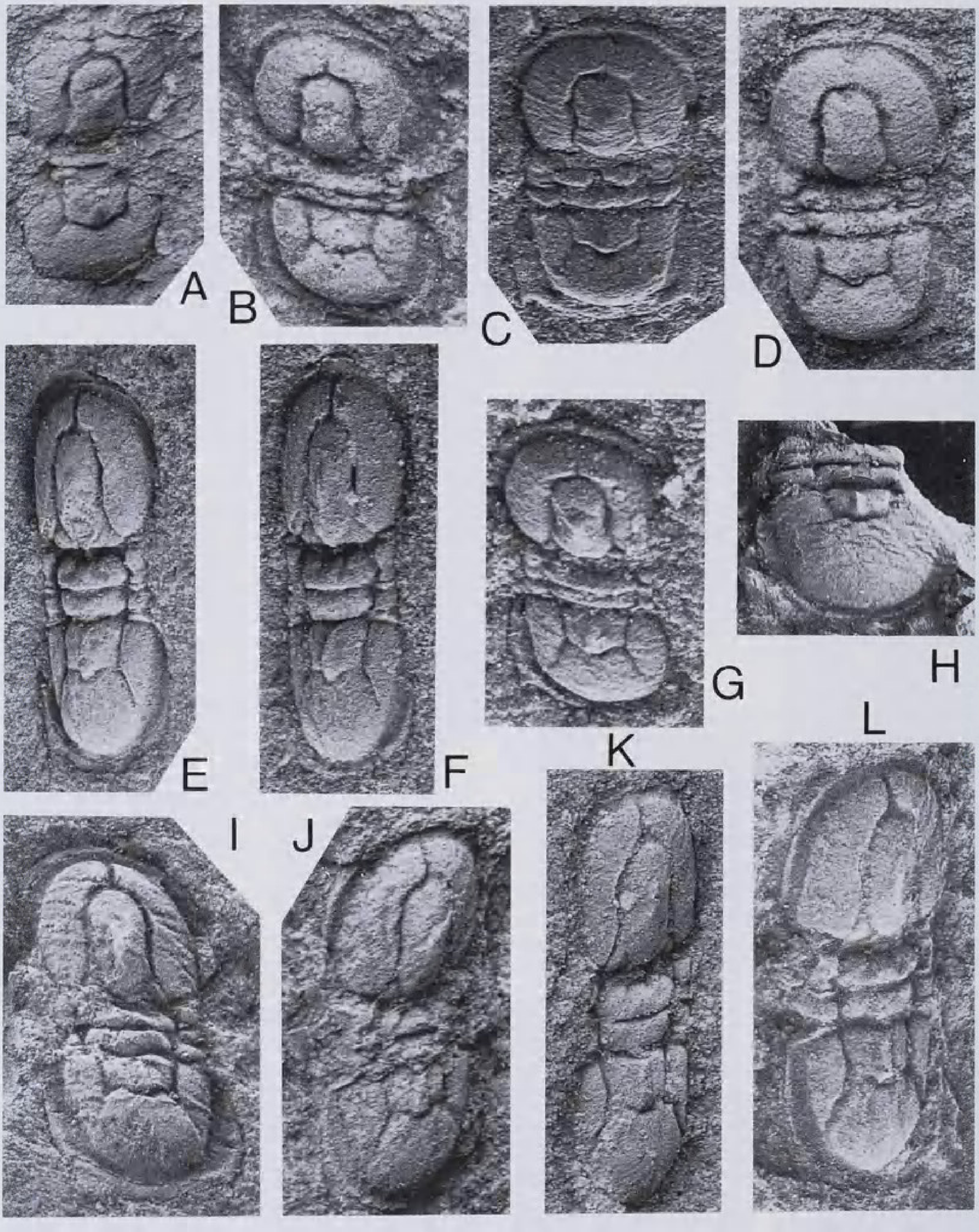



FIG. 4. *Pseudagnostus* sp. from Loc. 2. A, latex cast of articulated specimen GST14381, x8. B, G, internal mould and latex cast of articulated specimen GST14382, x10. C,D, latex cast and internal mould of articulated specimen GST14383, x10. E,F, internal mould and latex cast of articulated specimen GST14384, x10. H, internal mould of pygidium GST14385, x5. I, J, internal moulds of articulated specimens GST14386 and 14387, x6 and x8, respectively. K, L, latex cast and internal mould of articulated specimen GST14388, x6.

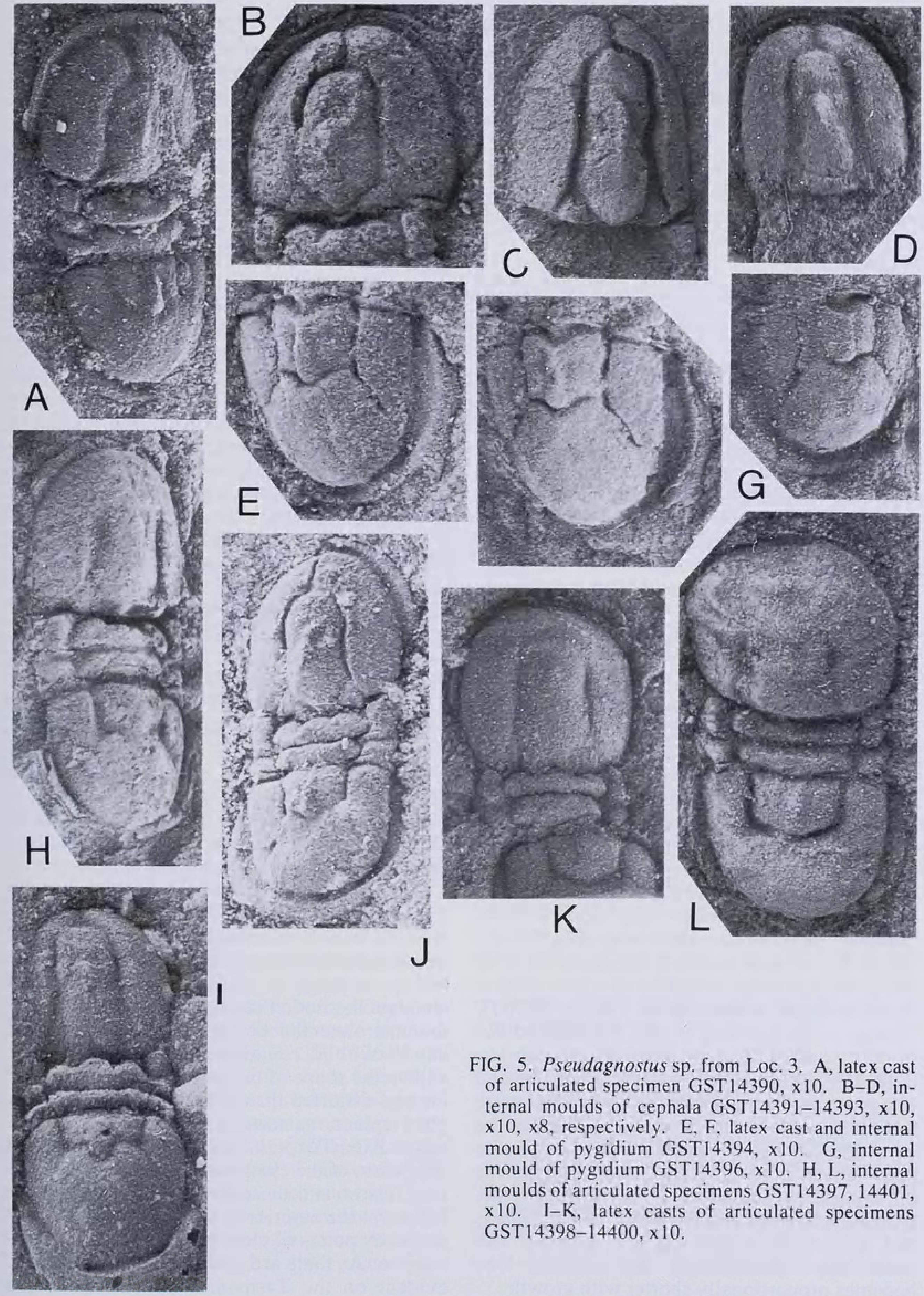



FIG. 5. *Pseudagnostus* sp. from Loc. 3. A, latex cast of articulated specimen GST14390, x10. B–D, internal moulds of cephala GST14391–14393, x10, x10, x8, respectively. E, F, latex cast and internal mould of pygidium GST14394, x10. G, internal mould of pygidium GST14396, x10. H, L, internal moulds of articulated specimens GST14397, 14401, x10. I–K, latex casts of articulated specimens GST14398–14400, x10.

Kaolishan Formation, Shandong by original designation.

**Rhaptagnostus mji** sp. nov.
(Figs 2D–F, K(left), 3A–F)

ETYMOLOGY
For M.J. Clarke, Geological Survey of Tasmania, who facilitated completion of this paper.

MATERIAL
Holotype GST14367 (Fig.3A) from Loc. 9. Paratypes GST14357, 14358, 14365 from Loc. 1 and GST14368–14372 from Loc. 9.

DIAGNOSIS
Glabella relatively narrow, short, anteriorly rounded, with angular posterior, with short anterior lobe isolated by transverse transglabellar furrow, with small anterolateral lobes separated by the elongate glabellar node and bounded posteroaxially by almost straight furrows running to the glabellar node. Basal lobes short, triangular. Borders narrow throughout (proportionally wider in juvenile pygidia), with pair of posterior marginal spines decreasing in size to almost nothing in largest specimens. Preglabellar median furrow and axial furrow well-impressed. Accessory furrows not impressed on pygidium, but terminal pygidial node present. Pygidial axis not segmented, with long prominent node extending almost to the articulating furrow and giving axis pentagonal shape as it extends posteriorly slightly beyond the extend of the axial furrows.

