Significance of Late Cambrian (Idamean) Fossils in the Cupala Creek Formation, northwestern New South Wales

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Late Cambrian (Idamean) fossils occur about 22 km southeast of Nuntherungie station, northwestern New South Wales, in the upper part of a terrigenous, transgressive succession (Cupala Creek Formation — new name) lacking carbonates. The succession, about 1 km thick, consists of a basal conglomeratic unit overlain by red and grey sandstone, the latter containing brachiopods, which in turn is overlain by olive-grey siltstone containing trilobites and brachiopods. The basal part of the formation represents one of the first pulses of clastics derived from the rising Delamerian mountains to the south. Sedimentation was probably rapid from streams intermediate between braided and meandering sinuosity. The middle and upper parts of the formation are paralic and neritic, respectively.

The Cupala Creek Formation unconformably overlies the ?Vendian or Early Cambrian Copper Mine Range Beds, and is unconformably overlain by the ?Late Devonian Mulga Downs Group. The nearby Kandie Tank Limestone has the same stratigraphic relations as the Cupala Creek Formation, but is probably younger (post-Idamean — pre-Payntonian).

Six trilobite species, including one new genus, *Notoaphelaspis* Jell, gen. nov., and one new species, *N. orthocephalis* Jell, sp. nov., two brachiopods and a mollusc are described. The discovery of fossils in the Cupala Creek Formation demonstrates that the Copper Mine Range Beds were folded before the Late Cambrian. The Cupala Creek Formation was subsequently folded about southeasterly-trending axes between Late Cambrian and Late Devonian, and the whole succession was again folded, probably in the Carboniferous.

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Introduction

The White Cliffs 1:250,000 geological map (Rose *et al.*, 1964) shows a north-northwesterly-trending syncline on the northeastern side of, and truncated by, the more westerly-trending structure of Copper Mine Range. Sediments in the north-northwesterly trending syncline are marked as ?Proterozoic on the map, but suggested to be Lower Devonian in the explanatory notes (Rose, 1974) on the basis of correlation with rocks about 20 km south near Mt Daubney and Old Gnalta homestead where fragmentary plant remains had been found (Brown *in* Freeman, 1965; Neef *et al.*, in prep.). The overlying, more shallowly-dipping and westerly-trending quartzose sandstone and siltstone in Copper Mine Range were correlated by Rose (1974) with the Middle to Upper Devonian Mulga Downs Group further east. The structure thus indicated is a mid-Devonian unconformity (Webby, 1972; Evans, 1977), which two of us (Crane and Powell) set out to investigate as part of a more regional study of mid-Devonian tectonism.

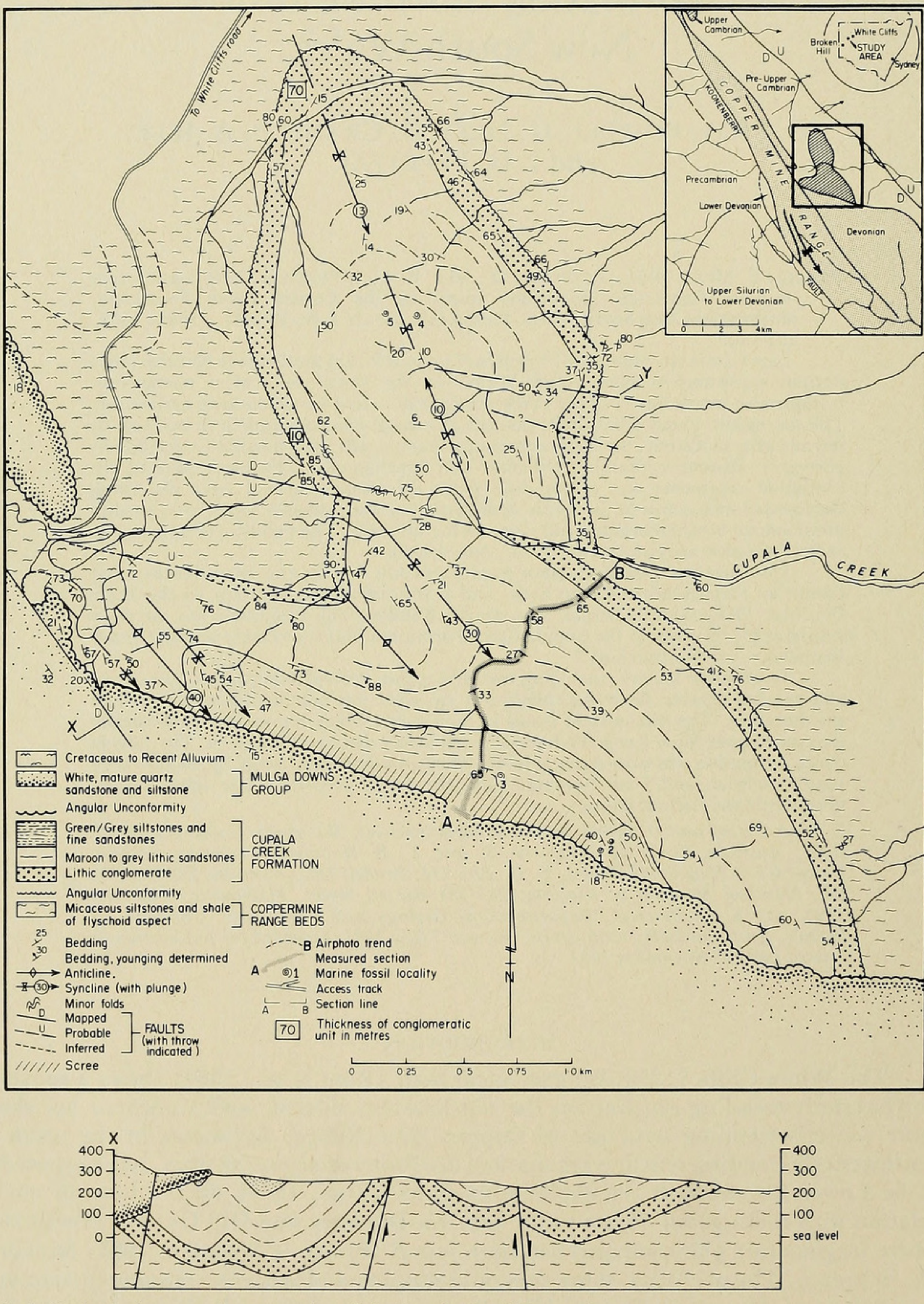


Fig. 1. Geological map and cross section of the Cupala Creek Formation.

Late Cambrian (Idamean) trilobites and brachiopods were found by Crane and Neef thus ruling out the correlation with the plant-bearing part of the Mt Daubney Beds (also known as the Cootawundy Beds, Pogson and Scheibner, 1971), which lie west of the Koonenberry Fault. Previous correlation of the two successions was tentative, on the basis of photogeological similarity (Rose *et al.*, 1964; Wilson, 1967). Three of us (Crane, Neef and Powell) mapped the area, examining the stratigraphy, sedimentology and structure, and searching for fossils. Jell described the trilobites and mollusc, and Percival the brachiopods. The main purpose of this paper is to document the occurrence of Idamean fossils and to point out their significance in determining the timing of regional deformation in northwestern New South Wales.

Cupala Creek Formation

The strata, herein named Cupala Creek Formation, are well exposed over an area of 4.5 km^2 in the dry tributaries at the headwaters of Cupala Creek, and there are also exposures in the low hills between the tributaries (Fig. 1). The structure (discussed in detail below) is a faulted syncline that plunges gently south-southeast and is erosionally truncated by mature quartzarenites of the overlying Mulga Downs Group (Fig. 2). Approximately 1 km of sediment is present in the southern part of the area, where the type section was measured (Fig. 3, A-B on Figs 1 and 2). The stratigraphic succession consists of a basal conglomeratic unit overlain by a sandstone unit in which a pale-grey sandstone is sandwiched between a lower and upper red sandstone. The top of the formation is an olive-grey siltstone interbedded with very fine sandstone. In the northern part of the area, only the conglomeratic and sandstone units are present.

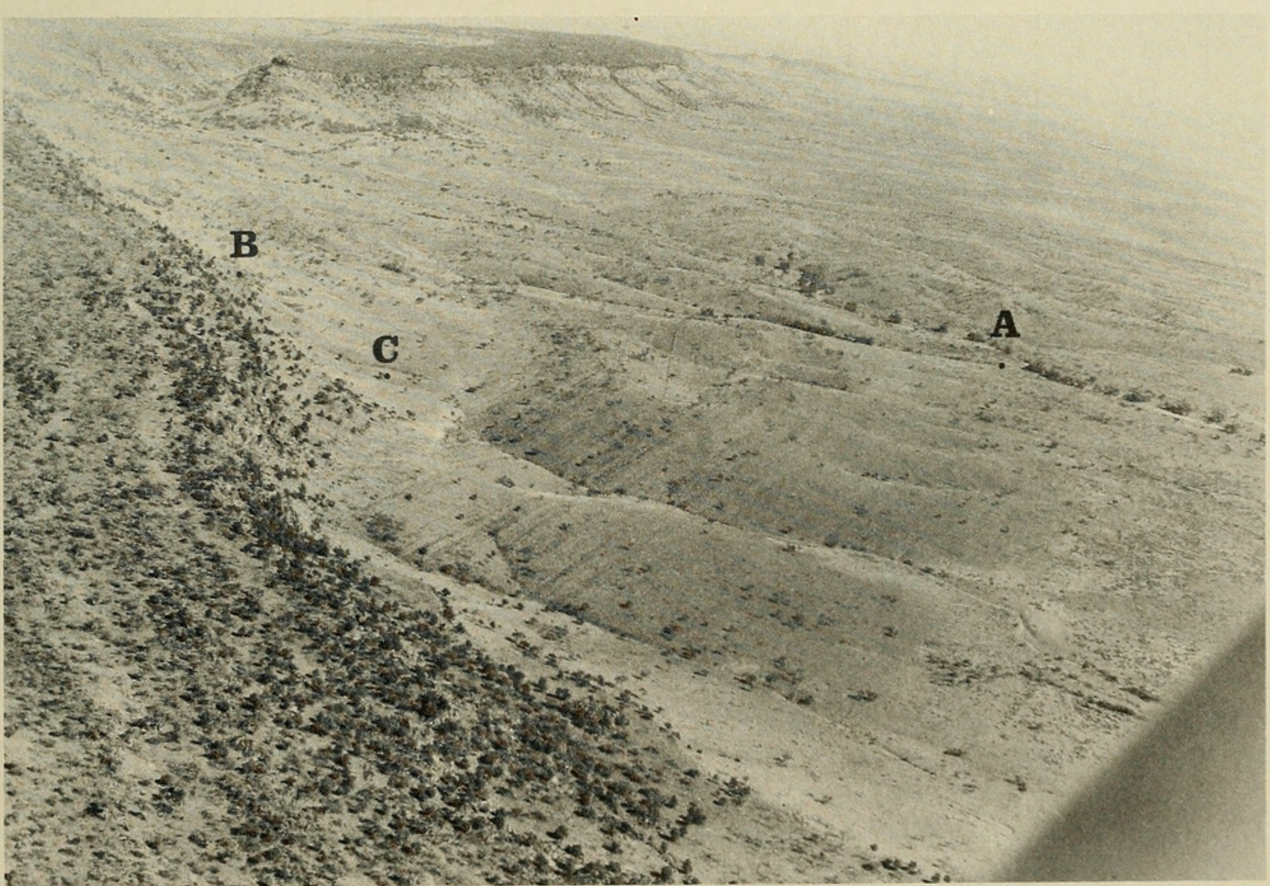


Fig. 2. Oblique aerial photograph, viewing north, shows steeply dipping Cupala Creek Formation overlain by gently dipping Mulga Downs Group. Type section is A-B, and Cupala Creek is in the centre background. The most fossiliferous locality containing numerous trilobites (1 in Fig. 1) is at C.

