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Devonian trilobites from the Broken River region of northeastern Australia

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Abstract – The Broken River Group in northeastern Queensland has produced the first Middle Devonian trilobites from Australia. With the exception of an undetermined phacopid from Emsian shales, all faunas were recovered from earliest Eifelian through Givetian to ?earliest Frasnian shallow water bioclastic limestones and marlstones. The specifically determinable part of the material consists entirely of five new taxa: *Proetus* (*Devonoproetus*) *sparsinodosus* (Eifelian), *Proetus* (*Devonoproetus*) *latimargo* (Eifelian), *Burgesina mawsonae* (Eifelian), *Scutellum tenuistriatum* (Givetian) and *Phacops* (*Phacops*) *brocki* (Givetian) A new genus of proetine, *Burgesina*, with type species *B. mawsonae* n. sp. is proposed. Preliminary palaeogeographical comparisons suggest only weak linkages with typical North Gondwanan faunas from Bohemia, southwestern Europe and North Africa. By contrast, the trilobites from the Broken River region are closely related to faunas from Inner Mongolia.

INTRODUCTION

Middle Devonian trilobites have not previously recorded from Australia. The youngest previously recorded were from the Taemas Group of southeastern New South Wales (Chatterton 1971); these are no younger than mid-Emsian, appoximately *perbonus–inversus* zones (R. Mawson, pers. comm.). Trilobites are herein recorded for the first time from the Middle Devonian of Australia – from seven localities in the Broken River Group of northeastern Queensland – from the late Emsian (*serotinus* Zone), late Eifelian (*kockelianus* Zone), various levels in the Givetian, and one possibly earliest Frasnian (Figure 1) All come from localities (see Appendix) in the Broken River Group on the WandoVale and Burges 1:100,000 topographic sheets south of Greenvale, in the Townsville hinterland of northeastern Australia.

STRATIGRAPHIC CONTEXT

The late Emsian–early Frasnian Broken River Group (Mawson and Talent 1989; Sloan *et al.* 1995; Withnall *et al.* 1992, 1993) cropping out widely in the Broken River region (Figure 1) can be viewed as consisting of two platform areas with shallow-water sequences, the Dosey–Craigie and Pandanus Platforms, in the south and northwest respectively (Mawson and Talent 1989; Sloan *et al.* 1995), separated by a northeasterly directed tract of deeper water sediments, the Burges Submarine Valley (compare Figures 1 and 2). Sediments in the latter consist of a stratigraphically cryptic complex of mudrocks and subordinate arenites with debris flows, olistoliths and carbonate fans. The sedimentary complex in the Burges Submarine Valley has been referred to as the Burges Formation (Withnall *et al.* 1988, 1993: 116–122) but, largely because of lack of stratigraphic differentation, has been referred to in subsequent publications, as well as herein, as undifferentiated Broken River Group (Sloan *et al.* 1995). The debris flows and carbonate fans have been built out into the Burges Submarine Valley primarily from the Dosey–Craigie Platform. The best material has come from these carbonate fans.

TRILOBITE FAUNAS

Most of the material is inadequate, either because of poor preservation or because of an insufficient number of exoskeletal pieces with characteristics that would allow specific or even generic attribution. With the exception of a single phacopid from a siliceous nodule in late Emsian shales (Bracteata Formation) and a faunule from ?early Frasnian but possibly latest Givetian decalcified mudstone (Mytton Formation), the Broken River trilobites are from bioclastic crinoidal limestones and marlstones in the above-mentioned carbonate fans. The lithologies include algae indicating a shallow water context (or shallow water derivation)

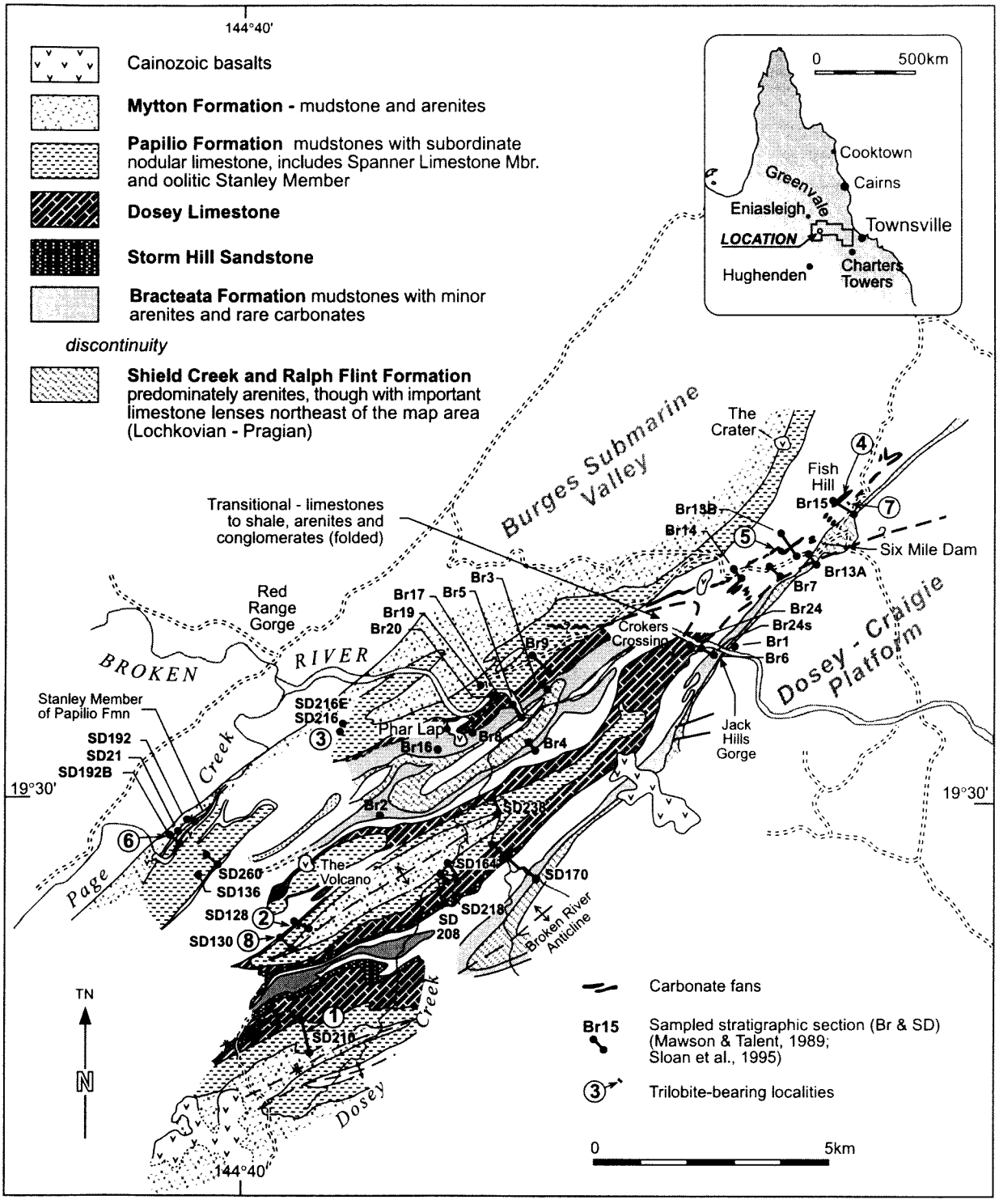


Figure 1 Stratigraphic units in portion of the Broken River area of northeastern Australia, simplified from mapping by Mawson and Talent (1989), Withnall and Lang (1992) and Sloan *et al.* (1995).

in which trilobites tend normally to be extremely rare. Interestingly, the identifiable part of the collections consists entirely of new taxa. Our collections are very poor in individuals; they are mostly present – especially in the case of the Eifelian ones – as detached, often fragmented pieces of carapace accumulated in downslope-transported debris-flows derived from presumably reefal limestones. The Givetian brachiopod- and coral-rich marlstones have produced a few entire phacopids, typical of quiet-water, muddy habitats. All the trilobites have rather large, protruding eyes – typical for shallow platform environments.