GROWTH
Several small (cephala about 0.7–0.9mm and a pygidium 0.5mm long) from Loc. 1 and a complete specimen 3.7mm long (Fig.3F) are referred to this species based on comparison with the growth series recorded for the related *Pseudagnostus communis* by Palmer (1955). Changes with growth are 1, the posterior border of the pygidium becomes progressively shorter; 2, the pygidial marginal spines become less and less prominent and their position becomes more and more anterior relative to the posterior of the acrolobe; 3, the accessory furrows on the pygidium are incomplete on the small specimens but disappear altogether with growth; 4, the glabella is straight-sided in the small specimens but develops slight bulges around the anterolateral lobes with growth; the anterior lobe becomes proportionally shorter with growth

DISCUSSION
Generic assignment is based on the position of the glabellar node between the anterolateral lobes, the loss of accessory lobes in the pygidium and pygidial shape with tiny marginal spines well forward. There is distinct similarity with *Pseudagnostus communis*, particularly in the narrow border throughout, glabellar shape, and pygidial shape (Rasetti, 1961, pl.23, figs 15–17) with only a marginal difference in position of the glabellar node and remnant accessory furrows to separate them. The latter feature disappears with growth in the Tasmanian species but may still be a species discriminator. Separation from *R. leitchi* Webby et al., 1988 is difficult due to that species being sheared on the bedding plane. However, in the Tasmanian species the border is narrower and the anterior glabellar furrow is more transverse. It should be noted in passing that the 'raised, median axial bar' described by Webby et al. (1988:914), in the articulating furrow of the first thoracic segment is in fact the flange around the cephalothoracic aperture (Shergold et al., 1990, figs 3,4). *R. gunnari* Ludvigsen and Westrop in Ludvigsen et al., 1989 is a more effaced form with wider border furrows and pygidial border. *R. obsoletus* Lermontova, 1951 *R. bifax* Shergold, 1975 and *R. papilio* Shergold, 1972 are all effaced or semi-effaced.

**Rhaptagnostus convergens** (Palmer, 1955)
(Fig. 3N,O)

MATERIAL
GST14380, a complete specimen from Loc. 8.

DISCUSSION
Tectonic deformation has shortened and distorted the axial furrow so that glabellar shape is difficult to determine with certainty. Nevertheless, it definitely has a broad subangular anterior and lateral bulges at the anterolateral lobes with the glabellar node between the posterior half of the anterolateral lobes. These features align it closely with *R. convergens* (Palmer, 1955) and adding the shape of the pygidium (which seems far less distorted than the cephalon), tiny marginal spines, narrow borders throughout, and pygidial axial expression including the posterior projection of the elongate node intruding on the ring furrow and the definition of the first ring furrow at the anterior of the median node there are many points of close similarity with *R. convergens*. As there are no distinguishing features evident on the Tasmanian specimen we are

forced to make this specific assignment but we understand that future collecting may necessitate revision of this identification if degree of impression of axial and preglabellar furrows becomes specifically important. In our opinion these features are not specifically important and may vary due to postdepositional history also. The impression as to their depth given by photographs may be misleading due to different lighting arrangements. For example the type cephalon as presented by Palmer (1955, pl.19, fig.14) was photographed with very low angle light as witnessed by the deep shadow on the right of the specimen; in that lighting the furrows seem extremely shallow, while in Shergold, 1977 (pl.16, fig.1) vertical lighting suggests deeper axial and preglabellar furrows. The only feature that appears different is the size of the basal lobes, but it is not clear on the Tasmanian specimen just how much of the posterior of the cephalon is curved down into the junction between it and the thorax. We suggest that the posterior of the glabellar and the basal lobes are not fully exposed in our specimen.

**Pseudagnostids** indet.
(Figs 2C,J,L, 3L)

MATERIAL
GST14356 and 14362 from Loc. 1, GST14363 from Loc. 5, and GST14378 from Loc. 7.

DISCUSSION
These unidentifiable specimens are recorded because 1, GST14356 is the only effaced agnostoid among these collections and since effaced forms seem to dominate in contemporary platform carbonates of western Queensland (Shergold, 1972, 1975, 1980) it may prove significant that one specimen be recorded; 2, GST14362 is a whole specimen apparently with the accessory furrows of the pygidium fully enclosing the deuterolobe which is laterally bulbous towards the posterior; this feature is unknown in other agnostoids described herein; 3, GST14363 is the only agnostid in the collection from Locality 5 and although it could be assigned to the species from Loc. 2 this identification is not certain on this specimen alone; and 4, GST14378 is the only pseudagnostid from Loc. 7 and could also belong to the same taxon as occurs at Loc. 3 but requires better material for assignment. None of these specimens is well enough preserved to be described taxonomically but their occurrence needs to be recorded.

Order POLYMERA Jaekel, 1909
Suborder ASAPHINA Salter, 1864
Family CERATOPYGIDAE Linnarsson, 1869
Subfamily PROCERATOPYGINAE
Wallerius, 1895

**Proceratopyge** Wallerius, 1895

TYPE SPECIES
*Proceratopyge conifrons* Wallerius, 1895.

**Proceratopyge** sp. cf. **P. gordonensis** Jago, 1987
(Fig. 6)

*Proceratopyge gordonensis* Jago, 1987:222, pl. 26, figs 1-10; pl. 27, figs 1-8.

MATERIAL
Holotype UTGD88350a. Other material of this study GST14403, 14406, 14407 from Loc. 1, GST14408 from Loc 5, GST14404 from Loc. 7, GST14405 from Loc. 8, and GST14402 from Loc 9.

DISCUSSION
Jago (1987) described and discussed this species in considerable detail. Our specimens are tectonically deformed with considerable shortening (Fig.6B) in some and elongation (Fig.6D) in others. After accounting for this deformation the only distinction that could be drawn may be in the greater divergence of the anterior limbs of the facial suture, longer preglabellar length and more rounded glabellar anterior (in elongate specimens) in our material. These features are not sufficient for specific separation but at this stage the assignment is considered tentative until an objective assessment of all the species of *Proceratopyge* is carried out. The internal mould of a complete specimen (Fig. 6A) shows the median suture and numerous terrace lines on the doublure, which features were not evident on Jago's illustrations.

Subfamily IWAYASPIDINAE Kobayashi, 1962

**Cermatops** Shergold, 1980

TYPE SPECIES
*Cermatops vieta* Shergold (1980, p.87, pl.34, figs 3-11).

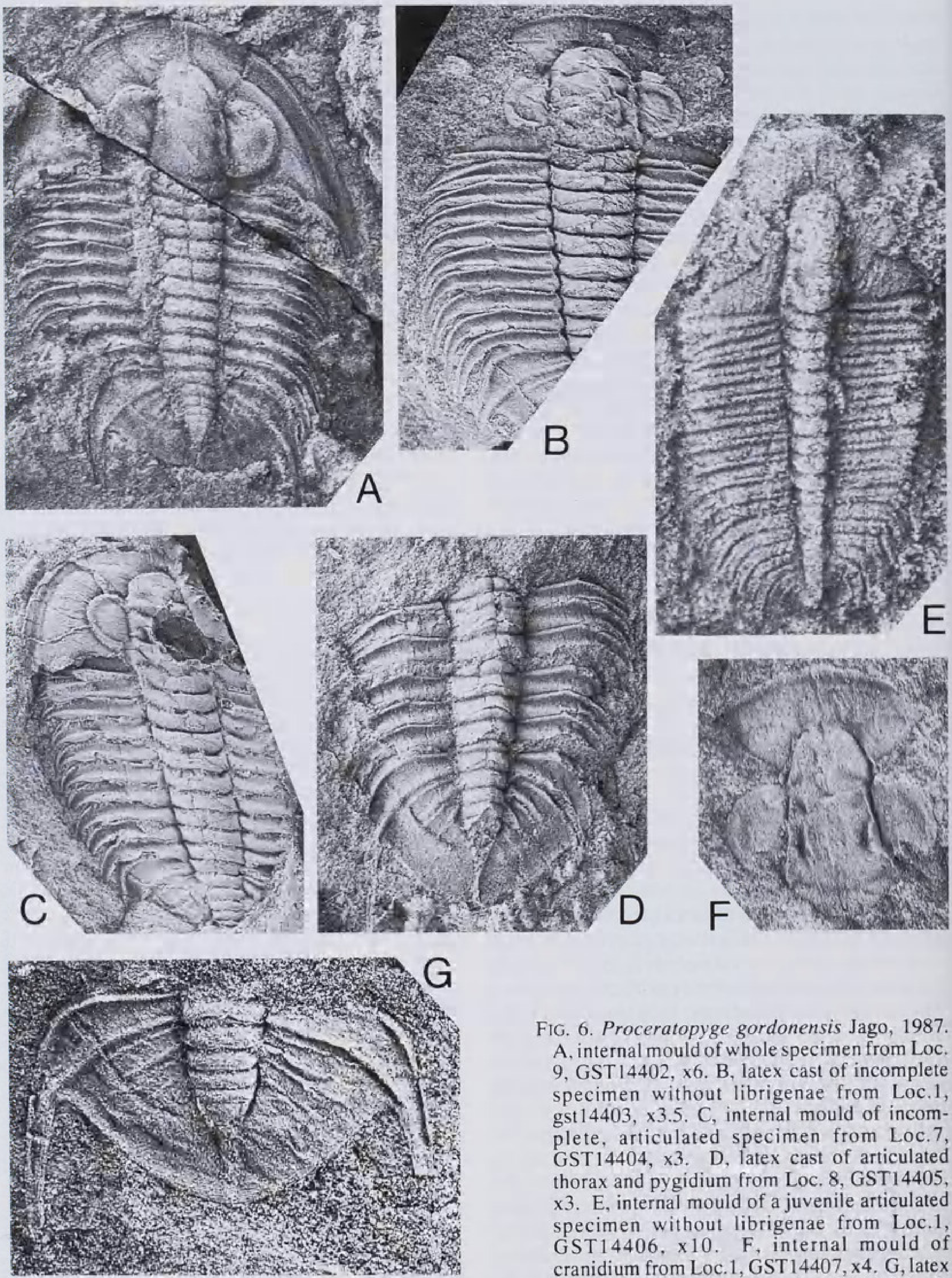



FIG. 6. *Proceratopyge gordonensis* Jago, 1987. A, internal mould of whole specimen from Loc. 9, GST14402, x6. B, latex cast of incomplete specimen without librigenae from Loc.1, gst14403, x3.5. C, internal mould of incomplete, articulated specimen from Loc.7, GST14404, x3. D, latex cast of articulated thorax and pygidium from Loc. 8, GST14405, x3. E, internal mould of a juvenile articulated specimen without librigenae from Loc.1, GST14406, x10. F, internal mould of cranidium from Loc.1, GST14407, x4. G, latex cast of pygidium from Loc. 5, GST14408, x5.