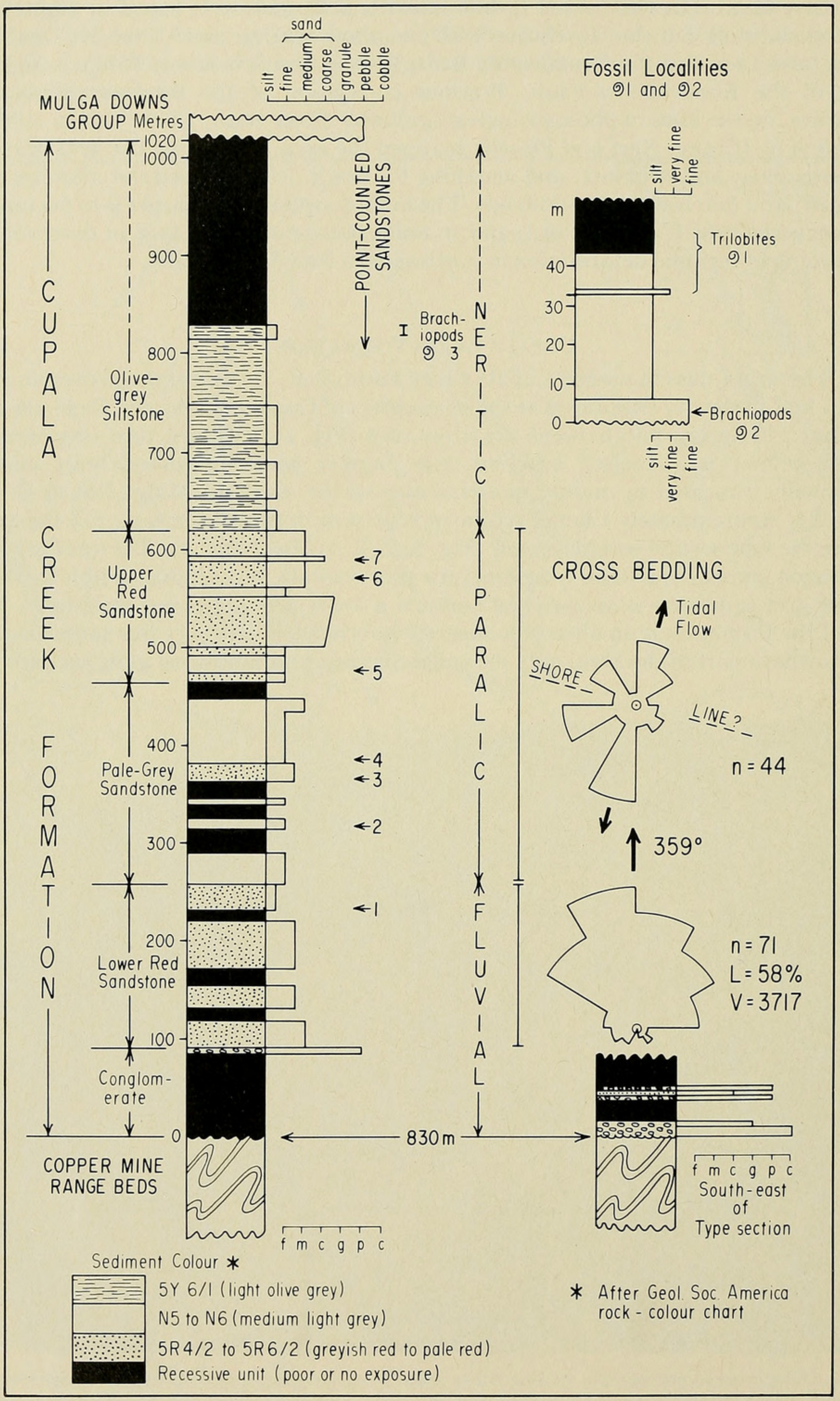


Fig. 3. Type section of the Cupala Creek Formation.

In the western part of the area, the pale-grey sandstone passes laterally into red sandstone, and the succession appears thinner than at the type section.

Conglomeratic Unit

Thickness of the conglomeratic unit varies from 10 m to approximately 90 m (see Fig. 1). The conglomerate is either clast-supported (Fig. 4), or matrix-supported. Locally, it is interbedded with lenses of coarse maroon sandstone. Clasts are generally rounded with a maximum length of 35 cm. Many of the clasts, and much of the matrix, have been derived from the underlying Copper Mine Range Beds, which, in this area, consist of thinly-bedded graded sandstones in a mudstone matrix. Other clasts are basic volcanics and quartz-veined chert.

Sandstone Unit

The conglomeratic unit interfingers with the overlying friable, medium- to fine-grained red sandstone with decimetre-scale crossbeds. In the type section, the red sandstone (170 m thick) is overlain by 235 m of light-grey fine- to medium-grained sandstone, which, in turn, is overlain by 125 m of medium- to locally coarse-grained red sandstone. This upper red sandstone is cross-bedded in places, but massive elsewhere, and reflects an interruption to the overall upward-fining trend of the formation. Seven samples from various levels in the sandstone unit (see Fig. 3) were point-counted, and all fall close to the feldspathic-litharenite field of Folk (1974) (Fig. 5). Plagioclase grains are present, and rock fragments are most commonly volcanogenic, with lesser amounts of sedimentary and tectonite grains. Much of the original porosity is infilled by quartz overgrowths, and some feldspar overgrowths are present. Carbonate and ferruginous cement also occur. There appears to be no petrological difference between the framework components of the red- and grey-coloured sandstone beds — the colour difference being caused by a ferruginous cement or coating on the grains in the red sandstone.

Siltstone Unit

The upper part of the formation is a pale, olive-grey siltstone with minor interbeds of very fine-grained sandstone. A 10 m thick fossiliferous zone occurs in the middle of the unit (about 800 m above the basal unconformity, Figs 1 and 3), and the best fossil collections were made from a nodular, micaceous, very fine sandstone about 600 m southeast of the type section (fossil locality 1, Fig. 1).

Environment of Deposition

The conglomeratic unit and lower red sandstone represent a fluvial mega-cycle in which the grain size decreases upwards. The orientation of cross-beds in sets generally 10 to 20 cm thick, but up to 60 cm thick, was taken wherever found, and the palaeocurrent direction was determined stereographically by rotating the regional bedding from each outcrop to horizontal using local fold axes and, where appropriate, fault traces. Seventy-one cross-beds in the lower red sandstone give a unimodal distribution with a vector mean of 359°, a consistency ratio of 58% and variance of 3717 (Fig. 3). The unimodal nature of the distribution together with the moderate variance is consistent with the lower red sandstone being deposited by streams intermediate between braided and meandering sinuosity.

In the pale-grey and upper red sandstone, 44 cross-bedding measurements define a polymodal distribution (Fig. 3). The cross-beds are generally inclined at a lower angle to the regional bedding than cross-beds in the lower red sandstone, and mutually-opposed current directions are common in single outcrops. The prominent bimodal distribution oriented NNE-SSW is approximately parallel to the northward-

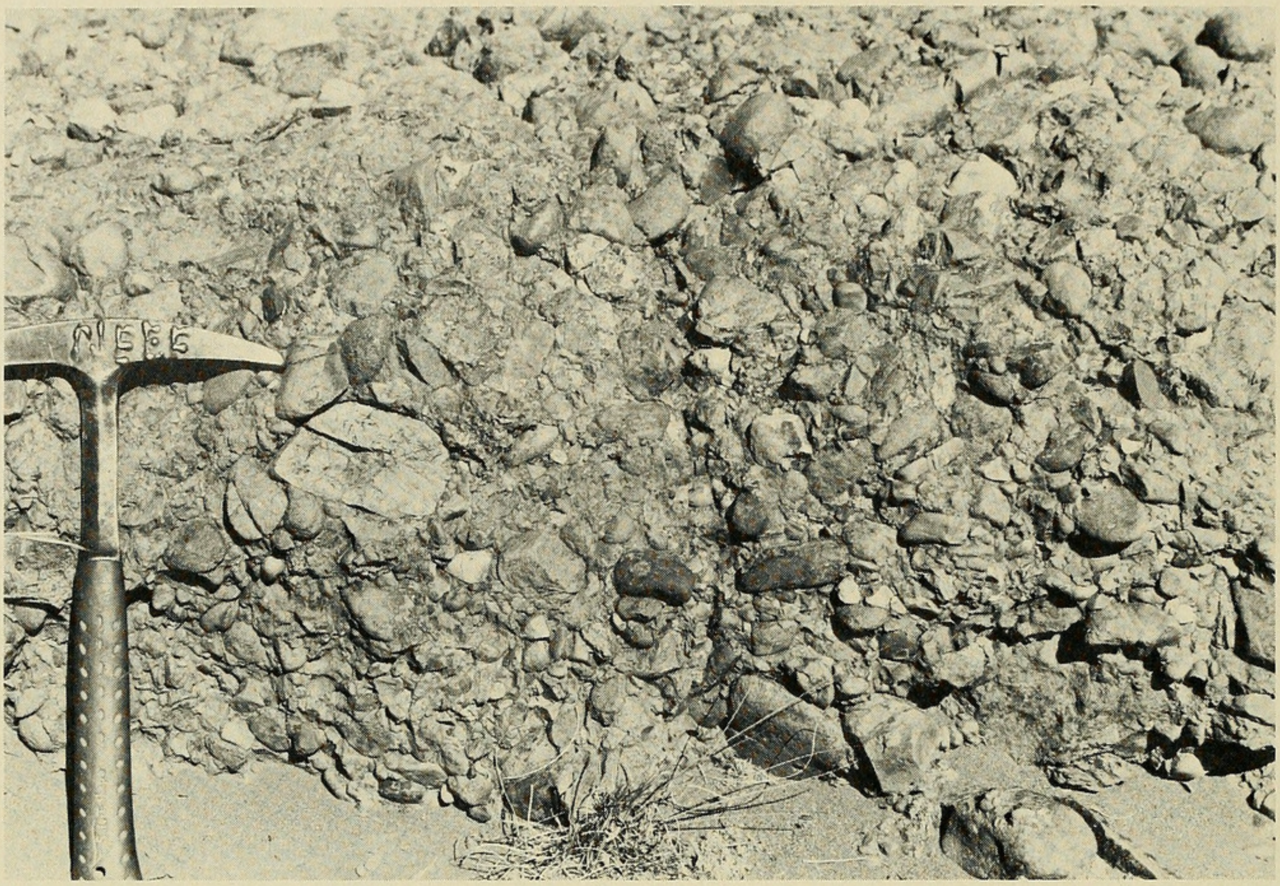


Fig. 4. Clast-supported massive conglomerate from the northernmost part of the Cupala Creek Formation (GR 6582 5794 Kayrunnera 1:100,000 Orthophotomap).