Two associations were encountered in the late Eifelian (*kockelianus* Zone) where four families are represented (phacopids, proetids, tropidocoryphids

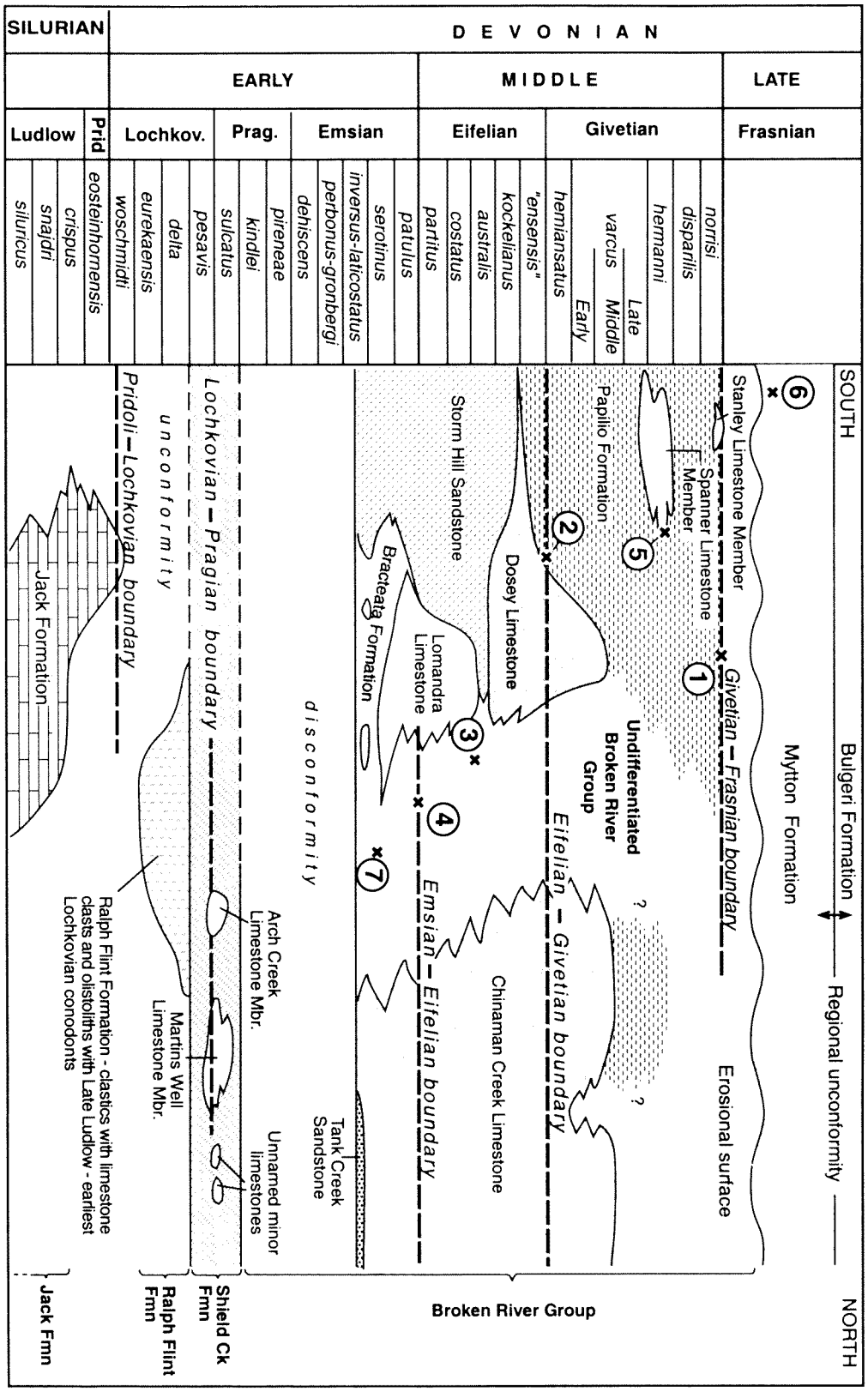


Figure 2 Schematic north–south cross-section of the Broken River area of northeastern Australia, from the Dosey–Craigie Platform in the south to the Pandanus Platform in the north, showing Ludlow–Frasnian units and relative stratigraphic position of localities from which late Emsian–?early Frasnian trilobites documented here have been obtained (modified from Sloan *et al.* 1995). Note the southern and northern carbonate platforms and the intervening submarine valley (Burgess Submarine Valley) with undifferentited Broken River clastics with carbonate fans (at localities 3 and 4), debris flows and olistoliths. Note also that the Stanley Limestone Member is shown as extending very slightly above the Givetian–Frasnian boundary on the basis of meagre, though not compelling conodont data, and that locality 6, low in the Mytton Formation, is separated from the Stanley Limestone Member by a break in sedimentation of uncertain duration.

and aulacopleurids), two associations in the early to mid-Givetian Papilio Formation (phacopids and scutelluids), and one in the Mytton Formation (with phacopids and aulacopleurids). Due to the stratigraphic position and the depositional environment, the fauna is different in composition from all previously described trilobite faunas from Australia. Preliminary palaeobiogeographical comparisons reveal only mild affinity with typical North Gondwanan faunas from Bohemia, southwestern Europe or North Africa. The scutelluid seems to be closer related to Avalonian, especially Rhenish forms, whereas the phacopids and the proetids are unusual; they appear to have some traits in common with Mongolian taxa. More material is needed to complete knowledge of the identified taxa and to enable specific assignment of the several taxa for which specific and even generic location is problematic.

SYSTEMATIC PALAEONTOLOGY

Family Styginidae Vogdes, 1890

Subfamily Scutelluinae Richter and Richter, 1955

Genus *Scutellum* Pusch, 1833

Type species
Scutellum costatum Pusch, 1833

Scutellum tenuistriatum n. sp.
Figure 3C

Name
Referring to the fine, striated sculpture covering the surface of the exoskeleton.

Type material
Holotype, AMF 112492, a partly exfoliated pygidium from locality 8; Figure 3C. Paratype: pygidium, AMF112493 from locality 2. Age: late Eifelian (*kockelianus* Zone) to possibly earliest Givetian (*hemiansatus* Zone).

Occurrence
Brachiopod-rich mudstones of the Papilio Formation; late Eifelian (*kockelianus* Zone) to possibly earliest Givetian (*hemiansatus* Zone)

Diagnosis
A species of *Scutellum* Pusch with pygidium characterised by having a median rib narrowest in its proximal third, expanding towards the axis to become wider than median axial lobe; pleural ribs having proximal ends bent outwards; ribs flattened distally, sharply defined by narrow pleural furrows. Prosopon of dense ridges and sparse nodules; border pseudospinose.

Description
Pygidium moderately vaulted, elongate pentagonal in outline (width to length = 2.9:2.6) with, in lateral view, the proximal third of the pleural field flattened with a slightly depressed median rib and a moderately elevated small axis declining forward. Pleural field vaulted medially, with a markedly flexed median rib; outer part gently sloping to broad border depression; border flat and horizontal. Axis triangular in dorsal view, sharply separated from the pleural field by a continuous dorsal furrow, and with narrow median lobe not reaching the dorsal furrow. Doublure two-thirds the length of the pleural field (sagitally). Seven pairs of pleural ribs and a broader unbifurcated median rib, all cylindrical in their adaxial third, flattened to the rear, reaching the posterolateral borders, sharply defined by narrow and deep interpleural furrows. Median rib, twice as broad as the adjacent ribs at its posterior end, tapers continuously to the anterior border of the doublure, at which point it expands again to reach a maximum width at the junction with the dorsal furrow where it is wider than the median lobe of the axis. In the proximal third of the pleural field all pleurae (except the first one) are strongly bent forward and outward to meet the dorsal furrow in a rather narrow angle. The entire surface of the exoskeleton is densely covered with thin, transversely directed, anastomosing ridges of equal size that, at the junction with the borders, curve abruptly back in the form of minute hooks that terminate obliquely at the border in a succession of parallel chevrons giving to it a pseudospinose aspect ("Pseudozähnelung" of Erben 1967). In addition to this sculpture sparse nodules of moderate size are displayed throughout the surface.