**Cermatops thalasta** sp. nov.
(Fig. 7)

ETYMOLOGY
Greek *thalao*, bruise, crush.

MATERIAL
Holotype GST14412 from Loc. 4. Paratypes GST14413–14416,14418 from Loc.4, GST 14417 from Loc.8 and GST14409–14411 from Loc. 9.

DIAGNOSIS
Glabella tapering forward; anterior margin evenly curved except for a slight medial projection and suggestion of narrow plectrum; frontal area long and concave; anterior limbs of facial suture diverging strongly forward; librigena with doublure more than half width, with median suture in doublure, and with short stout genal spine. Thorax of 10 segments. Pygidium with rounded anterolateral corners; propleural band extremely short and truncated laterally at or just beyond paradoublural line; doublural width c. 0.3 of pygidial width.

DESCRIPTION
Large (2 cm cranidial length, 2.5 cm pygidial length), smooth species of low convexity, with distinct furrows. Glabella tapering forward to rounded anterior, with crescentic almost exsagittal S1 (typically ceratopygid) and more anterior furrows unavailable. Occipital furrow shallow medially, with short deeper crescentic depressions laterally but isolated from axial furrow. Frontal area 0.25 cephalic length, concave; border not distinctly separated but a short marginal piece upturned, with small medial projection in margin and weak medial ridge running back to glabella. Palpebral lobe 1/2 cephalic length, flat, projecting strongly, and well rounded laterally. Posterolateral limb long, wide, with shallow border furrow near posterior margin. Facial suture with anterior section diverging forward at c. 45°–60° to exsagittal line, widest point close to margin, in middle section running in a broadly rounded curve (convex adaxially), interrupted only by the prominent palpebral lobe, leaving a narrow fixed cheek in the middle 1/3 of glabella.

Librigena with paradoublural line about halfway between eye and margin in transverse line through centre of eye; eye socle low; lateral margin weakly upturned but border not defined; genal spine stout, c. 1/2 length of cheek; doublure wide; sagittal medial suture anteriorly.

Thorax of 10 segments (Fig.7J) smaller specimen with 9 segments (Fig. 7K) interpreted as last meraspid. Pleural furrows well-impressed, running from anterior at axial furrow to midlength and deepening in articulating line, then shallowing on free pleura; pleural tips with retral curve, becoming more so on more posterior segments.

Pygidium semicircular except for well-rounded anterolateral corners; axis of 6 rings plus terminus, reaching just above border furrow, barely tapering, with rounded posterior indistinctly extended posteriorly in lower decreasing ridge. Pleural areas with well-impressed pleural and interpleural furrows proximally; propleural band extremely short and fading out at paradoublural line so that only ridge of the postpleural band extends out towards the margin. Border furrow broad, indistinct as concave trough. Doublure wide, 1/2 pleural width, with close spaced comarginal terrace lines.

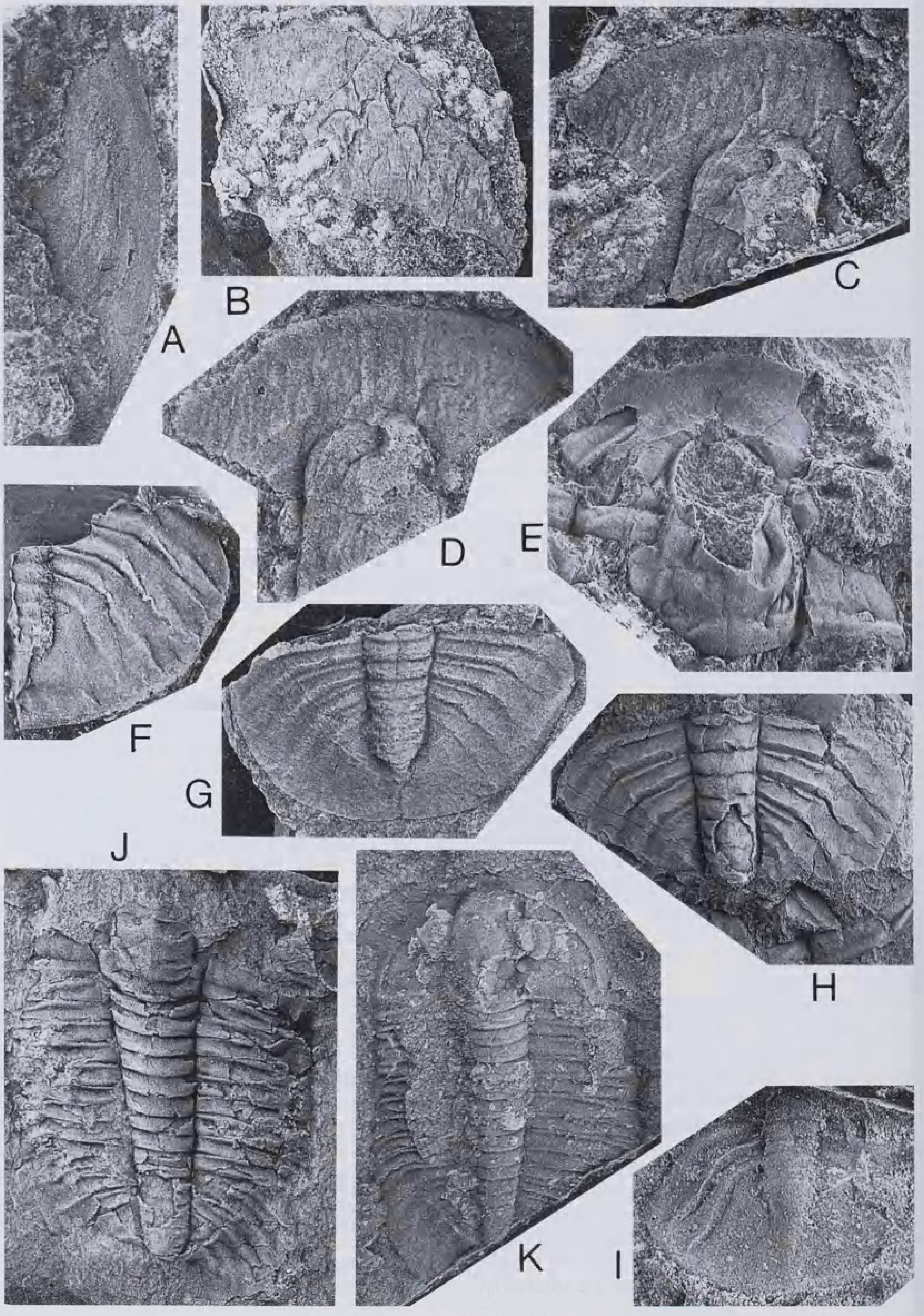
REMARKS
This species is known from a few fragmentary specimens, severely distorted by tectonism but the available features are enough to identify a new species. Generic assignment is based to large extent on the pygidium where comparison with *C. vieta* is extremely close. Only the greater taper of the axis and fewer axial rings distinguish that Queensland species. In the cephalon, the Tasmanian glabella is more rounded anteriorly, the course of the facial suture is different, the anterior margin has a slight forward projection, glabellar furrows are better impressed and the free cheek has a wider doublure and less prominent border furrow.

*C. discoidalis* (Salter, 1866) (Hughes & Rushton, 1990) is distinguished from the new species by the squared glabellar anterior (although a rounded anterior is possible (e.g. Hughes & Rushton, 1990, pl.1, fig.9) through tectonic distortion), larger palpebral lobes, short genal spine, and excavated posterior pygidial margin.

The two articulated thoraxes (Fig. 7J,K) with this type of pygidium, and with a ceratopygid cephalon, are assigned to this species on the pygidia but they do serve to confirm association of head and tail suggested by Shergold (1980) and Hughes & Rushton (1990) for this genus.

**Asiocephalus** Palmer, 1968

TYPE SPECIES
*Asiocephalus indigator* Palmer, 1968 from


A
B
C
D
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F
G
H
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I

Franconian strata in the Hillard Peak area of east central Alaska.

REMARKS

Although Apollonov and Chugaeva (1983) considered *Asiocepahlus* a subgenus of *Hedinaspis* Troedsson, 1951 we consider them generically separate, in light of new information from the Tasmanian species and in particular because of the larger pygidium with 5 or more axial rings.

Discovery of this species, which also occurs in Kazakhstan in older strata than other *Asiocephalus* or *Hedinaspis* indicates a possible intermediate between the Iwayaspidinae (e.g. *Cermatops*) and the *Hedinaspis* group, particularly in development of thoracic and pleural features. This lineage involves increasing numbers of thoracic segments and decreasing number of pygidial segments as well as specialization of thoracic segments. All of the changes are possible through *A. latosuggrundus*.

**Asiocephalus latosuggrundus** sp. nov.
(Fig. 8)

*Hedinaspis* (*Asiocephalus*) *sulcata* Lisogar; Apollonov & Chugaeva, 1983:83, pl.10, figs 2,3.

ETYMOLOGY

Latin *latus*, broad and *suggrunda* eaves; referring to the wide pygidial doublure.

MATERIAL

Holotype GST14419 from Loc. 1. Paratype GST14420 from Loc. 2.

DIAGNOSIS

Cephalic doublure narrow laterally, expanded anteromedially to be as long as frontal area; distinct eye ridges oblique posteriorly away from axis, running to small kidney-shaped palpebral lobes. Cephalic surface (except glabella) caecate. Thorax of 13 segments; each segment with short propleural band and long postpleural band; pleural tips curved posteriorly, more so posteriorly. Pygidium semicircular; axis of 6 rings plus terminus; pleural bands as on thoracic segments; doublure wide (nearly 0.25 pygidial width at widest), with prominent comarginal terrace lines.