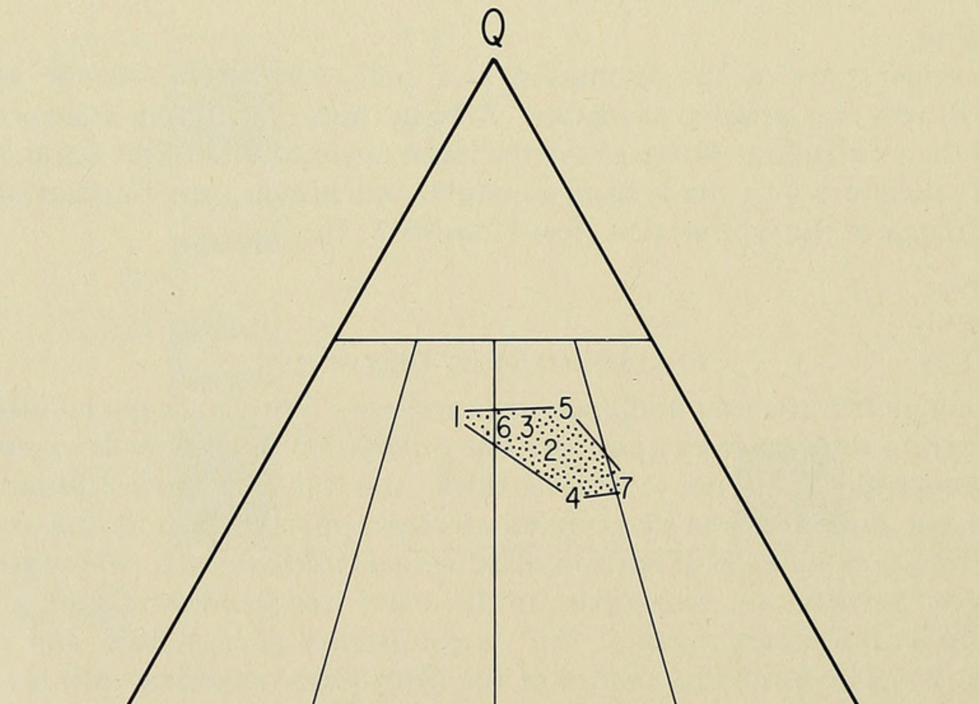


Fig. 5. QFR diagram for sandstones from Cupala Creek Formation. Specimens numbered in stratigraphic order on type section (Fig. 3).

dipping palaeoslope inferred from the orientation of the underlying fluvial cross-beds, and, in light of the marine environment indicated by the presence of brachiopods, probably represents on-shore off-shore tidal flow.

The depositional environment of the upper red sandstone is not clear. The coarser grain size than in the underlying pale-grey sandstone suggests that it might represent a transient fluvial influx interrupting the general transgressive trend. There are insufficient cross-bed measurements to determine whether current flow in the upper red sandstone is unimodal or bimodal. Marine fossils are absent, and only one ichnofossil was found.

The olive-grey siltstone, which contains trilobites and brachiopods, is clearly marine and its grainsize, sorting and absence of cross-bedding suggest that it was deposited in mid-neritic or deeper water.

Structure and Boundary Relationships

The Cupala Creek Formation is preserved in an open syncline offset by several 100°-trending faults near Cupala Creek (Fig. 1). North of Cupala Creek (Domains 1 and 2, Fig. 6), the structure is basinal, with fold axes plunging gently (10° to 13°) inward on a trend of 144°. Faults near Cupala Creek, and just south of it, define a horst-like basement structure (cross-section, Fig. 1), and several mesoscopic folds are developed parallel to the fault planes (Fig. 7). South of Cupala Creek there are several parasitic folds (150 m to 600 m wavelength) with a general fold axis plunging moderately southeast (Domains 3 and 4, Fig. 6).

The overlying Mulga Downs Group dips gently south-southwest at 15° to 20°, and is not affected by the southeast-trending folds in the Cupala Creek Formation. Angular discordances across the unconformity range up to 110° (i.e. overturned beds dipping steeply west-southwest), and thus most of the present structure of the Cupala Creek Formation was acquired before the Mulga Downs Group was deposited. Post-folding rotation on the 100°-trending faults may account for the discrepancy in fold-axis orientation between the areas north and south of Cupala Creek, as shown by Fig. 6(e) where removal of the tilt on the Mulga Downs Group rotates the fold axes in the southern domains closer to the orientation of fold axes in the northern domains. The pre-Mulga Downs fold axis in the Cupala Creek Formation thus trended around 144°, with slightly overturned western limbs and axial surfaces dipping steeply west.

The unconformity between the Cupala Creek Formation and the underlying Copper Mine Range Beds is exposed in the creek cutting the northwestern tip of the syncline, and can be narrowed to a zone of non-exposure of less than 5 m in several other places. Calculated angular discordances across these localities vary up to 131° (i.e. an overturned bed dipping 49°), indicating that Copper Mine Range Beds were highly folded prior to the deposition of Cupala Creek Formation. Attempts to calculate a pre-Late Cambrian fold axis in Copper Mine Range Beds from bedding couplets measured on either side of the unconformity using the method of Powell *et al.* (1978) were inconclusive.

Age

Several trilobite species occur about 800 m above the base of the formation (Table 1, Fig. 3). The occurrence of *Stigmatoa tysoni* with *Pseudagnostus idalis* and aphelaspids indicates a *Glyptagnostus reticulatus* to *Erixanium sentum* Zone range. The species of *Prismenaspis,* somewhat similar to *propinquum,* and *Aphelaspis* resembling *australis* vaguely suggest the Zone of *Proceratopyge cryptica* in the biostratigraphic scale outlined by Henderson (1976) for western Queensland. This is

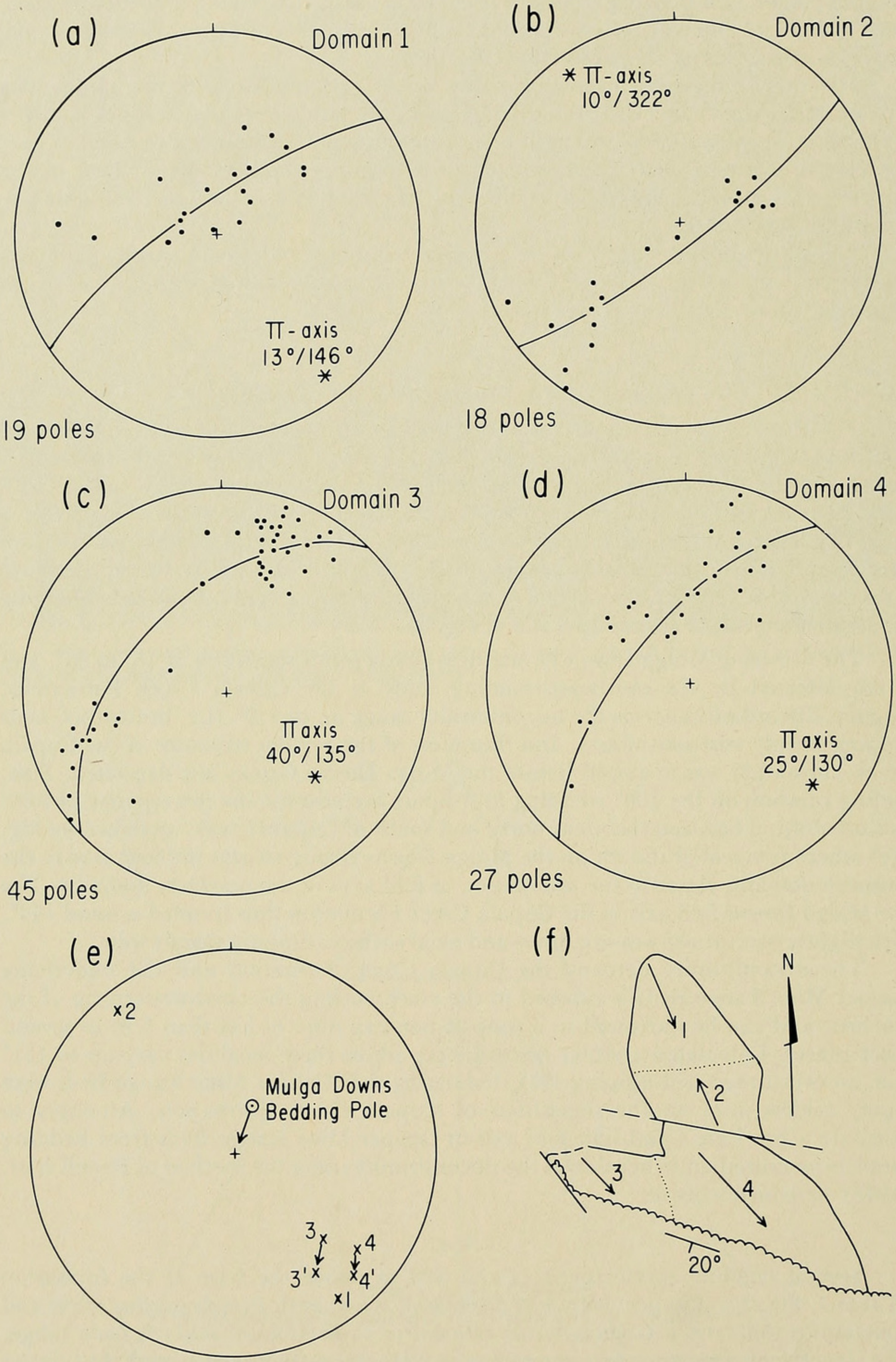


Fig. 6. Equal-area stereograms. (a) to (d) Bedding-pole data from 4 domains in Cupala Creek Formation. (e) Restoration of fold axes in domains 3 and 4 to pre-Mulga Downs Group attitude. (f) Map of domains.

Fig. 7. Minor fold in Copper Mine Range Beds. Fold axis parallel to 100°-trending faults is considered to be associated with post-Mulga Downs Group deformation (GR 6581 5779 Kayrunnera 1:100,000 Orthopotomap).

not a positive correlation but is the most probable using the material available. The age is certainly within the range of the *Glyptagnostus reticulatus* to *Irvingella tropica* Zones (i.e. the Idamean Stage).

The most common fossil present in the Cupala Creek Formation is the orthide brachiopod *Billingsella* sp., which is consistent with, but not diagnostic of the Idamean Stage.