Remarks
In her revision of the genus *Scutellum*, Archinal (1994) grouped all taxa with a long pentagonal outline of the pygidium and an adaxially widening median rib into a new subgenus *Scutellum* (*Calycoscutellum*). Because of this feature, the new species could be located in *S.* (*Calycoscutellum*), but the diagnostic features – and especially the widening of the adaxial median rib – seem not to be sufficiently expressed to allow unequivocal characterisation of that subgenus. Moreover, the adaxial portion of the median rib widens during the postlarval ontogeny; this feature cannot be seen in smaller specimens as for example in *S. depressum* Cooper and Cloud (1938). There is great variability of this feature in different morphotypes of *S. flabellifer* (the type-species of *Calycoscutellum*) as well as in other taxa such as *S.* ("*Calycoscutellum*") *sagitta* Archinal 1994. As stated by Basse (1996), additional

diagnostic features must be identified before this subgenus can be usefully employed.

Among Givetian species of *Scutellum* with a proximally widening median rib and narrow interpleural furrows the new species ressembles *S. brunopaulusi* Archinal from the Eifel Mountains, Germany, but has a much stronger outward curvature of the proximal pleurae. It differs from *S. delicatum* (Whidborne) from the Lummaton shellbed in Torquay (SW England) by the marked constriction of the median rib at the anterior border of the doublure. It resembles *S. depressum* Cooper and Cloud from Illinois, but has a much wider anterior termination of the median rib and stronger curved anterior pleurae. Moreover the border of the American species carries very tiny short spines seen only in large specimens; such true spines are not developed in *S. tenuistriatum*. Additionally, the characteristic prosopon makes the new species distinct from all other comparable species of *Scutellum*.

All previously described Australian representatives of *Scutellum* come from the Early Devonian. *S. calvum* Chatterton 1971 and *S. hollandi* Wright and Chatterton 1988 are both from the Emsian of New South Wales. *S. droseron* Holloway and Neil 1982 and *S. sudorum* Holloway 1996 are from the Lochkovian and early Emsian respectively of Victoria. All four forms may be discriminated from the present species by their prosopon and the configuration of the median rib.

Little is known about Givetian forms of *Scutellum* from Gondwana-related areas. A single cranidium of *Scutellum* sp. 2 gr. *costatum* has been found in Brittany (Morzadec 1983). The exoskeleton lacks the characteristic ridges developed in *S. tenuistriatum*. A poorly preserved pygidium from Cantabrian Mountains assigned to *S. costatum* cf. *lummatonensis* Selwood by Smeenk (1983) has much larger interpleural furrows than the new species. An undescribed pygidium of *S. costatum costatum* occurs in *Stringocephalus* limestones at Monumenz in the Central Carnic Alps (collections of G.B. Vai, number 23925, Bologna). Other representatives of the *costatum* group in the Montagne Noire, all with a narrow anterior median rib, do not occur earlier than earliest Frasnian (Feist 1974).

Scutelluid indet.

Remarks

Two fragments of a scutelluid cranidium and a few thoracic segments (AMF112494) occur in bioclastic, crinoidal and brachiopod-rich sparitic limestones at locality 4 (latest Emsian *patulus* Zone or earliest Eifelian, *partitus* Zone). They are associated with *Burgesina mawsonae* n. gen. n. sp.

Family Proetidae Salter, 1864

Subfamily Proetinae Salter, 1864

Genus *Proetus* Steininger, 1831

Subgenus *Proetus* (*Devonoproetus*) Lütke, 1990

Type species

Proetus (*Proetus*) *talenti* Chatterton, 1971

Remarks

Lütke (1990) placed *Devonoproetus* in *Gerastos* Goldfuss 1843 despite the close resemblance of its type species *P. talenti* to *Proetus* s.s. (Adrain 1997). Accordingly and because of the direct ancestor-descendant relationship between both taxa we consider *Devonoproetus* as a subgenus of *Proetus*.

Proetus (*Devonoproetus*) *sparsinodosus* n. sp.

Figure 3A, E, I, M, N

Name

Recalling the sporadic occurrence of small nodes on the smooth surface of exoskeleton.

Type material

Holotype, cranidium, AMF 112495, from locality 3, 216 m above the base of section Br 13B, Figure 3/A, E, I. Paratypes from same locality and stratum: juvenile cranidium, AMF 112496 ; fragmentary pygidium, AMF 112497, Figure 3/M, N; fragmentary pygidium, AMF 112498. Age: late Eifelian (zone uncertain).

Occurrence

Black crinoidal wackestone (Eifelian; *kockelianus* Zone) from a carbonate fan in undifferentiated Broken River Group in the Burges Submarine Valley.

Diagnosis

Species of the subgenus *Devonoproetus* characterised by: cranidium with vaulted, long subrectangular glabella reaching poorly defined anterior border; lateral occipital lobes unswollen, incompletely separated from occipital lobe; sparse tubercles on posterior part of glabella. Pygidium with long and high axis reaching to poorly defined, swollen margin; ring and pleural furrows very weakly impressed.

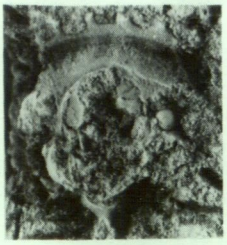
Description

The elongate subrectangular, parallel sided glabella is defined by straight dorsal furrows and a semicircular frontal outline. It is continuously but not very highly vaulted both in lateral and frontal views with a hemispherical shaped frontal lobe. S1 and S2 furrows, weakly impressed, separate