DESCRIPTION

Subisopygous, gently convex. Cephalon semicircular, with prominent fine caecal network except on glabella; major caecum running posterolaterally from eye on librigena has distinct angle in it about halfway across genal field. Glabella subparallel sided, with rounded anterior; S1 crescent shaped, S2 almost continuous over axis but separated by high area bearing the preoccipital node; S0 with deep lateral depression isolated from the axial furrow. Frontal area long, gently concave, with faintest suggestion of a plectrum; border short, upturned, poorly defined. Palpebral lobe short, at level of S2 and S3, kidney-shaped, elevated, defined by well-impressed palpebral furrow, connected to glabella via distinct eye ridge sloping forward to axial furrow. Facial suture diverging forward in pre-ocular part, curving gently adaxially towards margin; in central portion running in a wide curve, except where interupted by palpebral lobe, leaving narrow fixigena; postocular part running in sigmoidal curve to posterior margin anterior to a long wide posterolateral limb. Posterior border short, gently raised, uniform. Librigena with low eye socle, wide convex genal field and narrow border defined by shallow but distinct border furrow; genal spine c. 0.4 of cheek length to genal angle. Internal mould showing doublure on cephalon covered with prominent comarginal terrace lines; anteriorly doublure expands in length to be as long as frontal area medially, indicating a median suture and presumably conterminent hypostome. Although the hypostome is preserved beneath the glabella it is dislodged posteriorly away from the glabellar anterior and the only comment possible is its length of 60% of cranidial length.

Thorax of 13 segments; articulating halfring extremely short providing virtually no angle for enrollment. Pleurae with extremely short propleural band and extremely long gently rising

FIG. 7. *Cermatops thalastus* sp. nov. A–D from Loc. 9; E–I, K from Loc. 4; J from Loc. 8. A, internal mould of librigena, GST14409, x5. B, latex cast of large librigena with a thoracic segment preserved beneath and pressed through the exoskeleton GST14410, x2. C, D, latex cast and internal mould of anterior cranidial fragment GST14411, x2.5. E, internal mould of damaged cranidium GST14412, x2. F, latex cast of pygidial fragment GST14413, x3. G, internal mould of pygidium GST14414, x3. H, internal mould of damaged pygidium GST14415, x2. I, latex cast of juvenile pygidium GST14416, x6. J, latex cast of incomplete articulated specimen GST14417, x4. K, latex cast of incomplete articulated specimen GST14418, x3.

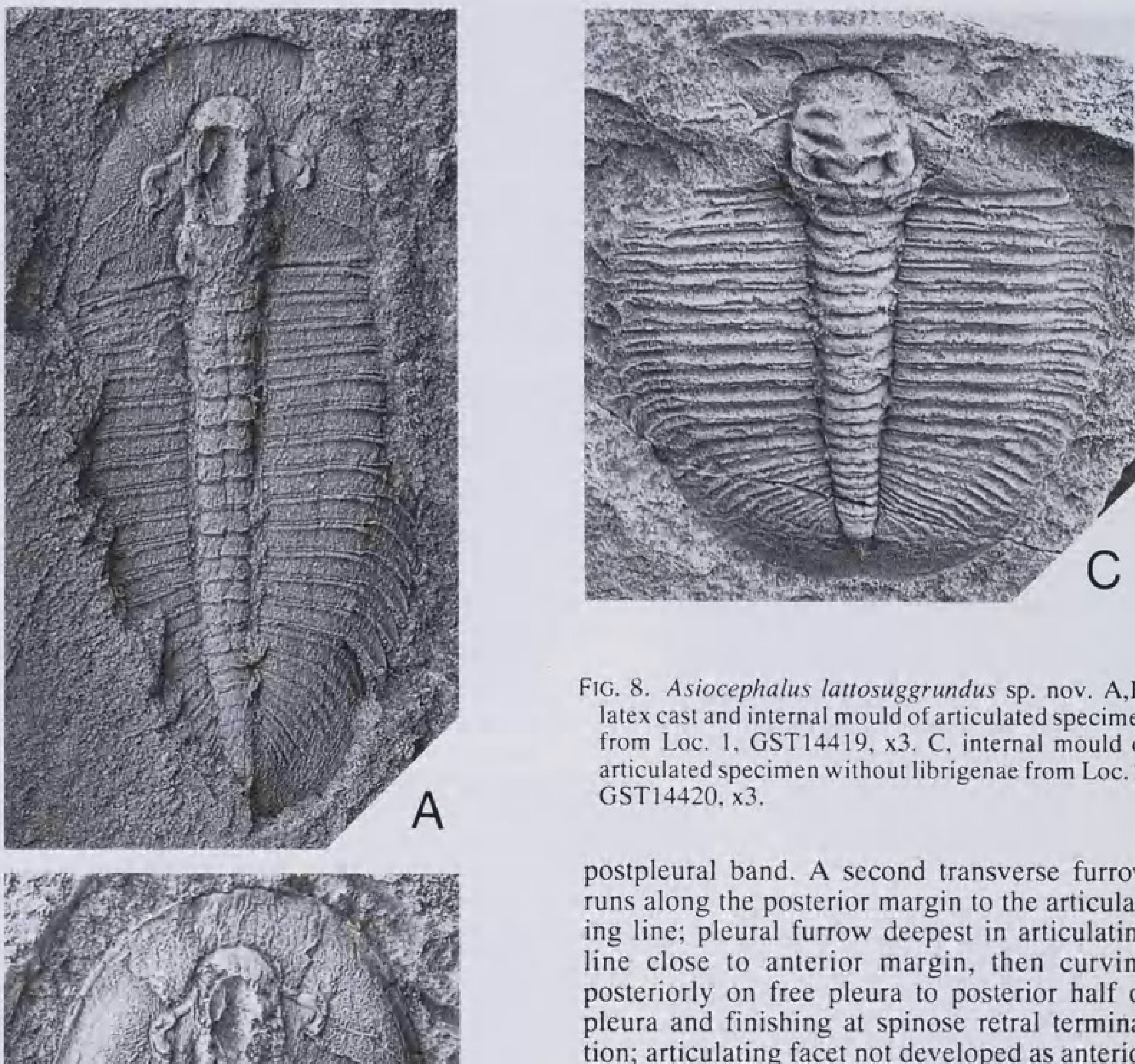


FIG. 8. *Asiocephalus lattosuggrundus* sp. nov. A,B, latex cast and internal mould of articulated specimen from Loc. 1, GST14419, x3. C, internal mould of articulated specimen without librigenae from Loc. 2, GST14420, x3.

postpleural band. A second transverse furrow runs along the posterior margin to the articulating line; pleural furrow deepest in articulating line close to anterior margin, then curving posteriorly on free pleura to posterior half of pleura and finishing at spinose retral termination; articulating facet not developed as anterior part of free pleura is raised and bears 4-6 fine but distinct ridges parallel to the anterior margin. Exsagittal terrace lines on doublure of free pleurae.

Pygidium semicircular, with axis of 6 rings plus terminus and low postaxial ridge running into posterior border furrow. Pleural area of 6-7 segments each with pleural, interpleural and posterior marginal furrows extending to paradoublural line then petering out distally before reaching margin. Anterolateral corner rounded, with small downsloping articulating facet. Border furrow wide and shallow; border narrow, poorly defined. Doublure wide, bearing prominent comarginal terrace lines.

REMARKS

The two articulated specimens are distorted in opposite directions so making it difficult to be certain of original dimensions.

Generic assigment is based on the large multisegmented pygidium, along with cephalic features of the *Hedinaspis* Troeddson, 1951–*Asiocephalus* group. This is essentially the differential diagnosis given by Palmer (1968:83). The Alaskan type species is distinguished by its shorter wider frontal area, transverse eye ridges, well-impressed occipital furrow, more prominent preocciptal node and narrower pygidial doublure. *A. sulcata* Lisogor,1970 is difficult to interpret because, two cranidia assigned there (Apollonov & Chugaeva, 1983, pl.10, figs 2,3) are identical with the Tasmanian species and are distinct from the cranidium of similar size figured earlier by Lisogor (1977, pl.30, fig.22) which represents *sulcata* as originally proposed (Lisogor, 1970). Therefore, we remove those two cranidia to our new species. The attitude of the eye ridges is distinctive in available material. Although adult pygidia associated with the known heads are not available we anticipate that they will have 6 or more axial rings and a wide doublure.

Family OLENIDAE Burmeister, 1843

**Olenus** Dalman, 1827

Type Species

*Entomostracites gibbosus* Wahlenberg, 1821.

**Olenus apoxysomatus** sp. nov.
(Fig. 9)

Etymology

Greek *apoxys*, tapering; *somatos*, body; referring to strongly tapering thoracic pleurae (less spine) posteriorly through thorax.

Material

Holotype GST14427 from Loc. 1. Paratypes GST14421, 14423, 14425, 14428, from Loc. 1, and GST14422, 14424, 14426, 14429–14431 from Loc. 7.

Diagnosis

Moderately sized palpebral lobe; genal spine continuous with lateral margin; inner spine angle right angled. Thoracic of 20 segments, with axial spines, with long pleural spines becoming gradually longer to about segment 12 corresponding to a narrowing of the pleurae. Pygidium extremely small, transverse.

Description

Largest available cranidium with basal glabellar width of 4 mm. Exoskeleton flat, except for raised convex axis and tall axial spines standing above it. Entire surface smooth.

Cranidium about as wide across palpebral lobes as long, gently convex but with anterior of glabella descending steeply. Glabella parallel sided to extremely gently tapering with bluntly rounded anterior. S1 deep, chevron shaped, not continuous across axis, at slightly lower angle to axial furrow than S2 which is more transverse, as wide as S1; S3 narrower, still more transverse, not reaching axial furrow. L0 of uniform length, with short geniculate median spine. Preglabellar field short (c. 20% of basal glabellar width); anterior border flat to gently convex near margin, strongly upturned, slightly elongate medially. Palpebral lobes of moderate length (c. 40% of basal glabellar width), elevated, kidney-shaped, convex, defined by shallow palpebral furrow situated only half glabellar width from glabella; eye ridge distinct, transverse, running laterally from axial furrow at level of S3. Preocular facial suture exsagittal, straight to gently convex laterally, curving adaxially near border to traverse border at extremely low angle and cross the margin near the midline; postocular suture running posterolaterally at c. 45% in slight curve to define a large triangular posterolateral limb. Posterior border furrow deep and short; posterior border short, convex, with sinuous curve to posterior in articulating line (i.e. exsagittally behind the eye), then gentle curve forward distally.