TABLE 1

Faunal List

Trilobites

Pseudagnostus sp. aff. *idalis* Öpik, 1967
Stigmatoa tysoni Öpik, 1963
Notoaphelaspis orthocephalis gen. et sp. nov.
Notoaphelaspis sp. cf. N. *orthocephalis* gen. et sp. nov.
(?) *Aphelaspis* sp. aff. *A. australis* Henderson, 1976
(?) *Prismenaspis* sp. nov.

Mollusc

Proplina sp.

Brachiopod

Billingsella sp.

Other poorly-preserved forms include a sponge and a hyolithid.

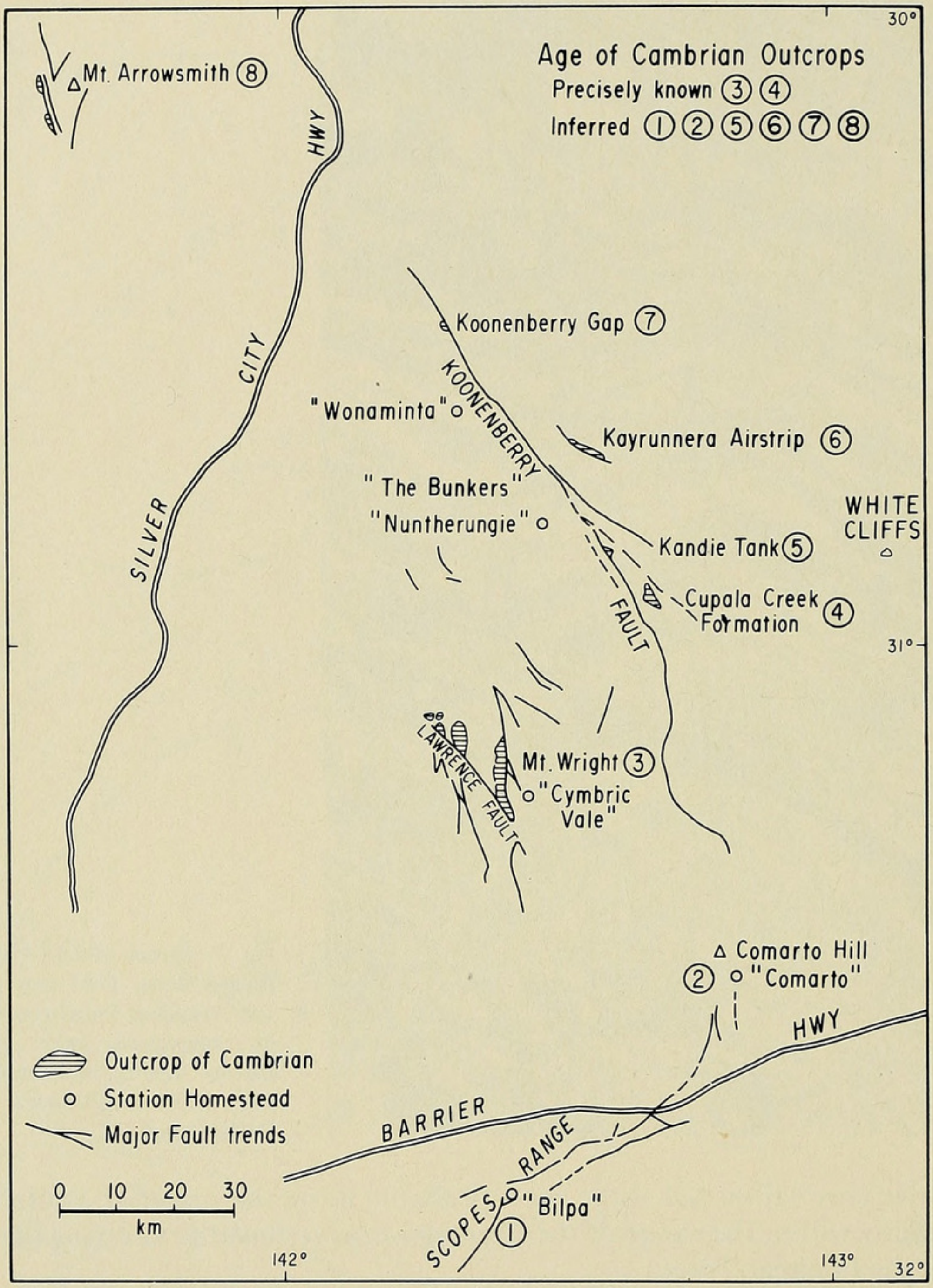


Fig. 8. Distribution of Cambrian strata in northwestern New South Wales.

Cambrian Deposits in northwestern New South Wales

Cambrian strata are known from at least seven other areas in northwestern New South Wales (Rose and Brunker, 1969; Warris, 1967; Wopfner, 1966; and, more recently, Neef, unpub. data) (Fig. 8). A precise age to zone or stage level is known for two of these areas, and the age of the others is inferred by lithological correlation. Fig. 9 summarizes the present stage of knowledge.

Cambrian deposits are most extensive near Mt Wright where Early to earliest Middle Cambrian limestone, shale and volcanics are separated from latest Cambrian strata by an unconformity (Öpik, 1975; Kruse, 1978). Early Ordovician strata of the Mt Wright district can be traced southward to the Scopes Range (near Bilpa station) so that the underlying conformable strata are probably Late Cambrian (Rose and Brunker, 1969). The stratigraphic relationship of Early or Middle Cambrian

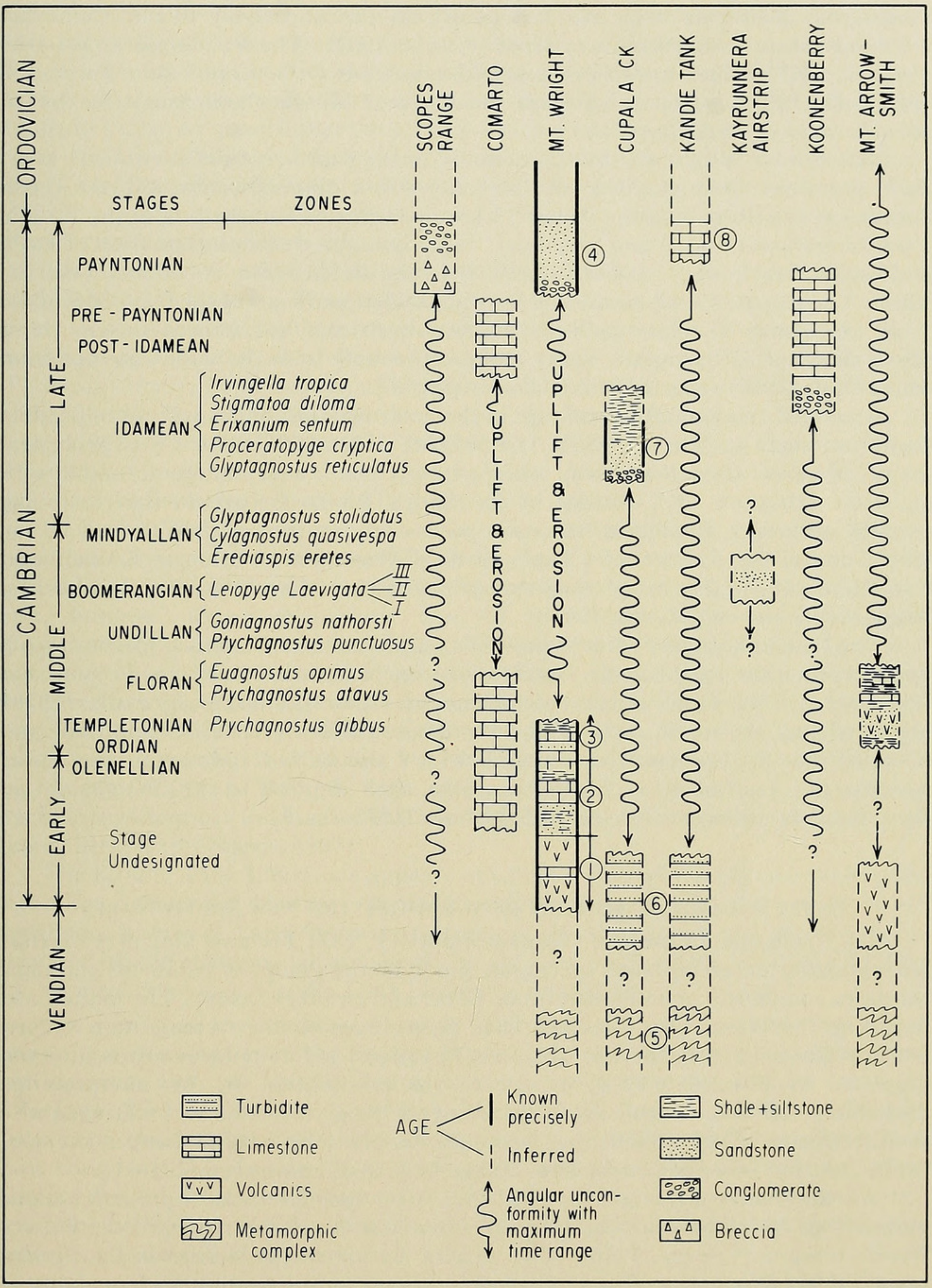


Fig. 9. Cambrian biostratigraphy of northwestern New South Wales, from Henderson (1976), Shergold (1971), and Öpik (1968). Age of Cambrian strata from Öpik (1968), Shergold (1971), Warris (1967), Wopfner (1966) and Jell (unpub. data). Circled numbers refer to the following formations. 1, Mount Wright Volcanics; 2, Cymbric Vale Formation; 3, Coonigan Formation; 4, Nootumbulla Sandstone; 5, Wonaminta Complex; 6, Copper Mine Range Beds; 7, Cupala Creek Formation; 8, Kandie Tank Limestone. Middle Cambrian is used in the sense of Öpik (1968), and Late Cambrian in the sense of Daily and Jago (1975).

fossiliferous sediments near Mt Arrowsmith to the underlying ?Early Cambrian volcanics is unknown (Wopfner, 1966; Warris, 1967). The Yandaminta Quartzite (Warris, 1967), which underlies the fossiliferous Early Ordovician Tabita Formation (Shergold, 1971), is separated from the Early or Middle Cambrian strata by an unconformity at Mt Arrowsmith.

Between Mt Wright and Mt Arrowsmith, in the Nuntherungie-Kayrunnera area, there are three isolated areas of Cambrian strata (including the Cupala Creek Formation described herein). About 13 km southeast of Nuntherungie, the Kandie Tank Limestone (Pogson and Scheibner, 1971) contains the latest Cambrian or Early Ordovician brachiopod, *Linnarssonella* sp., and distacodont conodonts (Warris, 1967). The Cupala Creek Formation lies about 9 km southeast of the exposed Kandie Tank Limestone. Trilobites collected by Neef from near Kayrunnera airstrip are of Mindyallan age (Jell, unpub. work) and are probably from the same outcrops from which Öpik (1966) reported Mindyallan trilobites.