A


B


C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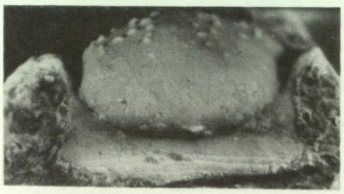
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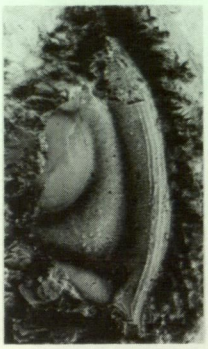
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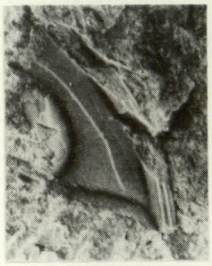
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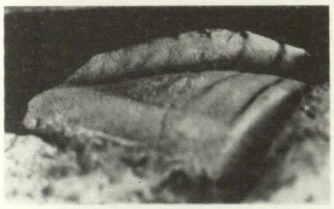
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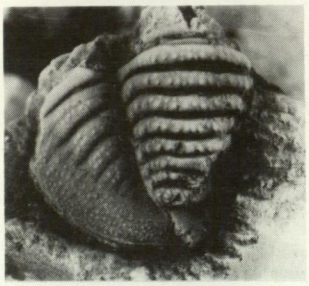
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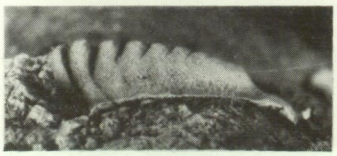
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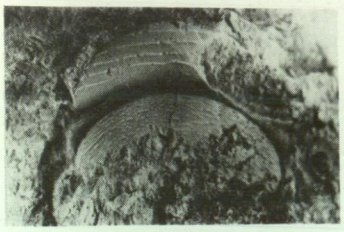
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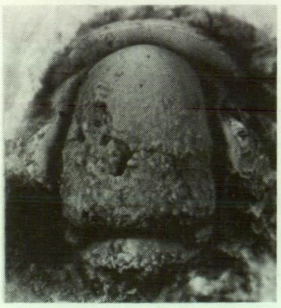
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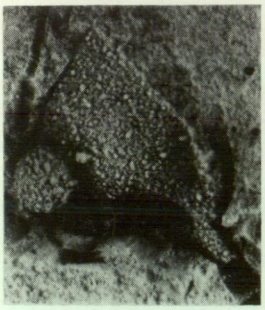
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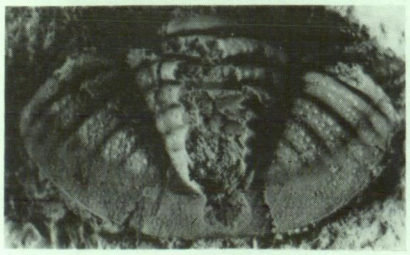
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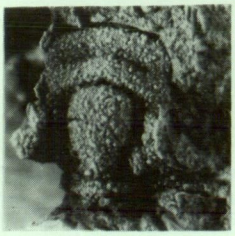
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unswollen lateral lobes. Basal angles of glabella behind L1 are slightly truncated by distally forward directed occipital furrow. Dorsal furrows, deep behind and in front of glabella, are shallow anterolaterally. Anterior border broad, slightly swollen, poorly defined by large border depression that merges with prefrontal furrow of glabella, protruding in dorsal view; broadly downcurving margin provided with continuous terrace ridges. Occipital ring narrow, strongly vaulted (sag.), of equal width as the base of glabella, exhibits incompletely separated, low, uninflated lateral lobes of moderate size that are bounded anteriorly by the deeply incised distal ends of the occipital furrow. Fixigenae adjacent to glabella extremely narrow and equal in width anteriorly and posteriorly of the palpebral lobe. Facial suture between b–g and e–z runs parallel to sagittal line. Palpebral lobe of sigmoidal outline, vaulted tranversely, two and a half times longer than wide, situated inmidst between the anterior border depression and the posterior border furrow. Prosopon smooth with the exception of characteristic, relatively big-sized nodules that are distantly dispersed on the posterior two thirds of the glabella. Pygidium, largely semielliptical in outline, has a long, relatively high axis defined by straight, little converging dorsal furrows and a broadly rounded, elevated end that reaches to the poorly defined border depression. There are 7 + 1 flat axial rings of which the anteriormost is narrower and more elevated than the following ones; ring furrows sigmoidal with a distally forward curving swing; only the two anterior ring furrows are deeply marked, the others are very faint. The pleural field is moderately vaulted with a poorly defined border depression and a large slightly swollen border. There are 4 or 5 flat pleural ribs that are separated by faint pleural furrows. Pleural ribs and furrows terminate at border depression far inside from posterolateral margin. Posterior border slightly up-tilted with narrow, swollen margin. Prosopon smooth; only the anterior ring of axis with a few nodules.

Remarks

The type species of *Proetus* (*Devonoproetus*) is *P. (D.) talenti* Chatterton from the late Emsian Taemas Formation, New South Wales. This species is different in exhibiting dense tuberculation, more diverging anterior sutures, a larger pygidial axis with throughout deeply impressed ring furrows. The new species is closest to *Proetus vescus* Zhou, Siveter and Owens from the Eifelian Yikewusu Formation of Inner Mongolia. It is distinct by the broader, somewhat flatter anterior margin and the sparse nodular sculpture on the cephalon. The Emsian and early Eifelian species *P. (D.) margo* Lütke and *P. (D.) cultrijugati* Richter and Richter from Germany are clearly distinct from *P. (D.) sparsinodosus* by the outline of their more tapering glabella and the curved dorsal furrows. In comparison to these species *P. (D.) sparsinodosus* has a longer rachis with a broader end-piece (sag.).

According to Lütke (1990) the subgenus *Devonoproetus* is represented in Avalonia-Baltica and North America whereas, besides Australia and Mongolia, its occurrence in Northern Gondwana (Bohemia and Armorica) is questionable. By contrast, the contemporaneous proetine *Gerastos* is well represented in western North Gondwana terranes such as Armorica, North Africa and Bohemia.

***Proetus (Devonoproetus) latimargo* n. sp.**
Figures 3B, G, K, O, V, W, X.

Name

Referring to the large, characteristic border of the pygidium.

Type material

Holotype, cranidium, AMF112499, from locality 3, 214.5 m along a metric tape from the base of the section (Figures 3B, G, K). Paratypes from the same bed: fragment of librigena, AMF112500; fragmentary pygidium, AMF 112501, Figures 3O, X; pygidium with fragmentary axis, AMF112502, Figures 3V, W.

◀ **Figure 3** Trilobites from the Broken River Group, N Queensland. The material is housed in the collections of the Australian Museum, Sydney (AM). All figured specimens were coated with MgO. **A, E, I, M, N,** *Proetus (Devonoproetus) sparsinodosus* n. sp. **A, E, I,** holotype, cranidium, AMF112495, dorsal view (A) x 4.4; frontal view (E) x 4.9; lateral view (I) x 4.4; **M, N,** pygidium, AMF112497, fragmentary, lateral view (M) x 5.4; dorsal view (N) x 5.4. **B, F, G, H, J, K, O,T, V,W, X,** *Proetus (Devonoproetus) latimargo* n. sp. **B, G, K,** holotype, cranidium, AMF112499, dorsal view (B) x 5.4; frontal view (G) x 5.7; lateral view (K) x 5.2; **F, J, T,** cranidium, AMF112503, frontal view (F) x 6.5; lateral view (J) x 5.7; dorsal view (T) x 6; **H,** librigena, AMF112504, dorsal view x 7.4. **O, X,** pygidium, AMF 112501, fragmentary, dorsal view (O) x 7.1; lateral view (X) x 7.1. **V, W,** pygidium, AMF112502, axis broken, dorsal view (V) x 6.4; lateral view (W) x 6.4. **C,** *Scutellum tenuistriatum* n. sp., holotype, pygidium, AMF 112492, partly exfoliated, dorsal view x 1.4. **D,** *Otarion* sp. cranidium with broken glabella, AMF112534, dorsal view x 8.7. **L, P,** *Astycoryphe* sp. **L,** librigena, AMF112529, dorsal view x 8.3; **P,** fragment of cranidium, AMF112528, dorsal view x 8.8. **Q, S,** Proetinae gen. et sp. indet., fragmentary pygidium, **Q,** AMF112526, lateral view x 6; **S,** dorsal view x 5.7. **R,** Cornuproetinae gen. et sp. indet., fragmentary anterior portion of cranidium, AMF112527, dorsal view x 5. **U, Y,** *Aulacopleura* sp., **U,** librigena, AMF112533, internal mould, dorsal view x 6.8; **Y,** cranidium, AMF112532, internal mould, dorsal view, x 7.7.

Occurrence

Black crinoidal wackestone from undifferentiated Broken River Formation, late Eifelian *?australis* Zone. Supplementary material assigned to same species from locality 4, crinoidal brachiopod sparitic limestone also from undifferentiated Broken River Formation: cranidium, AMF 112503, Figure 3/T, F, J; librigena, AMF 112504, Figure 3/H.

Diagnosis

Species of the subgenus *Devonoproetus* with following characteristic features: cranidium with long tongue-shaped glabella, not overhanging anterior border; border thick, protruding, not up-tilted; genal spines short. Pygidium with large axis, markedly tapering to the rear, with deeply marked axial ring furrows; margin very large, defined by shallow border furrow.