Librigenae yoked, with low eye socle, wide genal field bearing well-developed caecal network; border furrow well- impressed just inside the inner edge of doublure; border narrow, flat to gently convex near margin, upturned; doublure with distinct terrace lines, elongate anteromedially over a glabellar width; genal spine slightly advanced, almost maintaining curve of margin, just directed a little laterally, 1.5 times length of rest of librigena, with border furrow extending a little way down dorsal surface of spine; angle between genal spine and posterior border 90–100°; facial suture reaching posterior margin a considerable distance from the genal spine.

Thorax of 20 segments; each axial ring with prominent geniculate median spine. Pleurae narrow, each about as wide as axis, becoming markedly narrower to posterior; pleural spine long, longer than pleura of same segment, becoming progressively longer back to about segment 12, then progressively shorter to posterior, emanating from propleural band; well-impressed pleural furrow near anterior of segment throughout, running onto base of the spine laterally. Articulating facet short, wide.

Pygidium tiny, transverse, with indistinctly segmented axis reaching posterior margin, no segmentation on pleurae, no border defined.

REMARKS

This species is most simply distinguished by the strong taper of the thorax of 20 segments. Perhaps most similar is *O. attenuatus* (Boeck) (Westergård, 1922, pl.4, figs 15-19, pl.5, figs 1-9) which has 15 or 16 thoracic segments, spinose pleural tips and almost identical cephalon but that species has a relatively large pygidium. *O. wahlenbergi* Westergård, 1922 is similarly distinguished.

Librigenae are interpreted as being yoked (Fig.9G) although one specimen (Fig.9E,F) suggests a median furrow. This is not the case though, because the fracture is to the right of the elongate part of the doublure indicating that it is not symmetrical.

**Chekiangaspis** Lu in Chien, 1961

TYPE SPECIES

*Chekiangaspis chekiangensis* Lu in Chien, 1961 from the Late Cambrian, Sandu Shale, Yangiawen, Guizhou.

REMARKS

Lu (in Chien, 1961) likened this genus to *Olenus* Dalman and *Leptoplastus* Angelin so it is difficult to understand why it was referred to the Agraulidae unless because of his comparison with *Acrocephalina*. However, that genus was originally and subsequently placed in the Solenopleuridae. We agree with the comparison with the olenid genera mentioned and also with *Parabolina*. It differs from these genera principally in containing forms with diverging preocular facial sutures curving strongly across border area (Lu & Lin, 1989). Distinctive features of *Chekiangaspis* are found in various olenid species of Scandinavia, such as the long occipital spine in *Parabolina mobergi* Westergård, 1922, *P. megalops* Moberg & Moller, 1898 (Westergård, 1944); the advanced genal spine of most species of *Leptoplastus*; the excavated anterior margin as in *L. norvegicus* Holtedahl, 1910 or *L. ovatus* Angelin (Westergård, 1922, pl.8, fig.18); the triangular pygidium of many *Leptoplastus*; and the 12 thoracic segments of most of these olenid genera. However, no other olenid has the combination of features exhibitied by *Chekiangaspis*. Assignment of the Tasmanian species extends its distribution considerably and although this species cannot be considered truly typical because it lacks the furrows running forward from anterolateral corners of glabella its correspondence in all other features makes this slight extension of the generic concept necessary.

**Chekiangaspis concavus** sp. nov.
(Fig. 10)

ETYMOLOGY

Latin *concavus*, arched concave; referring to anterior margin.

MATERIAL

Holotype GST14432; paratypes GST14433–14437 all from Loc. 5.

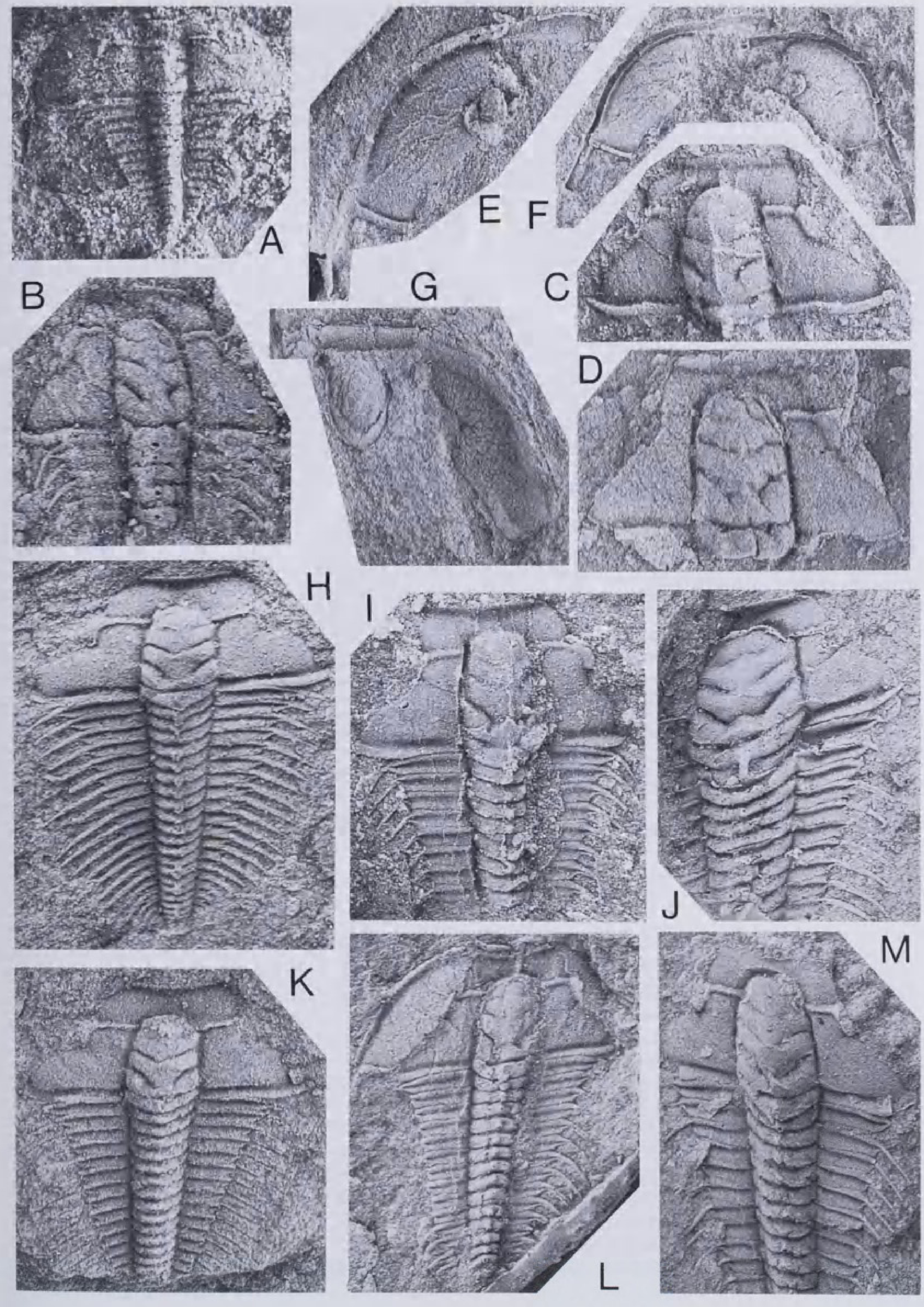
DIAGNOSIS

Pair of broad shallow depressions rather than distinct furrow running forward from anterolateral corners of glabella to anterior margin. Anterior margin of cephalon strongly concave, posterolateral limb wide and short. Short palpebral lobe opposite S2. Thorax of 12 segments, each with median tubercle and 8th segment bearing long subhorizontal spine extending well beyond posterior of pygidium; pleural tips truncated, nonspinose. Pygidium subtriangular, transverse, with 3 axial rings plus terminus that reaches close to posterior margin.

DESCRIPTION

Moderately sized, wide, strongly convex in

FIG. 9. *Olenus apoxysomatus* sp. nov. A, C, E, F, H, I, K from Loc. 1; B, D, G, J, L, M from Loc. 7. A, internal mould of articulated juvenile specimen GST14421, x10. B–D, latex casts of series of of small cranidium of increasing size GST14422, 14423, 14424, x7, x6, x6, respectively. E, F, latex cast and internal mould of librigenae GST14425, x6 and x5, respectively. G, internal mould of hypostome and rostral plate and external mould of librigena GST14426, x8. H, K, latex cast and internal mould of articulated holotype without librigenae GST14427, x9. I,J,L,M, latex casts of articulated specimens GST14428–14431, x5, x5, x7, x4, respectively.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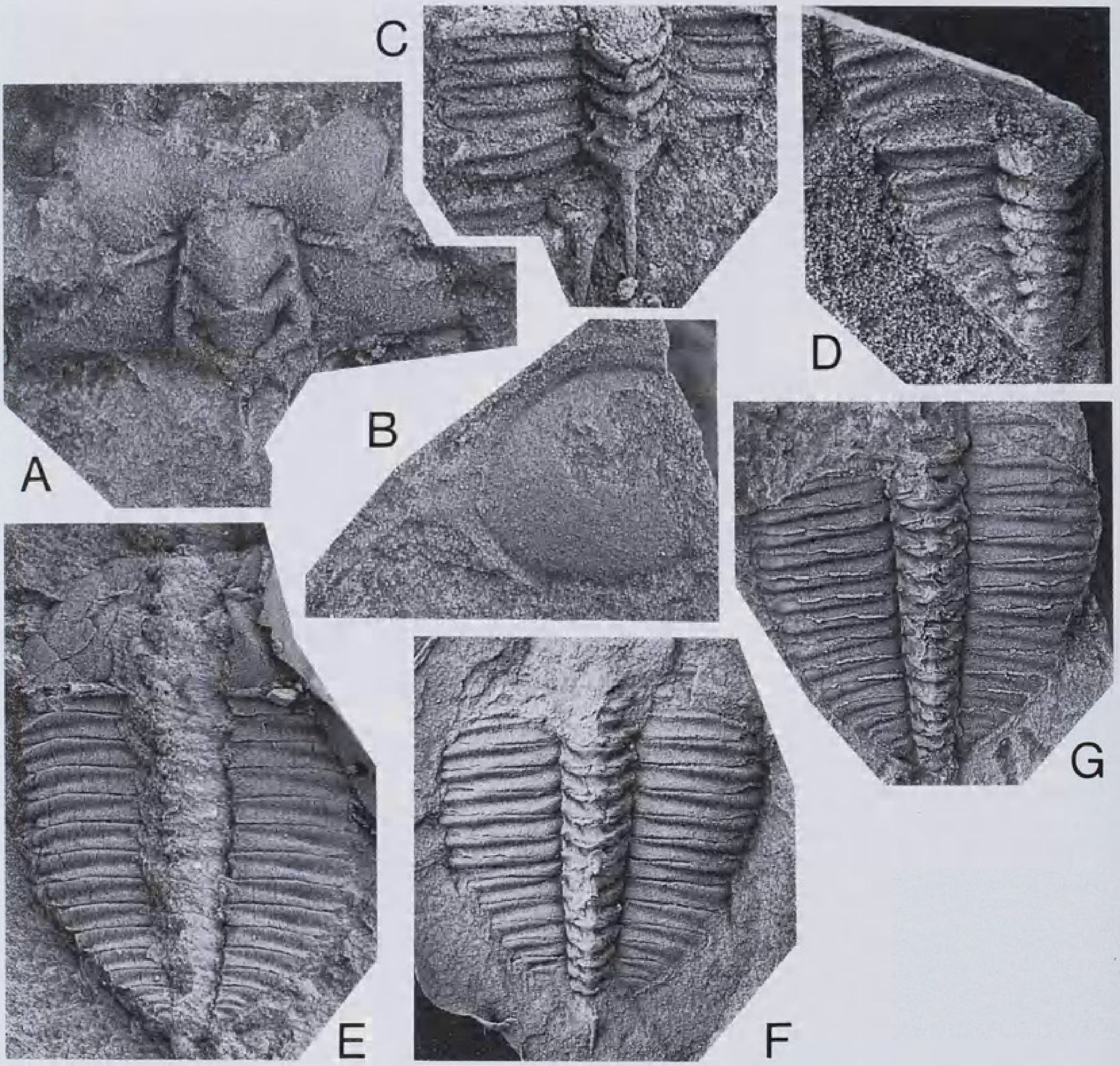