Rose (1974) reported *Lingula* sp. in the lower beds of a small outcrop of possible Cambrian rock at 'The Bunkers' (GR557194, 1:250,000 White Cliffs geological map); however, these lower beds are apparently continuous and conformable with quartzose sandstone and siltstone of the Mulga Downs Group, so that their age remains uncertain. Cambrian strata are present in a narrow graben formed by the bifurcation of the Koonenberry Fault north of Wonaminta station at Koonenberry Gap. Here a ?Late Cambrian conglomerate and a ?Late Cambrian hyolithid-bearing limestone are known (Warris, 1967).

The flyschoid Copper Mine Range Beds, which unconformably underlie Cupala Creek Formation and Kandie Tank Limestone, are considered by Pogson and Scheibner (1971) to be either Adelaidean or Early Cambrian. Edwards (1978) suggested that the mafic rocks of the Wonaminta Block are Early Cambrian, and reasoned that the Copper Mine Range Beds are also Early Cambrian in age – i.e. deeper-water equivalent of Early Cambrian shelf deposits at Mt Wright – an interpretation consistent with that of Scheibner (1973, fig. 7).

Early Palaeozoic History of northwestern New South Wales

The Wonaminta Complex (Wonaminta Block, 1971 Tectonic Map of Australia) is a regionally metamorphosed succession (up to biotite grade) of sediments and some volcanics considered to be Precambrian (Rose and Brunker, 1969). The mafic rocks intruding the Wonaminta Complex have been shown on the tectonic map of New South Wales as Early Palaeozoic island-arc intrusives, and a similar interpretation was suggested by Edwards (1978) as one of the possibilities. In this interpretation (Scheibner, 1973) a volcanic arc in the west (Mt Wright volcanic arc) is fringed with shelf sediments (Gnalta Shelf) and a fore-arc terrace (White Cliffs Deeper Terrace) to the east, and here the Copper Mine Range Beds would have accumulated.

An alternative hypothesis is that the mafic igneous rocks represent basaltic outpourings associated with the Vendian or earliest Cambrian rifting of the Palaeo-Pacific margin (Veevers, 1976). The alkaline nature of the basalts on the western margin of the Wonaminta Block (Edwards, 1978) is consistent with this hypothesis, in which case the Copper Mine Range Beds would be turbidites on a passive, divergent continental margin.

No matter which model of the Early Cambrian palaeogeography is correct, the Copper Mine Range Beds (clasts of which occur in the basal Cupala Creek Formation) were highly folded and eroded before the Idamean. The age of this folding cannot be constrained more tightly than latest Precambrian to earliest Late

Cambrian from the Cupala Creek area, because of the uncertain age of the Copper Mine Range Beds. Other stratigraphic successions in northwestern New South Wales (Fig. 9) show a paucity of Mindyallan and Idamean deposits. Admittedly, the lacunae in each of the stratigraphic successions are of differing magnitudes, but if, for argument's sake, we assume that the uplift associated was broadly synchronous for this region (50 km × 200 km), the uplift occurred either in the Undillan to Mindyallan stages (the Mootwingee Movement of Webby, 1978) or in the latest Precambrian. The importance of the Cupala Creek Formation in this interpretation is that it marks the upper limit of the age of the uplift.

Scheibner (1976, p.141; 1978) concluded that deformation in northwestern New South Wales (Delamerian Orogeny) started in late Early Cambrian time. Further afield, in southeastern South Australia, deformation and uplift began in the Late Cambrian and continued with increasing intensity into the Early Ordovician (Thomson, 1969). In Tasmania, uplift with deformation (Tyennan Orogeny) began in the Middle Cambrian and continued into the Early Ordovician (Campana *in* Banks, 1962; Williams, 1978). The possible late Middle to earliest Late Cambrian deformation in northwestern New South Wales would correlate with the early movements in the Delamerian Fold Belt of Rutland (1976).

In the Mt Wright area, the contact between the latest Early to earliest Middle Cambrian Coonigan Formation and the conglomeratic Late Cambrian Nootumbulla Sandstone, is paraconformable north of the Lawrence Fault (Fig. 8). South of the fault, however, the conglomeratic base of the Nootumbulla Sandstone rests disconformably on the Early Cambrian Cymbric Vale Formation, the Coonigan Formation having been removed by mid-Cambrian erosion (Leu, 1980). Abundant grey-green sandstone clasts (possibly derived from the Early Cambrian Cymbric Vale Formation of the Mt Wright area) in the basal conglomeratic unit of Cupala Creek Formation, suggest that the Cymbric Vale Formation may have been deeply eroded in the Idamean. Clasts of Cymbric Vale-type sediment, and limestone clasts bearing brachiopods identical to those of the overlying Coonigan Formation, also occur at Koonenberry Gap (Warris, 1967).

The Kandie Tank Limestone appears to be Early Ordovician because it contains distacodont conodonts. However, the fossil evidence is not strong, and in view of the terrigenous nature of Early Ordovician strata at Mt Arrowsmith and Mt Wright in contrast with the limestone facies inferred for the Late Cambrian in the Comarto Hills and Koonenberry areas, Kandie Tank Limestone may be Late Cambrian.

The timing of the southeast-trending folding of the Cupala Creek Formation cannot be constrained from the Copper Mine Range area any more accurately than post-Idamean and pre-Mulga Downs Group (assumed to be Middle or Late Devonian). Webby (1978) suggested that, during the latest Cambrian and Early Ordovician, clastics were deposited from northward- and eastward-flowing rivers in a delta complex. The Cupala Creek Formation represents an early pulse of these clastics, derived from the Delamerian Mountains rising to the south and west. According to Webby (1978) these clastics were probably deformed in the Middle Ordovician Dulingari Movement.

The last folding occurred after the Mulga Downs Group was deposited. These open folds, commonly with nearly vertical to slightly overturned dips on the western limb of the syncline adjacent to the Koonenberry Fault, and gentle (15° to 50°) dips on the eastern limb, probably occurred during the Carboniferous when the rest of the Lachlan Fold Belt was similarly folded (Powell *et al.*, 1980). Tilting, rotation and minor folding associated with the steep faults trending 100° occurred in the Cupala Creek Formation at this time.

SYSTEMATIC PALAEONTOLOGY

The trilobites and mollusc were collected from locality 1, and brachiopods from localities 2-5 (Fig. 1). Trilobite debris is also present at locality 3. All described material is housed in the Palaeontological Collection of the National Museum of Victoria (numbers prefixed P).

ARTHROPODA (P.A.J.)

Class TRILOBITA Walsh, 1771

Order MIOMERA Jaekel, 1909

Superfamily AGNOSTOIDEA McCoy, 1849

Family DIPLAGNOSTIDAE Whitehouse, 1936

Subfamily PSEUDAGNOSTINAE Whitehouse, 1936

Genus *PSEUDAGNOSTUS* Jaekel, 1909

Pseudagnostus sp. aff. *idalis* Öpik, 1967

Fig. 10, 1, 2

Material: One cranidium P61493 and one pygidium P61494.

Discussion: This species is related to *P. idalis* in the squarish glabellar anterior and weak median preglabellar furrow, in the shape of the basal glabellar lobes and in the wide border furrow. In the pygidium the shape of the posterior of the deuterolobe is particularly reminiscent of *P. idalis* and the extremely wide border furrow and narrow pleural area are also similarities.

The preservation of this material is too inferior for positive specific identification but enough morphology is revealed to indicate a resemblance to *P. idalis*.

Order POLYMERA Jaekel, 1909

Superfamily PTYCHOPARIOIDEA Matthew, 1887

Family EULOMATIDAE Kobayashi, 1955

Genus *STIGMATOA* Öpik, 1963

Stigmatoa tysoni Öpik, 1963

Fig. 10, 3-6

1963 *Stigmatoa tysoni* Öpik, p.92, pl. 4, fig. 3

1976 *Stigmatoa tysoni* Henderson, p.354, pl. 51, figs 8, 9

Material: One well-preserved (P61496) and three damaged (P61495, 61497 and 61498) cranidia.

Dimensions: Cranidial lengths range from 4 to 7 mm.

Diagnosis: As given by Henderson (1976) and Öpik (1963).

Discussion: There can be no doubt that this material belongs to *S. tysoni*; glabellar furrows, occipital ring and palpebral areas are all distinctive.

Fig. 10. **1, 2,** *Pseudagnostus* sp. aff. *idalis* Öpik, 1967. **1,** internal mould of cephalon, P61493, x7.2; **2,** damaged internal mould of pygidium, P61494, x7.2.

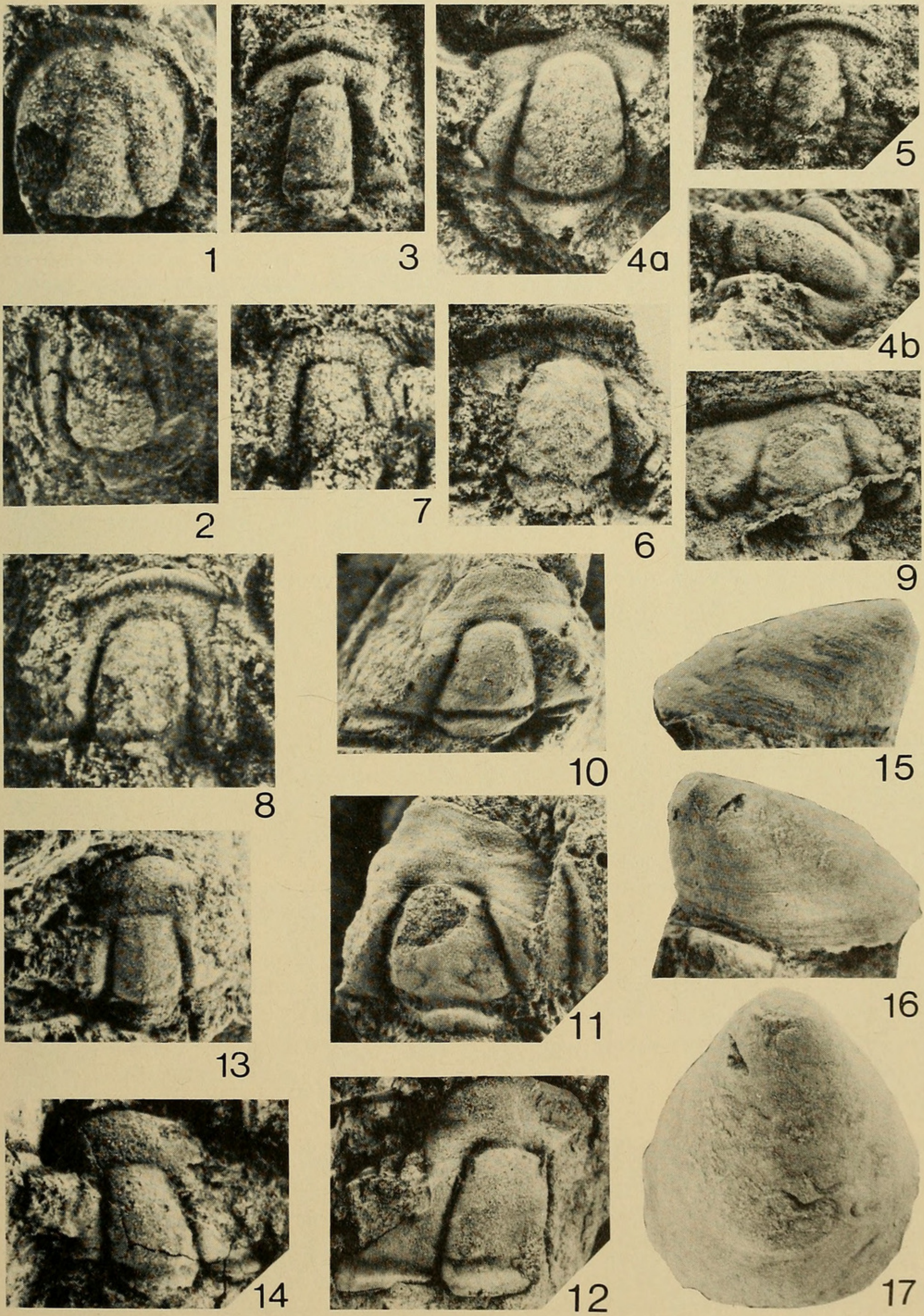
3-6. *Stigmatoa tysoni* Öpik, 1963. **3,** badly damaged and deformed cranidium P64195, x7.2; **4 a, b,** dorsal and right anterolateral oblique views of internal cranidial mould, P61496, x5.4.; **5,** internal mould of damaged cranidium, P61497, x3.6; **6,** internal mould of damaged cranidium, P61498, x5.4

7, 8. ? *Aphelaspis* sp. aff. *A. australis* Henderson, 1976. Internal moulds of damaged cranidia, P61499 and 61500, x6.3 and x7.2 respectively.