Description

The cranidium exhibits a tongue shaped glabella, bounded by slowly but continuously converging, straight dorsal furrows of equal depth. The glabella is strongly vaulted (tr. and sag.), highly arched in frontal view, and is longer than wide (5.5 : 4.5), broadest at base. There is no praeglabella field. Protruding anteriorly, the large, subcylindrical (sag.) border is defined by a marked border furrow that deepens in front of glabella when merging with the prefontal furrow. Front lobe of glabella not overhanging but slightly impinging on border. Glabella furrows inconspicuous; S1 and S2 slightly impressed adjacent to dorsal furrow. Occipital furrow straight, deepening behind L1 and meeting dorsal furrows at right angles. Occipital ring narrow (sag.), as broad as glabella (tr.), anteriorly subdivided by deep, discontinuous incisions of occipital furrow that isolate elongate, anteriorly swollen lateral lobes; median lobe protruding forward. Anterior fixigenae large, vaulted, down sloping. Anterior branches of suture first parallel to the dorsal furrow then flexing markedly outward. g and e are situated very near to dorsal furrow. Narrow sigmoidal shaped, strongly inclined, small palpebral lobes remain behind S2. Posterior branches of suture parallel to dorsal furrow. The librigena is provided with a rather robust, cylindrical border, a large eye with a weak eye-socle and a narrow anterior librigenal field. The genal angle protrudes into a small spine. The pygidium is largely parabolic in outline with slightly truncated posterior margin. Axis robust, high, larger than one pleural region, defined by straight, markedly converging dorsal furrows and a truncated posterior outline. It is provided with 7 + 1 prominent, cylindrical rings separated by rather deep, slightly sigmoidal ring furrows. Pleural field large, moderately vaulted, subdivided into a more vaulted inner part with well defined pleural ribs and a very large gently sloping outer margin separated by a shallow but distinct border furrow. There are 5 – 6 bicomposite ribs defined by deeply incised pleural furrows. Interpleural furrows are less marked distally. Only the pleural bands of the two anterior ribs continue onto the outer margin; the posterior ones terminate at border furrow. The outer slope of the margin carries two or three terrace ridges. Prosopon tuberculate. On glabella tubercles increase in size from front to rear.

Remarks

The new species is distinct from *P. (D.) talenti*, *P. (D.) sparsinodosus* and *P. (D.) vescus* by its tongue-shaped glabella; it shares this feature with *Proetus zhusilengensis* Zhou, Siveter and Owens from the Emsian Zhusileng Formation of Inner Mongolia; however it is distinct by its much larger pygidial border and denser nodular sculpture.

Genus *Burgesina* n. gen.

Type species

Burgesina mawsonae n. sp.

Name

After Burges 1:100,000 topographic sheet, Townsville hinterland, of northeastern Australia, where the trilobites were found.

Diagnosis

A genus of the subfamily Proetinae with the following characteristic features: Cranidium large with up-tilted border ridge; glabella subquadrangular, flattened with backward protruding basal lobes; lateral occipital lobes high; librigena with prominent eye, lacking genal spines. Pygidium semicircular with thick border; axis long, prominent, larger than pleural region, with 9 + 1 rings. Sculpture of coarse discontinuous ridges and tubercles.

Species

B. formosa (Zhou, Siveter and Owens 2000), *B.* sp. indet. 1 (Zhou, Siveter and Owens 2000), *B.* sp. indet 2 (Zhou, Siveter and Owens 2000), *B. mawsonae* n.sp.

Time and occurrence

Emsian to Eifelian; Western Inner Mongolia and Broken River Region, North Queensland

Remarks

Among the proetines with pronounced lateral occipital lobes the new taxon shares features of the cranidium such as the up-tilted anterior border and the shape of the glabella with some American species of *Crassiproetus* Stumm such as *C. sibleyensis*

and *C. norwoodensis* (cf. Lieberman 1994, Figure 20). But the particular trait of backward projected basal lobes does not occur in *Crassiproetus*. Besides, the new taxon has a much shorter and less arched pygidial axis with fewer rings. In this regard, the pygidium is nearer to that of *Coniproetus* Alberti though it has a much thicker border (Alberti 1966). The Silurian genus *Hedstroemia* Pribyl and Vanek 1978 to which Zhou, Siveter and Owens originally attributed the Mongolian taxa is characterised by its anteriorly tapering glabella, the presence of a preglabellar field, and the deeply incised lateral glabellar furrows. The new genus is distinct from *Hedstroemia* by characteristic features such as absence of the praeglabellar field, uptilted ridge-like anterior border, faint lateral glabellar furrows, very broad and inflated pygidial border, fewer axial rings and straight pleural bands of even height and length. In the outline of the large quadrangular glabella and in the shape of its posterior border, the new taxon differs considerably from all other proetines.

Burgesina mawsonae n. sp.

Name

For Prof. Ruth Mawson who has contributed so importantly to improving knowledge of the chronologic framework for the Broken River and other mid-Palaeozoic sequences in Australia.

Diagnosis

Type species of *Burgesina* n.g. characterised by: quadrangular, highly vaulted glabella with notched base and elongated lateral occipital lobes.

Type material

Holotype, cranidium, AMF112505, from locality 4, Figure 4/A, U. Paratypes from same bed: cranidium, AMF112506, Figure 4/ F, R ; fragment of anterior cranidium, AMF112507, Figure 4/ B; librigena, AMF112508, Figure 4/ M; pygidium, AMF112509, Figure 4/ I, T; pygidium, AMF112510, Figure 4/ K, D, S; pygidium, AMF112511, Figure 4/ N. Supplementary material from same bed: 5 cranidia (AMF112512-516), 2 librigenae (AMF112517-518), 2 thoracic segments (AMF112519-520), 5 pygidia (AMF112521-525).

Occurrence

Bioclastic, crinoidal and brachiopod rich sparitic limestones at the base of Fish Hill, locality 4 (latest Emsian *patulus* Zone or earliest Eifelian, *partitus* Zone).

Description

Cranidium square-shaped with large, subquadrangular glabella, slightly broader at base than in sagittal length, nearly parallel-sided, tapering in front, strongly vaulted anteriorly (sag.), less transversely, flattened behind; frontal lobe semicircular, vertically sloping, not overhanging. Glabellar furrows unimpressed, large, sculpturless; S 1 broad, backward directed without reaching to occipital furrow; lateral lobes unswollen. Base of glabella notched by inserts of occipital furrow and markedly backward shifted median and lateral lobes (L 1). Dorsal furrows narrow, deep, nearly parallel behind, thinning and strongly convergent in anterior third. Rather narrow, deeply incised anterior border furrow merges with prefrontal furrow of glabella. Anterior border ridge-like uptilted, with vertical, slightly vaulted outer slope, steeply inclined posteriorly, forming a narrow crest separated from front of glabella by deep, gorge-like border furrow. Occipital furrow homogenously deep and narrow, sigmoidal, bifurcated distally. Occipital ring as high and broad (tr.) as base of glabella, flattened at top, slightly protruding medially, with completely separated, prominent, elongated lateral lobes. Fixigenae moderately large (tr.), arched anteriorly to the same degree as glabella. Palpebral lobe short (exsag.), rearward positioned, of narrow sigmoidal outline, slightly flexed inward and backward. e lies nearer to dorsal furrow than g. Anterior branches of suture long, straight, little diverging until border furrow, strongly inward curved on border. Short portion of posterior suture e–z straight and parallel to dorsal furrow. z lies in posterior border furrow opposite to the posterior branch of occipital furrow. Posterior border cylindrical, short and bent backward. Librigena subtriangular with prominent eye on high, unswollen eye-socle that merges continuously with slightly arched and deeply downsloping librigenal field. Border furrow sharp and deeply impressed. Lateral border broad, as large (tr.) as genal field, twice as large as posterior border, flattened at top with thick outer margin. Genal angle without spine; short residual spine may still be present in young holaspids. Prosopon of cephalon: coarse wrinkles and discontinuous ridges on glabella and occipital ring, discontinuous parallel terrace ridges on anterior fixigenae, continuous terrace ridges on the outer slopes of the anterolateral borders, minute grooves in border furrows and on eye-socle. Pygidium semicircular with thick border separated by continuously marked border furrow that interrupts the vault of the pleural field. Axis long, highly arched transversely, anteriorly broader (tr) and, in lateral view, as high as the pleural region, tapers with continuously straight dorsal furrows and terminates with a high, rounded end shortly before reaching at the border furrow. There are 9 + 1 slightly backward inclined axial rings, completely separated by thin ring furrows that tend to vanish rearwards

(especially in larger specimens). Pleural field strongly arched and sharply bounded by border furrow. There are 8 conspicious, bicomposite, prominent pleural ribs that all abruptly terminate in border furrow. Pleural bands of equal heighth, the posterior slightly broader than the anterior; the anterior ones clearly separated by faint but continuous interpleural furrows. Border swollen, of equal breadth, slowly downsloping from border furrow outwards, in lateral view as high as pleural field. Outer slope carries 6 continuous, parallel terrace ridges. Prosopon: tubercles on each pleural band and on the posterior axial rings.