FIG. 10. *Chekiangaspis concavus* sp. nov. from Loc. 5. A, damaged internal mould of holotype cranidium GST14432, x5. B, internal mould of damaged librigena GST14433, x5. C, latex cast of thoracic fragment GST14434, x6. D, internal cast of damaged pygidium and thoracic rear GST14435, x6. E, latex cast of damaged articulated specimen GST14436, x4. F,G, latex cast and internal mould of articulated thorax and pygidium GST14437, x3.

anterior profile; axis with near vertical median spine stands above gently convex pleural areas. Cranidium wider across eyes than long. Glabella occupying large part of cranidium, straight to gently convex sides tapering gently forward to truncated anterior, with subangular corners; 3 pairs of lateral furrow, all discontinuous across axis and S3 barely more than a pit isolated from axial furrow. S0 well-impressed, longer and deeper laterally; occipital ring with long median spine more than half glabellar length. Frontal area 16-20% of cephalic length, with flat anteriorly descending preglabellar field leading to border furrow; border strongly upturned, longest medially; anterior margin concave, markedly so in one specimen (Fig. 10A). Palpebral lobe short, raised, oblique, opposite S2 on glabella; eye line distinct, leaving axial furrow forward of S3, running obliquely back to palpebral lobe; interocular cheeks 1/3 basal glabellar width. Preocular parts of facial suture diverging forward, convex laterally, curving adaxially anteriorly in broad arc; postocular section of facial suture concave just behind eye then running laterally at low angle to transverse and swinging sharply to margin distally to isolate large, wide posterolateral limb. Posterior border furrow well-impressed, shallowing distally; posterior border short, transverse to articulating line behind eye then curving sinuously back and forward in broad curve to facial suture. Surface of frontal area and fixed cheek with caecal network. Librigena wide, with advanced stout genal spine tapering strongly and extending laterally to disturb curve of margin.

Thorax of 12 segments, of uniform width to about 8th segment then tapering back; axial rings with short halfring but long articulating furrow, with short vertical median spine on each of first 7 segments, large geniculate spine on 8th extending back well beyond rear of pygidium and prominent tubercle on suceeding segments. Pleurae wide, with only 12th pleura equal to width of axis, anterior and posterior margins parallel throughout but extremity of segments 1-8 swung forward. Pleural furrow sharply impresssed, running diagonally across pleura. Articulating facet wide and short. Pleural tips truncated, together forming smooth lateral margin.

Pygidium transverse to elongate triangular, with 3 axial segments and terminus reaching posterior margin; pleural areas poorly segmented; border indistinct; doublure narrow.

Remarks

This species is distinguished from *C. chekiangensis* by its lack of distinct furrows forward from the glabella, more divergent preocular facial sutures and wider posterolateral limbs. The few specimens available make complete understanding uncertain but sufficient to make generic assignment and identify a new species.

### **Wujiajiania** Lu & Lin, 1980

Type Species

*Wujiajiania expansa* Lu & Lin, 1980 from the Siyangshan Formation, late Changshanian - early Fengshanian, in western Zhejiang.

Remarks

This genus was distinguished from *Westergaardites* Troedsson, 1937 by its 16 rather than 19 thoracic segments, its narrower axis, and lack of marginal pygidial spines (Lu & Lin, 1989). The Tasmanian species fits with *Wujiajiania* on these features except for the number of thoracic segments which is closer to *Wujiajiania* than *Westergaardites*. In all respects, the Tasmanian *W. distorta* sp. nov. may be considered ancestral to *W. expansa* Lu & Lin, 1980 which in turn may be considered ancestral to *Westergaardites*. An ancestor for *W. distorta* is probably to be found within *Parabolina* where 12 thoracic segments is standard. This lineage may, therefore, be seen as being accompanied by an increase in number of thoracic segments. Cephalic features of the Tasmanian species are indistinguishable from those of *W. expansa* and so the diagnosis of *Wujiajiania* is amended to include a range in the number of thoracic segments.

### **Wujiajiania distorta** sp. nov.
(Figs 11,12)

Etymology

Latin *distorta*, misshapen, deformed; referring to the ubiquitous tectonic deformation.

Material

Holotype GST14442 from Loc. 9. Paratypes GST14440 from Loc. 2, GST14438, 14441, 14443, 14456 from Loc. 3, and GST14439, 14444–14455, 14457–14459 from Loc. 9.

Diagnosis

Glabella wide, with convex lateral margins and broadly rounded anterior. Thorax of 13 segments. Pygidium transverse; axis of 3 rings plus terminus extending to gently excavated posterior margin.

Description

Exoskeleton gently convex in anterior view, up to 23 mm long in available sample, with smooth surface. Cranidium occupied mainly by large glabella. Glabella slightly wider than long; lateral margins convex (almost parallel-sided in some smaller specimens but this may be due to tectonic distortion), greatest width adjacent to lateral end of S2, with broadly rounded to truncated anterior at border furrow; S0 well-impressed, transverse or curving forward laterally, S1 and S2 slit-like, chevron-shaped, continuous across axis, S3 slit-like, parallel to S2 but isolated from axial furrow and extremely shallow across axis; L0 longer laterally than medially, with prominent median tubercle. Anterior border uniformly short, upturned; anterior border furrow well-impressed. Prominent eye ridge running a short distance posterolaterally into short upturned curved palpebral lobe well-defined by palpebral furrow that extends axially behind eye line. Fixigena narrow anteriorly, widening behind palpebral lobe into triangular posterolateral limb. Facial suture diverging forward in short preocular section; postocular section running almost in a straight line posterolaterally at c.45° to exsagittal to posterior margin; posterior border angularly convex, with wide posterior facet beyond lateral articulating point which is less than the axial width away from axial furrow. Librigenae yoked by short doublure, with well-developed caecal network, low eye socle; border subrounded in section, with distinct comarginal terrace lines laterally; genal spine continuing lateral margin in exsagittal line, longer than cheek itself, with prominent longitudinal terrace lines dorsally and ventrally; narrow lateral and anterior doublure bearing terrace lines; facial suture meeting posterior margin well inside genal angle. Hypostome olenid, conterminent.

Thorax of 13 segments; axis extremely wide anteriorly, tapering strongly to posterior, with median spine on each segment situated near the anterior of ring and curving backwards as it rises; articulating halfring large, occupying half segmented length. Pleura with articulating line /3 pleural width from axial furrow; propleural band extremely short at axial furrow, longer at lateral articulating point then of uniform length behind long wide steeply sloping articulating facet, with posteriorly curving pleural spine; pleural furrow deeply impressed in articulating line in midlength of segment, running to lateral margin just behind pleural spine; postpleural band long at axial furrow tapering strongly to articulating line then of uniform length to tip.

Pygidium transverse; axis of 3 rings plus terminus reaching posterior margin medially at small distinct excavation in margin; pleural and interpleural furrows impressed; border furrow poorly defined, not depressed, poorly defining narrow border; doublure of moderate width, narrowing posteromedially, bearing distinct comarginal terrace lines; margin without spines.

REMARKS

This species is most simply distinguished from Chinese (Lu & Lin, 1989; Chien, 1961, Lin & Zhang in Zhu *et al.* 1979) by the number of thoracic segments. In the absence of articulated specimens, cranidia may be extremely difficult to separate if preserved in different matrix or if distorted after deposition. Only greater lateral inflation of the glabella and S4 in Chinese forms give a distinction but even these are not entirely reliable. Nevertheless, the number of thoracic segments, which is consistent through the 15 articulated Tasmanian individuals and through the available Chinese material is sufficient to distinguish species.

## Family PTEROCEPHALIIDAE Kobayashi, 1935

### **Aphelaspis** Resser, 1935

TYPE SPECIES

*Aphelaspis walcotti* Resser, 1938.

DISCUSSION

Palmer (1960, 1962, 1965), Henderson (1976); Shergold (1982), Jell in Powell et al. (1982) and Jago (1987) have commented on this genus.