9-12. *Prismenaspis*? sp. nov. **9,** latex cast of damaged and tectonically shortened cranidium P61501, x2.7; **10-12,** internal moulds of damaged and distorted cranidia, P61502, 61503 and 61504, x2.7.

13, 14. Genus and species indeterminate. Internal moulds of damaged distorted cranidia P61505 and 61506, x3.6.

15-17. *Proplina* sp. Right and left anterolateral and dorsal views of internal mould, P61507, x1.8.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Family PTEROCEPHALIIDAE Kobayashi, 1935
Subfamily APHELASPIDINAE Palmer, 1960
Genus *APHELASPIS* Resser, 1935

Type species: *A. walcotti* Resser 1938, p.59, pl. 13, fig. 14.
Diagnosis: As given by Palmer (1965, p.58) with the addition made by Henderson (1976, p.345 in remarks on *Eugonocare*) that the interocular width approximately equals cranidial length.
Discussion: In Australia this genus is represented by *A. australis* Henderson (1976, p.342, pl. 49, figs. 5-7) and by a species from limestone in eastern Victoria (Thomas and Singleton, 1956). A case could be made to exclude *australis* from *Aphelaspis* on the basis of its very much shorter frontal area, its well impressed glabellar furrows, its longer palpebral lobes, and its more rounded glabellar anterior. I consider that it should remain in *Aphelaspis* but that it is a distant relative of the North American species described to date including *A. brachyphasis* Palmer, 1962 which Henderson considered the 'nearest match'. Future detailed work on Australian faunas of this age may well show that *australis* belongs to a lineage quite separate from the North American *Aphelaspis*. For the present it is placed in *Aphelaspis* as is the material compared with it herein.

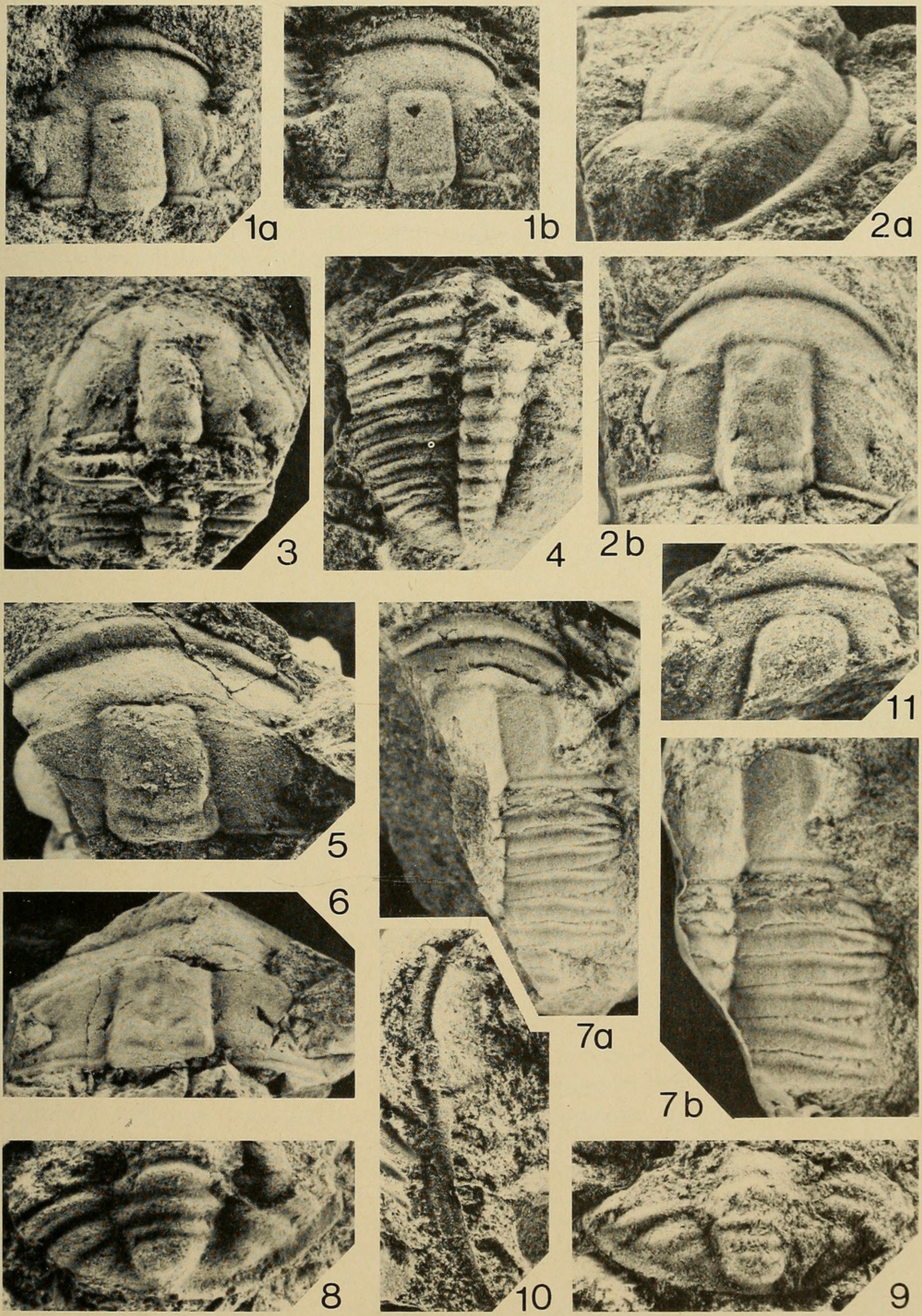
?Aphelaspis sp. aff. *A. australis* Henderson, 1976
Fig. 10, 7, 8

Material: Two poorly preserved, damaged internal moulds of cranidia, P61499 and 61500.
Description: Cranidium approximately as long as interocular width which is slightly compressed. Glabella slightly tapering, anteriorly truncated, with almost straight sides. Axial furrow well impressed but slightly shallower anteriorly. Frontal area short (approximately 40% of glabellar length). Border furrow shallow. Border short and convex, of uniform length except where the facial sutures cut across it. Interocular cheeks narrow. Palpebral lobes elongate, slightly raised and opposite middle of glabella.
Discussion: These specimens resemble *Aphelaspis australis* in their short frontal area measuring 40% of glabellar length and in their elongate palpebral lobes. They also resemble *?Aphelaspis* sp. B. of Öpik, 1963 in the type of border, glabellar shape, short frontal area and narrow interocular cheeks. However, their poor preservation and ignorance of the rest of the exoskeleton make closer identification impossible.

Family PTEROCEPHALIIDAE Kobayashi, 1935
Genus *NOTOAPHELASPIS* gen. nov.

Etymology: *Notios* Gr. southern, with North American genus name *Aphelaspis* (from *apheles* Gr. smooth).

Fig. 11. **1-10.** *Notoaphelaspis orthocephalis* gen. et. sp. nov. **1a**, latex of cranidium, **1b** internal mould of same cranidium P61508, x3.2 (approx.); **2a**, right anterolateral oblique view and, **2b**, dorsal view of internal mould of holotype cranidium P61509, x2.2; **3**, internal mould of cranidium with fixed cheeks only slightly displaced and three thoracic segments P61510, x1.4; **4**, internal moulds of damaged thorax and pygidium, P61511, x1.8; **5**, **6**, internal moulds of damaged cranidia P61512 and 61513, x1.8 and x1.4 respectively; **7a** internal mould and **7b**, latex cast from external mould of damaged cranidium and partial thorax P61514, x1.8; **8**, **9**, internal moulds of damaged cranidia P61515, 61516, x2.7; **10**, internal mould of free cheek broken down genal spine to reveal the external mould of the ventral surface P61517, x3.2.
11. *Notoaphelaspis* sp. cf. *N. orthocephalis* gen. et sp. nov. internal mould of incomplete cranidium P61518, x2.7.


1a
1b
2a
3
4
2b
11
5
6
7a
7b
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9

Type species: *N. orthocephalis* gen. et sp. nov.

Diagnosis: Aphelaspid with rectangular glabella, wide interocular cheeks, transverse eye ridges, anteriorly placed palpebral lobes, long downsloping preglabellar field, well impressed anterior border furrow, medially elongate anterior border, non-spinose pleural tips, and transverse, non-spinose pygidium.

Discussion: Although this species could, with some difficulty, be placed in *Aphelaspis* the combination outlined above is quite unlike any known species of that genus and the eye lines, glabellar shape and deep border furrow are particularly distinctive. It has no close relatives in North America. *Eugonocare* Whitehouse, 1939 is distinguished by its broader glabella with sloping lateral furrows, anterior border, more sloping eye ridges and longer pygidium. Its glabella and the furrows thereon are extremely similar to those of *Erixanium* which are themselves very distinctive among trilobites. The major differences between *N. orthocephalis* and *E. sentum* are the glabella shape, cephalic border, pleural tips and the pygidium. In view of the marked changes in pleural tip and pygidial morphology along an aphelaspid lineage (Palmer, 1965) the possibility that *N. orthocephalis* is an earlier member of the *Erixanium* lineage (and therefore a member of the Erixaniidae) should not be overlooked. Such placement would require considerable expansion of the Family concept given by Öpik (1963).

Notoaphelaspis orthocephalis sp. nov.

Fig. 11, 1-10

Etymology: *Orthos* Gr. right (angled) ; *kephale* Gr. head; for the angular glabella.

Holotype: P61509.

Other material: Several cranidia, two thoraxes, one free cheek and two pygidia including the paratypes P61508 and P61510-61517.