Comparison

The Mongolian representatives of the new genus share many traits with *B. mawsonae* from the Broken River region. In particular, *B. formosa* Zhou, Siveter and Owens from the Emsian Zhusileng Formation is very close to the new taxon. Whereas the pygidia are nearly identical, the cranidium of *B. mawsonae* is distinct in its more quadrangular, stronger and more highly vaulted glabella with its deeply notched base, the elongated lateral occipital lobes, and the broader fixigenal fields with posterior sutures that run parallel to the dorsal furrows. Both taxa doubtless belong to the same genus; they are distinct from *Hedstroemia* by characteristic features such as absence of the praeglabellar field, uptilted ridge-like anterior border, faint lateral glabellar furrows, very broad and inflated pygidial border, fewer axial rings and straight pleural bands of even height and length. The combination of these features justifies integration of the two species into a separate genus, i.e. *Burgesina* n.g.

Proetinae gen. et sp. indet.
Figure 3Q, S

Remarks

A undetermined fragmentary pygidium, AMF 112526, from locality 4, occurring in association with *Proetus (Devonoproetus) latimargo*. It may, however, belong to another species because the axial rings are not completely separated, and the ring furrows are displayed only in the centre of the axis. Effaced axial furrows occur on pygidia of *Orbitoproetus* Pillet 1969, but representatives of that genus have a broader and less elevated axis.

Subfamily Cornuproetinae Richter and Richter, 1956

Cornuproetinae gen. et sp. indet.
Figure 3R

Remarks

An undetermined fragment of the anterior of a cranidium, AMF 112527, from locality 3, 216 m along a metric tape from the base of section Br 13B, late Eifelian (*?australis* Zone). The fragment is assigned to the Cornuproetinae because of the configuration of the broad anterior glabella lobe, the rather narrow preglabellar field, the deep, flexed anterior border furrow, and the broad cylindrical border protruding slightly forward adaxially, and its continuous terrace lines.

Family Tropidocoryphidae Pribyl, 1946

Subfamily Tropidocoryphinae Pribyl, 1946

Genus *Astycoryphe* Richter and Richter, 1919

Type species

Astycoryphe senckenbergiana Richter and Richter, 1919

***?Astycoryphe* sp.**
Figure 3L, P

Remarks

Fragments of tropidocoryphine trilobites have been obtained from locality 3, at 214.5 m along a metric tape from the base of the section Br 13B, late Eifelian (*?australis* Zone). Figured are one cranidium, AMF 112528, Figure 3P and one librigena, AMF 112529, Figure 3L. Supplementary material: one fragment of the anterior of a cranidium, AMF 112530, and one librigena, AMF112531.

The material is not sufficiently complete for specific or even generic attribution. Because of the large frontal lobe of the glabella and the characteristic lateral border it is tentatively assigned to *Astycoryphe*. This genus has been reported from the Early Devonian of New South Wales (Wright and Chatterton 1988).

Family Aulacopleuridae Angelin, 1854

Subfamily Aulacopleurinae Angelin, 1854

Genus *Aulacopleura* Hawle and Corda, 1847

Type species

Arethusina konincki Barrande 1846

***Aulacopleura* sp.**
Figure 3U, Y

Remarks

A single cranidium, AMF 112532, Figure 3Y and a free cheek, AMF 112533, Figure 3U have been recovered from a small decalcified marlstone nodule at locality 6 in the Mytton Formation in the

Page Creek area. The specifically indeterminable material exhibits characteristic features of *Aulacopleura* such as the rectangular, anteriorly truncated, low frontal lobe of the glabella, the large, posteriorly projected praeglabella field and the prominent eye-ridges. However, the librigena ressembles those of the genus *Cyphaspis* Burmeister 1843. If the presence of *Aulacopleura* can be confirmed by the discovery of more complete and better preserved material a pre-Taghanic age could be assigned to the nodule as *Aulacopleura* has been regarded as disappearing at the Middle/Upper *varcus* Zone boundary. The matrix, however, is argued (see earlier) to be younger than this, the best estimate on available data being earliest Frasnian rather than late Givetian.

Subfamily Otarioninae Richter and Richter, 1926

Genus *Otarion* Zenker, 1833

Type species
Otarion diffractum Zenker, 1833

Otarion sp.
Figure 3D

Remarks
A fragment of a cranidium assigned to *Otarion*, AMF112534, occurs in association with *Burgesina* in brachiopod-rich, crinoidal sparites at locality 4 (latest Emsian *patulus* Zone or earliest Eifelian *partitus* Zone). The specimen exhibits a row of 6 spines of equal length on the anterior border. This feature occurs in some otarionines such as *O. davidsoni* Barrande 1852 and was earlier considered diagnostic of *Otarionella* Weyer 1965; it is now considered to be a paedomorphic feature (Adrain and Chatterton 1994), and *Otarionella* is accordingly viewed as a younger synonym of *Otarion*.

Phacopidae Hawle and Corda, 1847

Phacopinae Hawle and Corda, 1847

Phacops Emmrich, 1839

Phacops (*Phacops*) Emmrich, 1839

Type Species
Calymmene latifrons Bronn, 1825

Phacops (*Phacops*) *brocki* n. sp.
Figures 4H, L, P, Q

Name
For Dr Glenn Brock of Macquarie University Centre for Ecostratigraphy and Palaeobiology recognising his work in the Broken River area.

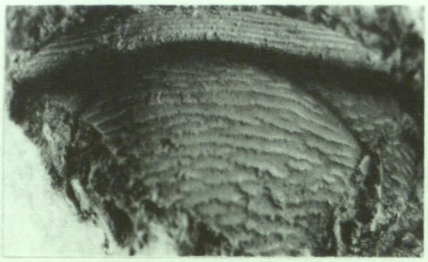
Type material
Holotype, AMF112535, enrolled entire specimen from locality 1, Figure 4P, Q. Paratype: cephalon, AMF112536, from locality 5, approximately half way between 146 and 147 m above the base of the section, Figure 4H, L. Supplementary material: enrolled thoraco-pygidium, AMF112537, from locality 1; 1 fragmentary cephalon, AMF112538, rom locality 8 at 223 m from the base of the sect on; cephalon, AMF112539, from locality 5, approximately half way between 150 and 165 m above the base of the section; cephalon, AMF112540, from locality 4 same horizon as the holotype.

Occurrence
From brachiopod-rich mudstones in the Papilio Formation–late Givetian, *hermanni* Zone, about 51–52 m above the entry of *Schmidtognathus* (see Sloan *et al.* 1995, Table 6). Because of rareness, the first record of *Schmidtognathus* in this section may be appreciably above the base of the *hermanni* Zone, and conceivably younger in the late Givetian.

Diagnosis
A species of *Phacops* (*Phacops*) characterised by having: cephalon low, flattened; glabella not overhanging, with slightly convex dorsal furrows; preoccipital ring elongate, large; occipital ring very narrow, not protruding medially; eyes very large and high, reaching to the posterior border furrow. Pygidium with narrow, high axis; axial ring and pleural furrows deep.