### **Aphelaspis** sp.
(Fig. 13A–E)

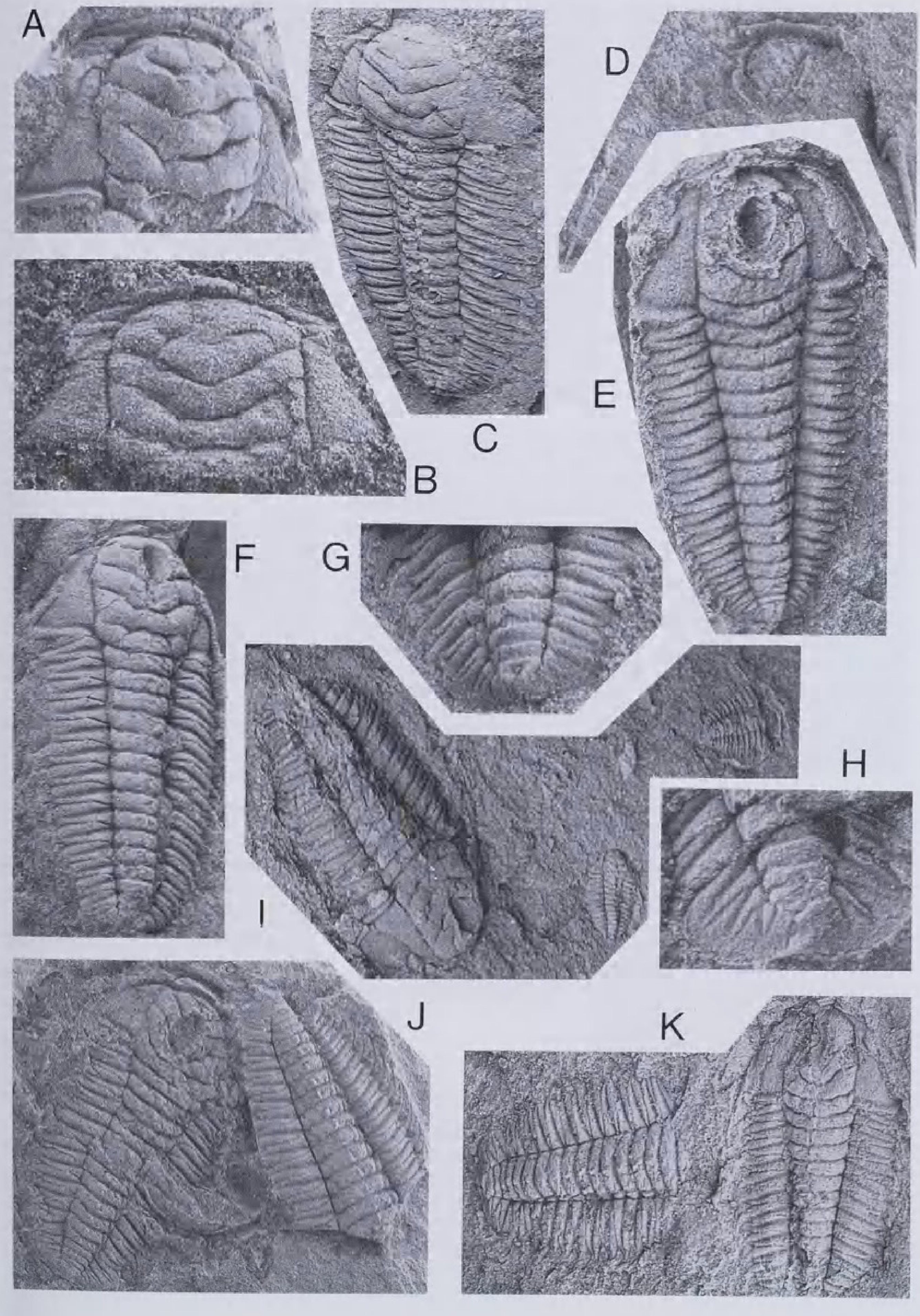
MATERIAL

GST14461, 14463 from Loc. 5, GST14461, 14462 from Loc. 9.

DESCRIPTION

Glabella with straight anteriorly converging sides, truncated anteriorly, angular anterolateral corners, without furrows. Preglabellar field convex, 15% of cranidial length. Anterior border, long, 19% of cranidial length, flat, tapering laterally. Palpebral lobes arcuate, long (30% of cephalic length), with their midlength opposite

FIG. 11. *Wujiajiania distortus* sp. nov. A, D, F from Loc. 3. B, E, G–K from Loc. 9. C from Loc. 2. A, B, internal moulds of cranidia GST14438 and 14439, x8. C, latex cast of articulated specimen GST14440, x3. D, latex cast of hypostome and ventral surface of rostral plate and genal spines GST14441, x10. E, internal mould of articulated holotype GST14442, x8. F, internal mould of articulated specimen GST14443, x6. G, internal mould of pygidium GST14444, x10. H, latex cast of pygidium GST14445, x10. I, latex cast of three articulated specimens of different sizes GST14446–14448, x3. J, internal mould of two articulated specimens GST14449 and 14450, x2.5. K, internal mould of two articulated specimens GST14451 and 14452, x2.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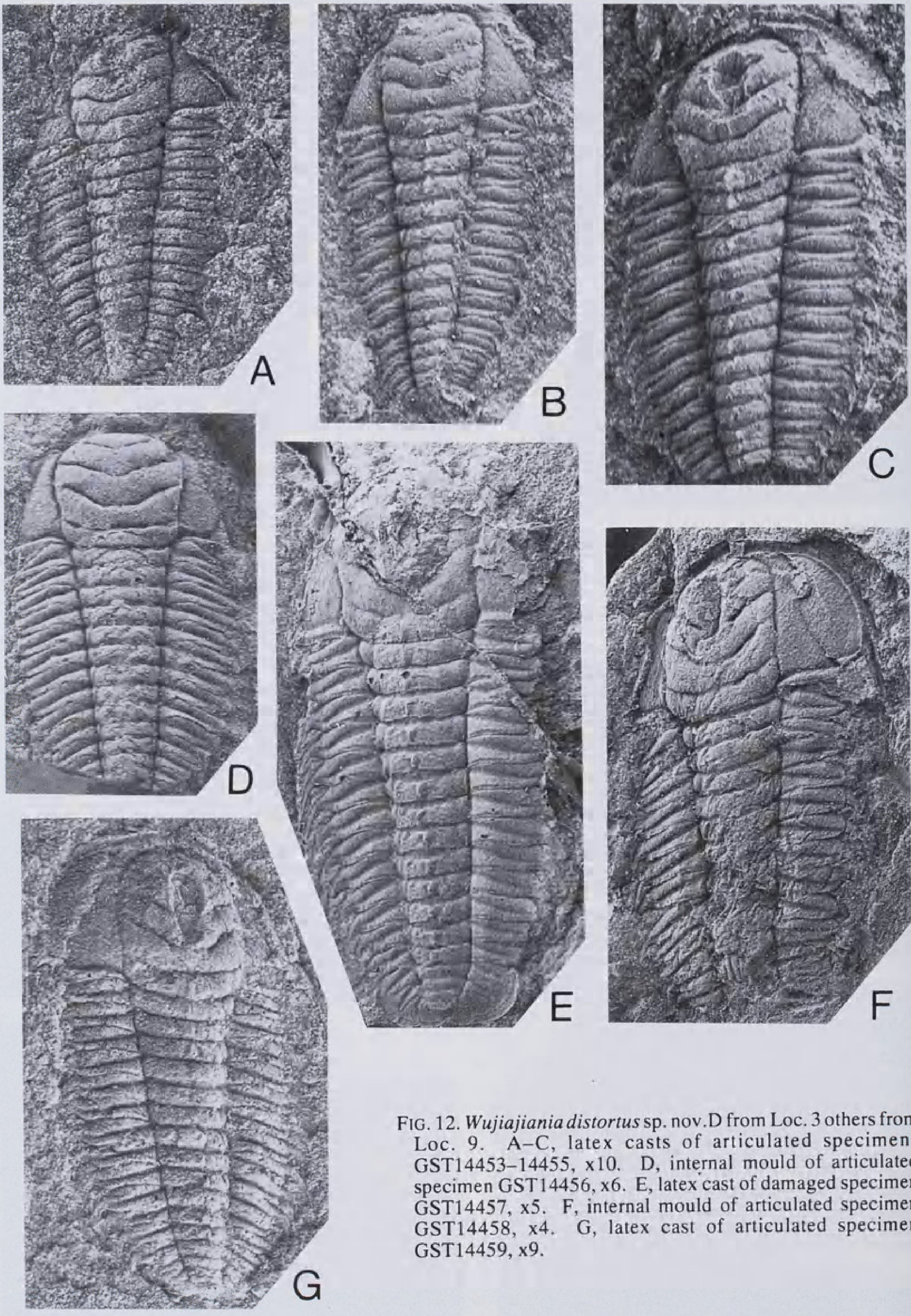


FIG. 12. *Wujiajiania distortus* sp. nov.D from Loc. 3 others from Loc. 9. A–C, latex casts of articulated specimens GST14453–14455, x10. D, internal mould of articulated specimen GST14456, x6. E, latex cast of damaged specimen GST14457, x5. F, internal mould of articulated specimen GST14458, x4. G, latex cast of articulated specimen GST14459, x9.

midlength of glabella, flattened on top but raised above interocular cheek. Facial suture with preocular part diverging strongly forward to midlength of border where it turns in a sharp angle to run at extremely low angle to margin; postocular part parallel to posterior margin for most of its course.

Librigena with distinct eye socle, wide genal field, moderately wide convex doublure, strong genal spine curving adaxially.

Pygidium small, transverse, highly convex; axis of 3 rings plus terminus that reaches excavated posterior margin. Three inflated pleural bands descending to margin almost vertically; doublure convex, narrow, almost vertical. In posterior profile margin strongly upswept over sagittal line.

Remarks

This rare species is not fully exhibited in available material but the unfurrowed, straight sided, tapering, trancated glabella, position and size of palpebral lobes and the anterior border are sufficient to allow generic assignment.

*Aphelaspis* has been identified in Australia as two named species *P. australis* Henderson, 1976 and *A. cantori* Jago, 1987. Jell (in Powell *et al.*, 1982) compared western NSW material to *A. australis* and Shergold (1982) referred 2 cranidia as well as shedding doubt on Opik's (1963) assignment of two cranidia to *Aphelaspis*. Each of these Australian taxa may be separated from the form described here by the long, flat, tapering anterior border of our specimens. It may be allied with North American species such as *A. haquei* Hall & Whitfield, 1877 (Palmer, 1965) but although that species could not be separated except on the pygidium, our available material is too poor to make specific assignment.