Diagnosis: Up to 8 cm in cephalic length. Cranidial length and interocular width approximately equal. Glabella rectangular, two-thirds cephalic length, with angular anterolateral corners and truncated anterior, with occipital furrow poorly impressed axially but not reaching axial furrow, with three pairs of very weakly impressed glabellar furrows as circular depressions on either side of axis, well separated from axial furrow. Preglabellar field relatively long, down sloping and slightly swollen in front of glabella. Anterior border furrow well impressed. Anterior border convex and expanded medially. Each interocular cheek as wide as glabella at midlength of relatively long arcuate slightly upturned palpebral lobes. Eye ridges transverse; very slightly posteriorly directed laterally in a few specimens. Facial sutures diverging anteriorly from palpebral lobe at about 45° posteriorly running laterally at a low angle to the transverse line so that the posterior part of the fixed cheek is short and wide. Posterior border furrow distinct, of almost constant length throughout, defining a short convex border also of constant length. Free cheek with convex genal field, well impressed border furrow, and long slender slightly incurved genal spine that continues the curve of the lateral margin. Thorax of at least 9 segments (no complete thorax available). Axis highly arched and relatively narrow. Axial furrow simply a change of slope. Articulating line about mid-width of each pleural area. Articulating facet very wide, steep and flat. Pleural furrows prominent occupying most of the pleural area. Anterior and posterior pleural margins parallel. Pygidium transverse, twice as wide as long, moderately convex with axis standing above pleural areas. Axis of three rings and a posteriorly rounded terminus that interrupts the border furrow. Pleural areas convex, crossed by three pleural and one interpleural (including anterior border furrow) furrows. Border furrow weakly impressed but not impressed at all behind the axis. Border widening anteriorly, not present behind the axis. The margin forms a smooth arc, except behind the axis where it is excavated to the extent that it comes very close to the axis.

Discussion: The material figured here is in a coarse matrix, is tectonically distorted to some degree in each specimen and is mainly of damaged internal moulds but the morphology available is so distinctive as outlined under discussion of the genus as to demand a separate taxonomic name. Comparison with any existing species is superfluous. The sample is too small to determine any intraspecific variation and no morphogenetic variation is visible over the size range available. As discussed below the small cranidium (Fig. 11, 7) could possibly be a juvenile of this species although this is a remote chance.

Notoaphelaspis sp. cf. *N. orthocephalis* sp. nov.

Fig. 11, 11

Material: One fragmentary cephalon P61518.

Discussion: This specimen differs from *N. orthocephalis* in that its anterior border does not taper laterally, its preglabellar field is shorter and its interocular cheeks are relatively narrower.

Family UNCERTAIN

Genus *PRISMENASPIS* Henderson, 1976

Prismenaspis? sp. nov.

Fig. 10, 9-12

Material: Six cranidia in various degrees of distortion due to deformation, including P61501-61504.

Description: Moderately large cranidium (up to 1.5 cm long) approximately as wide as long with broad squat anteriorly tapering glabella just over half cranidial length. Glabellar furrows not well impressed but 1P connected adaxially to 2P in at least one specimen (Fig. 10, 11). Occipital ring tapering laterally and with an almost imperceptible median node. Axial furrow well impressed with a marked pair of fossulae in front of the glabella adaxial to the rounded anterolateral corners. Preglabellar field slightly inflated medially, short and not distinguished from an almost indiscernible, long, shallow, border furrow which in turn is not separated from a long, flat, medially inflated border that tapers laterally and bears a low but distinct transverse ridge that may or may not correspond to the edge of the doublure. Eye ridges well defined and running posterolaterally to short wide, kidney-shaped palpebral lobes. Facial sutures diverging slightly forward and sloping posteriorly behind the palpebral lobe. Posterior portion of fixed cheek triangular, crossed by long border furrow that runs forward laterally to leave a lengthening and flattening posterior border.

Discussion: The state of preservation and small number of specimens make identification of this with any existing species impossible but it does not appear to be similar to any existing taxon. Even at the generic level the assignment to *Prismenaspis* is very tentative and requires expansion of that genus to include apparently unornamented species. This is in conflict with Henderson's concept of the genus as he stressed the pustulose ornament on both internal moulds and external surfaces. However, related genera such as *Dunderburgia* encompass smooth and ornamented species. Moreover, Henderson described four pairs of lateral glabellar furrows in *Prismenaspis* but material of the New South Wales species is too poorly preserved to see any but the 1P glabellar furrows. Glabellar shape, well-impressed axial furrow with prominent fossulae, narrow interocular cheeks, wide posterior portion of the fixed cheeks, position and length of palpebral lobes, and most importantly, the flat frontal area relate this species to *Prismenaspis*. *Prismenaspis propinquum* is the most closely related species but differs in ornament, glabellar shape and lack of transverse ridge on anterior border. As with *Prismenaspis* there are several younger Siberian genera described by Rozova (1968, 1977) that appear similar, including *Ketyna, Monosulcatina, Mansiella,* and *Maduiya* but the comparisons are obscured by the states of preservation and incomplete information.

Genus and species indeterminate

Fig. 10, 13, 14

Material: Two damaged cranidia P61505 and 61506.

Description: Small cranidium longer than wide with subrectangular glabella having only very slightly tapering sides, angular anterolateral corners, and no furrows impressed. Axial furrow well impressed, without fossulae. Preglabellar furrow transverse. Preglabellar field short, shorter than border. Border furrow shallow throughout and indistinct medially where the border is expanded into a poorly-defined plectrum. Border relatively long, tapering gradually laterally. Interocular cheeks narrow. Palpebral lobes elongate, weakly curved and defined by shallow palpebral furrows. Posterior part of fixed cheek rather long and narrow with a prominent laterally lengthening border furrow running across it.

Discussion: These two specimens are distinctive in their clearly truncated glabellar anterior, and broadly convex anterior border. They may belong to a genus that has not yet been named but a new name has not been assigned because of the small number of poorly-preserved internal moulds available and because of the lack of knowledge on the remainder of the exoskeleton. Perhaps the most distinctive aspect of this material is the long, convex anterior border, that is unique among this type of trilobite of this age. As with *Prismenaspis* the closest morphology is to be found among younger trilobites from the northwestern Siberian Platform. *Monosulcatina laeve* Rozova, 1963, particularly the cranidium, figured by Rozova in 1968 (pl. 9, figs 11, 12) is very close in morphology to the N.S.W. specimen.

Mollusca (P.A.J.)

Class MONOPLACOPHORA Wenz in Knight, 1952

Order TRYBLIDIIDA Lemche, 1957

Family TRYBLIDIIDAE Pilsbry in Zittel-Eastman, 1899

Genus *PROPLINA* Kobayashi, 1933

Proplina sp.

Fig. 10, 15-17

Material: One shell P61507.

Description: A large shell 14 mm high, 21 mm wide and 30 mm long with the shape of an inverted asymmetrical cone. Apex overhangs the margin of the oval aperture. Internal and external surfaces of shell exhibit fine closely-spaced growth lines parallel to the apertural margin. Dorsal surface of internal mould with a variety of curving impressions but none of these are symmetrical nor could they be interpreted as muscle scars.

Discussion: Ignorance of the muscle pattern and of the apex prevent specific assignment but the exterior surface, position of the apex and apertural shape make generic placement clear. The apex is presumably pointed but the infilling has broken on the surface shown in Fig. 10, **16.** As there is only one specimen available and the infilling does not easily separate from the external mould it has not been fully prepared out.

BRACHIOPODA (I.G.P.)
Class ARTICULATA Huxley, 1869
Order ORTHIDA Schuchert & Cooper, 1932
Suborder CLITAMBONITIDINA Öpik, 1934
Superfamily BILLINGSELLACEA Schuchert, 1893
Family BILLINGSELLIDAE Schuchert, 1893
Genus *BILLINGSELLA* Hall & Clarke, 1892

Billingsella sp.
Fig. 12, 1-5

Material: Eleven specimens (P61939-P61949) from locality 2; five specimens (P61950-P61954) from locality 4; three specimens (P61955-P61958) from locality 5; two specimens (P61959 and P61960) from locality 3.
Description: *Exterior of valves*. Outline subquadrate; maximum width at about midlength of pedicle valve, and occurring in posterior half of brachial valve; hingeline equal to, or slightly less than, maximum width; cardinal extremities obtuse to right-angled. Profile biconvex, with deeper brachial valve (depth about one-third valve length) bearing shallow posteromedian sulcus. Ornament poorly preserved on available specimens, but apparently finely multicostellate with prominent widely-spaced concentric growth lamellae. Ventral interarea long, equal to between 0.2 and

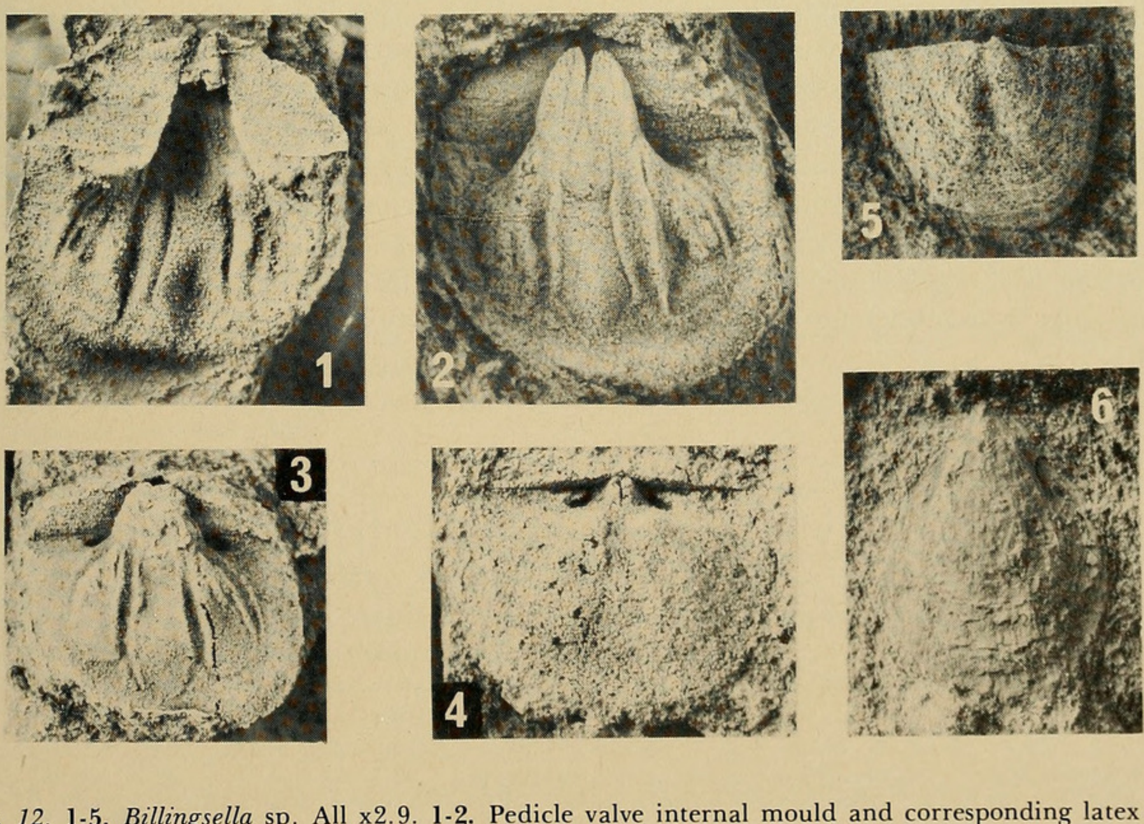

Fig. 12. 1-5. *Billingsella* sp. All x2.9. 1-2. Pedicle valve internal mould and corresponding latex cast, P61939. 3. Pedicle valve internal mould, P61940. 4. Brachial valve internal mould, P61941. 5. Brachial valve external (latex cast), P61942. 6. obolid indet., P61938, x3.5.