Description
Cephalon with a broad subtrapezoidal, low, flattened glabella with a vertically dipping anterior lobe that does not overhang but covers the narrow, medially withdrawn anterior border (in dorsal view). Glabella defined laterally by slightly outcurved dorsal furrows. Anterior and posterior corners of glabella blunt. S1 continuously marked, curved forward and shallowing medially. Preoccipital ring well developed, exhibiting an elevated, elongate median lobe protruding forwards medially, and low, small, moderately swollen lateral lobes. Occipital furrow straight, of even depth. Occipital ring rather narrow, stra ght, prominent, as broad (sagitally) as the preoccipi al ring, not protruding medially, as high as the g-labella. Eyes very large, extending to posterior border furrow, as high as the posterior glabella. Palpebral lobe narrow, horizontal, arched traversely, with shallow, curved palpebral furrow. Visual surface steeply inclined, kidney-shaped with 17 dorsoventral files of eye-lenses, with a maximum number of 10 lenses in a row in large specimens (for

A



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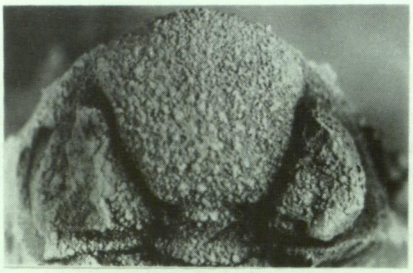

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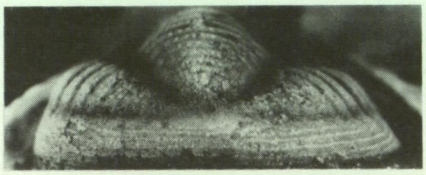

D

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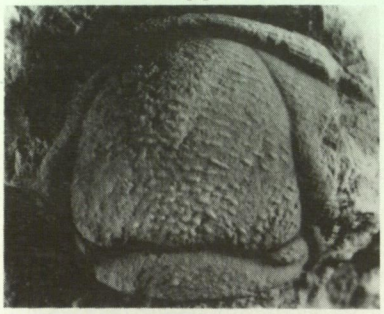

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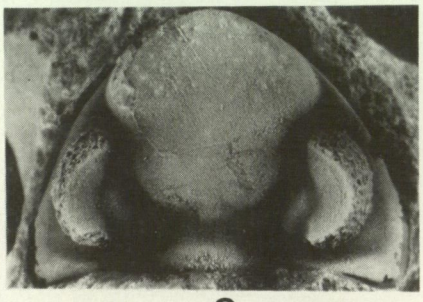

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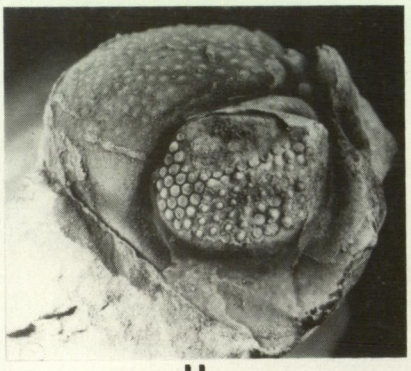

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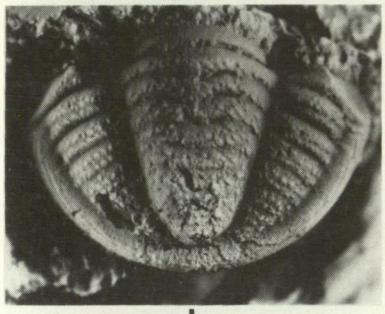
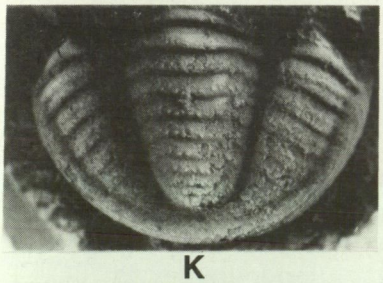


I

J

M



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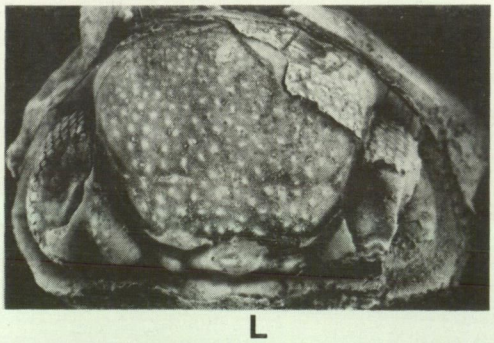

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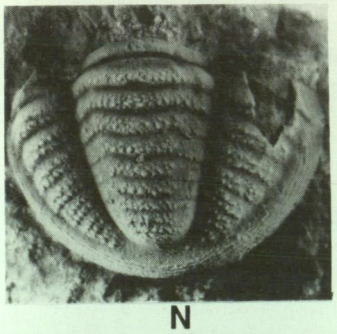

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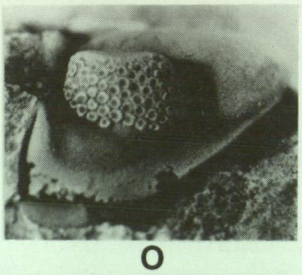

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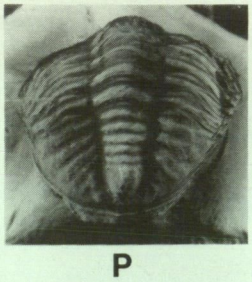

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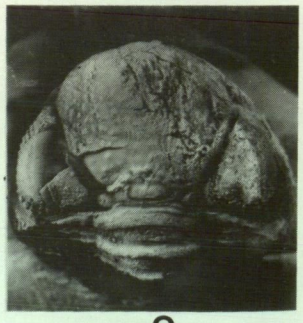

Q

R

S

T

U

example, from front to rear, 7 8 9 9 10 9 10 9 9 9 9 8 7 6 5 4 2), yielding a total of 130 lenses. Lens-files start shortly above base of eye which is surrounded by a large, shallow depression. Posterior genal field swollen between palpebral furrow and dorsal furrow. Outer genal field narrow, uninflated, moderately down-sloping; genal corners blunt. Vincular furrow very shallow and large medially. Prosopon consisting of low tubercles of medium size on glabella and occipital lobe. Pygidium semielliptical in posterior outline, with axis rather high and narrow, a little broader than half of one pleural region. Dorsal furrows straight, converging very gradually; end of axis elevated, higher than pleural regions. Axial rings 8 + 1, narrow, elevated, separated by straight, deep ring furrows. Pleural region homogenously arched, with 5–6 pleural ribs clearly defined by deep pleural furrows. Prosopon tuberculate.

Remarks

The combination of features such as low, non protruding glabella, outwardly convex dorsal furrows, very large, backwardly extending eyes, and narrow, medially non- protruding occipital lobe are characteristic of the new, first mid-Devonian phacopid reported from Australia. European species from the Givetian with comparably large eyes, such as *Phacops (Phacops) sobolewi* Kielan 1954 or *Pedinopariops simulator* Basse 1998, have rectilinear diverging dorsal furrows and medially enlarged occipital rings. A similar configuration of flexed dorsal furrows, medially broadening intercalating ring and narrow occipital ring is developed in *Toxophacops (Zhusilengops) ejinensis* Zhou and Campbell from the Emsian of western Inner Mongolia. However, this echinophacopid species differs from *P. (P.) brocki* in having a highly arched anterior border and triangular pygidium.

***Phacops* sp.**
Figure 4C, E

Remarks

An exfoliated, fragmental cephalon of an unidentified species of *Phacops*, AMF112541, has been recovered from a decalcified marlstone nodule, associated with *Aulacopleura* sp., at locality 5 in the Mytton Formation in the Page Creek area (see earlier for discussion of age of matrix at this locality).

Remarkable features of the specimen are the very flat, evenly forwardly expanding glabella with a rather low, dorso-ventrally flattened frontal lobe and backwardly displaced, large eyes that are higher than the glabella. Conceivably it is from a new species, but is poorly preserved; additional material is necessary for adequate delineation of the species.

Phacopidae indet.
Figure 4G, J

Remarks

An unidentified phacopid cephalon, was recovered from a small siliceous nodule in late Emsian age (*serotinus* Zone) shales outcropping in the gully at locality 7. The specimen is preserved as an internal mould. Glabella very low and flat, narrow, subpentagonal, with a medially pointed, dorso-ventrally compressed frontal lobe that strongly overhangs the anterior border. Border furrow faint, retreated on ventral side behind the tip of the glabella. Vincular furrow shallow but continuously marked, strongly arched adaxially. Medially very high occipital lobe that is higher than the glabella. Preoccipital intercalating ring broad with suppressed median lobe (on internal mould there is a large, gorge-like depression) and small, low lateral lobes. Very high eyes, backward shifted, reaching to the posterior border furrow, anteriorly intruding into the dorsal furrows, slightly impinging on the anterior sides of glabella (on internal mould only?). Visual surface steeply sloping, with 17 lens files with a maximum of 6 lenses per file. Palpebral lobes reniform, horizontal, as high as the glabella. Genal angles pointed, probably with short spines.