This taxon is similar to *Olentella* Ivshin, 1955 but at present no clear diagnoses exist to distinguish the two genera. *Olentella* occurs in Kazakhstan, northern Siberia and Antarctica (Shergold et al., 1976) in late Idamean and post-Idamean strata. The long flat anterior border, relatively longer palpebral lobes and course of the facial suture forward of the eye are the features we use to apply the generic name. Unless satisfactory discrimination can be achieved between *Aphelaspis, Olentella* and several other similar genera there may be no point in maintaining the separate names now being employed without clear diagnosis of any of them. In our opinion the best comparisons are made with species currently assigned to *Aphelaspis* although it is acknowledged that no species of that genus has a pygidium quite like the one attributed here. No species of *Olentella* has been attributed such a pygidium either but pygidia attributed to each of these genera are remarkably similar (cf. Palmer, 1965, pl.9, fig.21 and Shergold and Cooper, 1985, fig.6L).

Family CONOKEPHALINIDAE Hupé, 1953

**Conokephalinidae** indet.
(Fig. 13G–J)

Material

GST14465–14469 from Loc. 9.

Description

Large cranidium (Fig. 13H). Glabella pyriform, anteriorly truncated at border furrow but with rounded anterolateral corners; S1 running a short distance from axial furrow before bifurcating into barely visible transverse anterior branch and deep posterior branch apparently reaching occipital furrow at high angle to transverse; S2 narrower, well- impressed, curving slightly backwards adaxially. Anterior border convex, elongate posteriorly in medial section. Palpebral lobe long (2/3 glabella) and narrow, convex, arcuate, situated close to glabella; palpebral furrow deep and broad; interocular cheek narrow, inflated. Preocular facial suture diverging forward from anterior of palpebral lobe just lateral to axial furrow, curving adaxially across anterior border and almost parallel to margin for considerable distance.

Smaller cranidia (Fig. 13G,I,J). These two cranidia have more rectangular glabellae, glabellar furrows less distinct, anterior border not medially elongate, long geniculate occipital spine, and short wide posterolateral limb.

In the large cranidium a piece of exoskeleton probably a thoracic segment lies beneath the anterior of the glabella and has been pressed through the cranidium during compaction.

Remarks

These cranidia are assigned to one taxon on the basis of the palpebral lobe and long truncated glabella but their assignment is by no means certain with the few internal moulds available. It is taken into consideration that internal moulds show a different morphology from external surface and the concept of this taxon could be different when its exterior is known. Therefore,

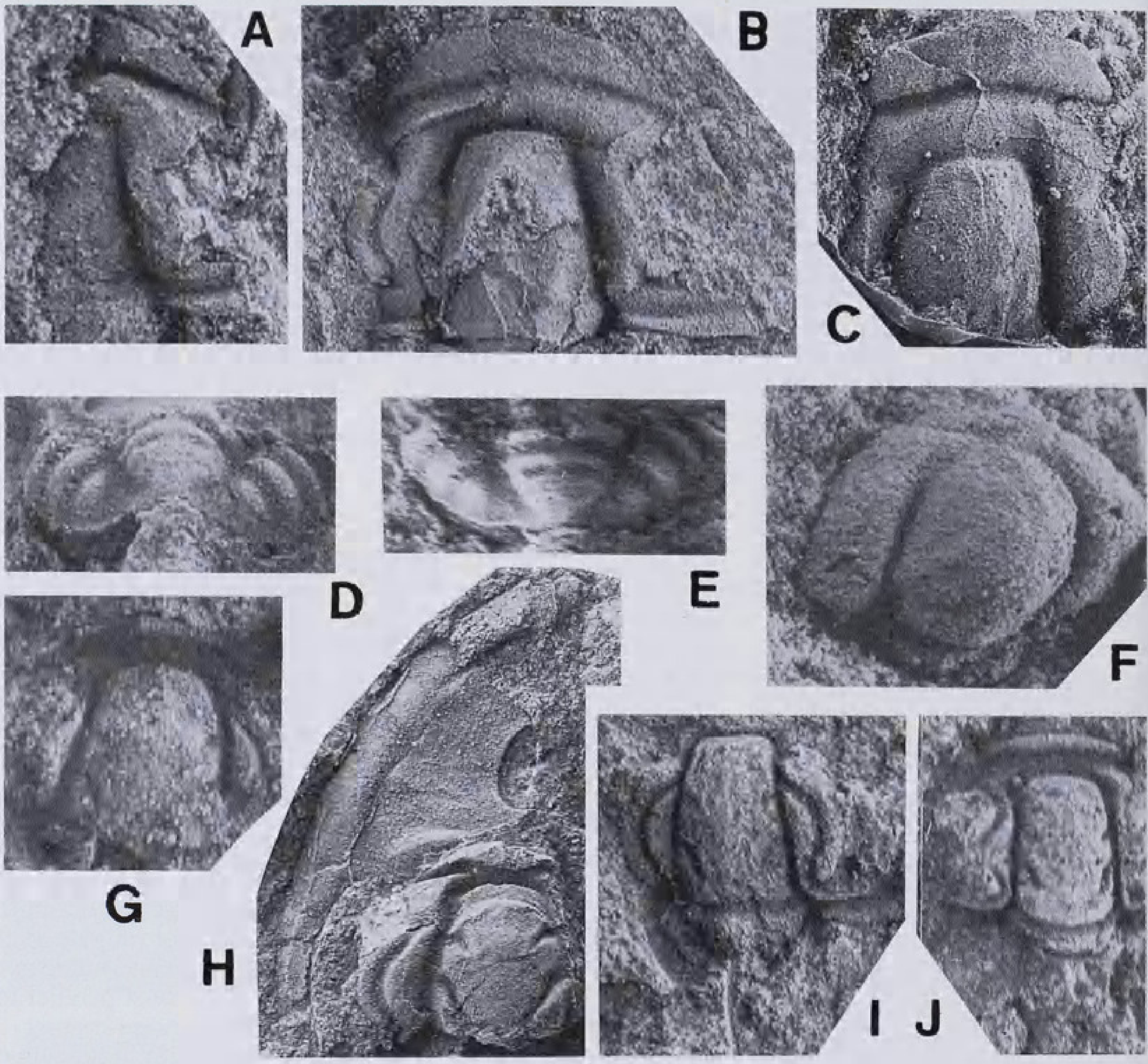

FIG. 13. A–E, *Aphelaspis* sp. A,C from Loc.9, B,D,E from Loc. 5. A–C, latex casts of cranidial fragments GST14460–14462, x6, x7 and x4, respectively. D,E, posterior and dorsal views of internal mould of pygidium GST14463, x10. F, *Aposolenopleura* sp. latex cast of distorted cranidium from Loc. 9, GST14464, x20. G–J, Conokephalinidae indet. all from Loc. 9. G,I,J, internal moulds of small cranidial fragments GST14465, 14468, 14469, x10. H, internal mould of larger cranidium and ventral surface of librigena GST14466, 14467, x3.

only features considered unlikely to be significantly different are used in this discussion.

Assignment is made to the Conokephalinidae on the basis of the pyriform glabella and palpebral structure. They may be compared to *Lobocephalina pyriceps* Öpik, 1967 from the early Late Cambrian of western Queensland but differ principally in the long occipital spine. Öpik (1967:247) considered this family and the Saukiidae as having common ancestry.

The laterally bulging glabella of this taxon (not apparent in juvenile specimens (Fig. 13I) but beginning to appear in others (Fig. 13J)) is evident in many Dikelocephaloidea and Remopleuroidea (Fortey & Chatterton, 1988 as well as Idahoiidae (Ludvigsen & Westrop, 1983, pl. 7, fig. 7 among others). If the librigena (Fig. 13H) with long forward extension of doublure is correctly assigned, a median furrow is a distinct possibility raising the question of whether or not one or more of the groups assigned to the Asaphida by Fortey (1990) may have had a separate origin via the Conokephalinidae. This suggestion would accommodate glabellar shape, palpebral structure in the transition to Remopleuroidea better than the suggested route via the Auritamidae Öpik, 1967 (Fortey & Chatterton, 1988) but the spinose pygidia of *Auritama* may have been more easily transformed into a kainellid pygidium. Certainly the long flat border, palpebral lobes well away from axis and more rounded straight sided glabella of *Auritama* speak against its possible ancestral position relative to Remopleuroidea and Dikelocephaloidea. In passing there seems no good reason to separate the Ryssometopoidea of Opik (1967) from the Conokephalinidae except perhaps in terms of rostral structure but this remains unclear for both groups.

The shape and depth of S1 suggest similarity with *Lorettina* Shergold, 1972 but preglabellar structure, glabellar shape and palpebral structure argue against a relationship.

Family Unassigned

**Aposolenopleura** Raymond, 1937

Type Species

*Aposolenopleura dunbari* Raymond, 1937 from the Gorge Formation at Highgate Falls, Vermont.

Discussion

The Chinese *Onchonotina* Lu, 1964 is here considered synonymous with *Aposolenopleura*, in particular because of the course of the facial suture across the anterior border being so oblique as to leave, on the cranidium, a border that is sharply pointed at each end and is little wider than the glabella.

**Aposolenopleura** sp.
(Fig. 13F)

Material

One incomplete external mould of a cephalon, GST14464 from Loc. 9.

Description

Highly convex cranidium with deep axial furrow; glabella anteriorly rounded, reaching border furrow; S1 shallow, oblique; S2, S3 etc not impressed; S0 well-impressed, transverse. Anterior border tapering laterally to be absent from cranidium before reaching facial suture; border furrow shallow, concave forward. Fixigena c.1/2 glabellar width. Palpebral lobe and other features unknown.

Remarks

The features of the anterior border furrow and border suggest *Aposolenopleura* but in the absence of better material it is not possible to make comparison with the North American species (Rasetti, 1944). Although several small Chinese genera have similar anterior borders (e.g. some *Solenoparia*, *Solenopleura*, *Trachoparia* and others (Lu et al., 1965)) none have it disappearing from the cranidium as in *Aposolenopleura*.

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