Remarks

The general outline of the glabella, the ventrally

Figure 4 Trilobites from the Broken River Group, N Queensland. The material is housed in the collections of the Australian Museum, Sydney (AM). All figured specimens were coated with MgO. **A, B, D, F, I, K, M, N, R–U** *Burgesina mawsonae* n.gen. et n. sp. **A, U,** holotype, cranidium, AMF112505, dorsal view (A) x 5.9; lateral view (U) x 5.9; **B,** cranidium, AMF112507, fragment of anterior part, dorsal view x 7; **D, K, S,** pygidium, AMF112510, posterior view (D) x 8; dorsal view (K):7.3; lateral view (S) x 8; **F, R,** cranidium, AMF112506, dorsal view (F): x 7.6; lateral view (R): x 7.6; **I, T,** pygidium, AMF112509, dorsal view (I) x 7.6; lateral view (T): x 7.4; **M,** librigena, AMF112508, partially exfoliated, dorsal view: x 6.3; **N,** pygidium, AMF112511, dorsal viex: x 7.8. **C, E,** *Phacops* sp., cranidium, AMF112541, internal mould, dorsal view (C) x 7.7; frontal view (E): x 7.9. **G, J,** Phacopidae gen. et sp. indet., cranidium, AMF112542, internal mould, dorsal view (G) x 5.1; frontal view (J) x 4.9. **H, L, P, Q,** *Phacops (Phacops) brocki* n. sp. **H, L,** cephalon, AMF112536, partly exfoliated, lateral view (H) x 2.8; dorsal view (L) x 2.8; **P, Q,** holotype, entire enrolled specimen, AMF112535, partly exfoliated; cephalon, dorsal view (Q) x 3; pygidium and posterior thoracic region, exfoliated, dorsal view (P) x 2.2.

situated anterior border furrow, and high posteriorly shifted eyes bring to mind species of *Toxophacops* (*Atopophacops*) Zhou and Campbell from Inner Mongolia and especially *T.* (*Atopophacops*) sp. indet. (Zhou and Campbell 1990: Pl. 5, Figure 12) which is approximately the same age (late Emsian). However, representatives of *Atopophacops* all have an elevated median lobe in the preoccipital intercalating ring and have strong tuberculation. Both features are lacking in our specimen. Confident location in *Atopophacops* requires more and better material as well as a pygidium.

ACKNOWLEDGEMENTS

Part of the trilobite material forming the basis of the present report was accumulated as a by-product of many years of field work in the Broken River region focused on conodont- and brachiopod-biostratigraphy and palaeoecology funded by Australian Research Council and Macquarie University research grants to JAT and Ruth Mawson. Postgraduate students participated in some these field ventures and, with an eye for trilobites, helped augment these collections. RF is grateful to Macquarie University for a research grant enabling him to undertake field work with JAT and Ruth Mawson and other MUCEP colleagues, particularly Brett Pyemont, Ken Bell and Ross Drury, focusing on a quest for trilobites. This considerably augmented the collections of this sparse component in the diverse faunas of the Broken River Group. We are indebted to Ruth Mawson for the conodont-based age determinations, Glenn Brock for sorting out the trilobites in the voluminous Broken River collections, Dean Oliver who made the drawings, Michel Pons (Montpellier) for printing the photographs of the trilobites, and to our anonymous reviewers for helpful suggestions. This is a contribution to ISEM, UMR 5554 CNRS (publ. 99-069) and to IGCP 421 *North Gondwana mid-Palaeozoic biovent/biogeography patterns in relation to crustal dynamics.*

APPENDIX: LOCALITY REGISTER

Locality numbers refer to locations on Figure 1.

LOCALITY 1. Uppermost Papilio Formation on stratigraphic section SD210 at spot–sample locality originally designated SD 43E. This locality (not shown on Mawson and Talent 1989, Figure 5) is in Storm Dam Creek where it meets the base of the Mytton Formation in the upper part of the widespread, approximately 1 m calcareous interval referred to by Mawson and Talent (1989) informally as the "Cinderella limestone".

Age: No older than late Givetian (*hermanni* Zone, conceivably *disparilis* or *norrisi* Zones).
Trilobites: *Phacops (Phacops) brocki* n. sp.

LOCALITY 2. Papilio Formation on stratigraphic section SD 128 of Mawson and Talent (1989). Trilobites obtained during initial sampling of the section, labelled interval B–C, from 50–70 m along a metric tape from the top of the Dosey Limestone.
Age: Latest Eifelian (*kockelianus* Zone) to possibly earliest Givetian (*hemiansatus* Zone).
Trilobites: *Scutellum tenuistriatum* n. sp.

LOCALITY 3. Undifferentiated Broken River Group on stratigraphic section Br 13B of Sloan *et al.* (1995: Table 8, Text–fig. 8). Section commenced at the top of the Shield Creek Formation and was oriented to cross a prominent 13 m limestone lens (Sloan *et al.* (1995) interpreted as a carbonate fan extending from the Dosey–Craigee Platform into the Burges Submarine Valley.
Age: Late Eifelian (*?australis* Zone).
Trilobites:
At 216 m: *Proetus* (*Devonoproetus*) *sparsinodosus* n. sp. Cornuproetinae gen. et sp. indet., This is approximately 2.3 m stratigraphically above the base of the fan.
At 214.5 m: *Astycoryphe* sp., *Phacops* sp., *Proetus (Devonoproetus) latimargo* n. sp. This is approximately 1 m above the base of the fan.

LOCALITY 4. Prominent carbonate interval in the undifferentiated Broken River Group interpreted as a carbonate fan extending northwards into the Burgess Submarine Valley (referred to informally as the "Fish Hill limestone") on stratigraphic section Br 15 of Sloan *et al.* (1995: Text-fig. 8, Tables 10A, 10B) at 348 m along a metric tape from the top of the Shield Creek Formation – approximately 8 m above the base of the "Fish Hill limestone".
Age: Latest Emsian (*patulus* Zone) or earliest Eifelian (*partitus* Zone).
Trilobites: *Burgesina mawsonae* n. sp., *Proetus (Devonoproetus) latimargo* n. sp., Proetinae gen. et sp. indet., *Otarion* sp.

LOCALITY 5. Spanner Limestone Member of Papilio Formation on stratigraphic section SD 216 of Mawson and Talent (1989), cf. Sloan *et al.* (1995: Table 6). Trilobites obtained from 145–146 m along a metric tape (equivalent to approximately 80 m thickness) from the base of the Spanner Member.
Age: Late Givetian (*hermanni* Zone or possibly slightly younger).
Trilobites: *Phacops (Phacops) brocki* n. sp.

LOCALITY 6. Low Mytton Formation, 24.7 to 30 m above the top of the Stanley Limestone Member

of the Papilio Formation, same horizon as producing charophytes (M. Feist *et al.* this volume).
Age: Postdating entry of *Icriodus symmetricus* and thus more likely early Frasnian rather than latest Givetian, but caution has been suggested (Mawson and Talent 1997).
Trilobites: *Aulacopleura* sp., Phacops sp.

LOCALITY 7. Undifferentiated Broken River Group mudrock in gully approximately 15 m east of the base of the "Fish Hill limestone" on sampled section Br 15 of Sloan *et al.* (1995).
Age: Late Emsian (*serotinus* Zone) – laterally equivalent to part of the Bracteata Formation farther south.
Trilobites: Phacopidae indet.

LOCALITY 8. Papilio Formation on stratigraphic section SD 130 of Mawson and Talent (1989). 223 m and 243 m along a metric tape above the top of the Dosey Limestone.
Age: Not well constrained by conodont data but stratigraphic position accords with late Givetian.
Trilobites:
At 223 m: *Phacops (Phacops) brocki* n. sp.
At 243 m: *Scutellum tenuistriatum* n. sp.

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