0.3 valve length, flat to weakly curved, orthocline to apsacline; delthyrium covered for about one-third its length by strongly arched pseudodeltidium. Dorsal interarea much lower, less than one-third length of ventral interarea; planar, anacline.

Pedicle valve interior. Teeth stout, extending from hingeline to floor of valve; dental plates lacking. Muscle field large, extending to between 0.4 and 0.5 valve length, and occupying approximately one-quarter valve width; elliptical diductors divided posteriorly by short, thin median ridge extending forward from apical callus; central adductor impression expands rapidly in front of median ridge. Mantle canal impressions prominent, of saccate pattern with thick *vascula media* weakly divergent medially, strongly arcuate anterolaterally. Broad shallow groove-like depression extends from hingeline adjacent to valve margin.

Brachial valve interior. Cardinalia simple, comprising fine ridge-like cardinal processes, and short widely divergent rod-like brachiophores, flanking cup-shaped sockets. Low, broad, median ridge extends from notothyrial platform to about one-third valve length, bisecting faintly quadripartite muscle field. Mantle canal impressions not discernible.

Measurements (in mm) *Figured specimens.* P61939 (pedicle valve): length 13.1, width 12.4, length of muscle field 6.5; P61940 (pedicle valve): length 9.5, width 10.8, length of muscle field 4.1; P61941 (brachial valve): length 8.8, width 11.7; P61942 (brachial valve): length 7.2, width 9.2.

Pedicle valves, 8 specimens. Range of lengths: 9.5-13.1, range of widths: 10.8-14.0, range of length/width ratios: 0.88-1.08, average length/width ratio: 0.99.

Brachial valves, 9 specimens. Range of lengths: 6.3-10.4, range of widths: 7.7-14.0, range of length/width ratios: 0.73-0.82, average length/width ratio: 0.78.

Discussion: *Billingsella* is restricted to strata of Middle Cambrian to Early Ordovician age, being particularly abundant in the Late Cambrian. The species found in the Cupala Creek Formation is most similar to (and may prove to be conspecific with) *Billingsella* sp. from the Middle to Late Cambrian Mariner Formation (Cooper *et al.*, 1976) of Northern Victoria Land, Antarctica, described and illustrated by MacKinnon (*in* Shergold *et al.*, 1976). Relatively minor differences between these forms include a proportionately shorter pseudodeltidium and slightly less pronounced dorsal median sulcus on New South Wales specimens. In other details such as outline, profile, dimensions and internal structures, species from these two areas are virtually indistinguishable. In common with the Antarctic species, the New South Wales form resembles several North American species, such as *B. perfecta* Ulrich and Cooper and *B. texana* Bell, typical of the Late Cambrian. Trilobites associated with the Antarctic *Billingsella* indicate its age as late Idamean, *Erixanium sentum* Zone (Shergold *et al.*, 1976).

Class INARTICULATA Huxley, 1869
Order LINGULIDA Waagen, 1885
Superfamily LINGULACEA Menke, 1828
Family OBOLIDAE King, 1846
Obolid indet.
Fig. 12, 6

Discussion: A single poorly-preserved valve (P61938) was found at locality 3. The available material does not permit precise identification or age determination.

Measurements: Length 9.2 mm, width 7.0 mm.

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References

BANKS, M., 1962. — Ordovician System. *J. geol. Soc. Aust.* 9:147-176.

BRUNKER, R. L., OFFENBERG, A., and ROSE, G., 1967. — 1:500,000 Koonenberry geological sheet. *Geol. Surv. N.S.W.*

COOPER, R. A., JAGO, J. B., MACKINNON, D. I., SIMES, J. E., and BRADDOCK, P. E., 1976. — Cambrian fossils from the Bowers Group, Northern Victoria Land, Antarctica (preliminary note). *N.Z. J. Geol. Geophys.* 19:283-288.

DAILY, B., and JAGO, J. B., 1975. — The trilobite *Lejopyge* Hawle and Corda and the Middle-Upper Cambrian boundary. *Palaeontology* 18:527-550.

EDWARDS, A. C., 1978. — Tectonic implications of the immobile trace-element geochemistry of mafic rocks bounding the Wonaminta Block. *J. geol. Soc. Aust.* 25:459-465.

FOLK, R. L., 1974. — *Petrology of sedimentary rocks.* Austin, Texas: Hemphill's.

EVANS, P. R., 1977. — Petroleum geology of western New South Wales. *Aust. Petrol. Explor. Assn. J.* 17: 42-49.

FREEMAN, R. N., 1965. — Geological appraisal of productive potential of P.E.L. 114, New South Wales. *Rep. Planet Explor. Co. Pty. Ltd. (Geol. Surv. N.S.W. Petrol. File, Geol. 1965/1)* (unpubl.)

HENDERSON, R. A., 1976. — Upper Cambrian (Idamean) trilobites from western Queensland, Australia. *Palaeontology* 19: 325-364.

KRUSE, P. D., 1978. — New Archaeocyatha from the Early Cambrian of the Mt. Wright area, New South Wales. *Alcheringa* 2: 27-47.

LEU, M. R., 1980. — Silicified early Middle Cambrian trilobites from the Gnalta District, N.S.W., and their stratigraphic context. North Ryde, N.S.W.: Macquarie University, B.A. (Hons) thesis, unpubl.

MOORE, P. S., 1979. — Stratigraphy and depositional environments of the Billy Creek Formation (Cambrian), central and northern Flinders Ranges, South Australia. *Trans. R. Soc. South Aust.* 103: 197-211.

NEEF, G., EDWARDS, A. C., HOLZBERGER, I., HARTY, J., KELLY, R., and VAUGHAN, J. — The geology of the Mt Daubeny/Wertago area (in prep.).

ÖPIK, A. A., 1963. — Early Upper Cambrian fossils from Queensland. *Bull. Bur. Miner. Resour. Geol. Geophys. Aust.* 64: 1-133.

———, 1966. — The early Upper Cambrian crisis and its correlation. *J. Proc. R. Soc. N.S.W.* 100: 9-14.

———, 1967. — The Mindyallan fauna of north-western Queensland. *Bull. Bur. Miner. Resour. Geol. Geophys. Aust.* 74: 1-404 and 1-67.

———, 1968. — The Ordian Stage of the Cambrian and the Australian Metadoxididae. *Bull. Bur. Miner. Resour. Geol. Geophys. Aust.* 92: 133-170.

———, 1975. — Cymbric Vale fauna of New South Wales and Early Cambrian biostratigraphy. *Bull. Bur. Miner. Resour. Geol. Geophys. Aust.* 159: 1-78.

———, 1979. — Middle Cambrian agnostids: Systematics and biostratigraphy. *Bull. Bur. Miner. Resour. Geol. Geophys. Aust.* 172: 1-188.

PACKHAM, G. H., (ed.), 1969. — The geology of New South Wales. *J. geol. Soc. Aust.* 16: 1-654.

PALMER, A. R., 1965. — Trilobites of the Pterocephaliid Biomere in the Great Basin, United States. *Prof. Pap. U.S. geol. Surv.* 493: 1-105.

POGSON, D. J., and SCHEIBNER, E., 1971. — Pre-Upper Cambrian sediments east of the Copper Mine Range, New South Wales. *Q. Notes Geol. Surv. N.S.W.* 4: 3-8.

POWELL, C. McA., GILFILLAN, M. A., and HENRY, N. M., 1978. — Early east-southeast trending folds in the Sofala Volcanics, N.S.W. *J. Proc. R. Soc. N.S. W.* 111: 121-128.

———, FERGUSSON, C. L., and WILLIAMS, A. J., 1980. — Structural relationships across the Lambian Unconformity in the Hervey Range-Parkes area, N.S.W. *Proc. Linn. Soc. N.S. W.* 104: 195-204.

RITCHIE, A., 1973. — *Wuttagoonaspis* gen. nov., an unusual arthrodire from the Devonian of Western New South Wales, Australia. *Palaeontographica* Abt. A. 143: 58-72.

ROSE, G., 1974. — Explanatory notes on the White Cliffs 1:250,000 Geological Sheet. *Geol. Surv. N.S. W.* Sydney, 48 p.

———, LOUDEN, A. G., and O'CONNELL, P., 1964. — 1:250,000 Geological Sheet SH 54-12, White Cliffs. *Geol. Surv. N.S. W.*

———, and BRUNKER, R. L., 1969. — The Upper Proterozoic and Phanerozoic geology of north-western New South Wales. *Proc. Australas. Inst. Min. Metall.* 229: 105-120.

ROZOVA, A. V., 1968. — Biostratigraphiya i trilobity Verkhnego Kembriya i Nizhnego Ordovika severo-zapada Sibirskoi platformy. *Trudy Inst. Geol. Geofiz. sib. Otd., Moscow* 36: 1-196.

———, 1977. — Nekotorye verkhnekembriyskie i nizhneordovikskie trilobity bassinov rek Rubnoy, Khantayki, Kureyki i Letney. *In* Biostratigrafiya i fauna verkhnego kembriya i pogranichnykh s nim sloev. *Trudy Inst. Geol. Geofiz. sib. Otd., Moscow* 313: 54-84.

RUTLAND, R. W. R., 1976. — Orogenic evolution of Australia. *Earth. Sci. Rev.* 12: 161-196.

SCHEIBNER, E., 1973. — A plate tectonic model of the Palaeozoic tectonic history of New South Wales. *J. geol. Soc. Aust.* 20: 405-426.

———, 1976. — Explanatory notes on the tectonic map of New South Wales. *Geol. Surv. N.S. W.*, Sydney.

———, 1978. — Tasman Fold Belt system in New South Wales — general description. *Tectonophysics* 48: 297-316.

SHERGOLD, J. H., 1971. — Resume of data on the base of the Ordovician in northern and central Austria [*sic*=Australia]. *Mém. Bur. Rech. géol. min.* 73: 391-402.

———, COOPER, R. A., MACKINNON, D. I., and YOCHELSON, E. L., 1976. — Late Cambrian Brachiopoda, Mollusca, and Trilobita from Northern Victoria Land, Antarctica. *Palaeontology* 19: 247-291.

THOMAS, D. E., and SINGLETON, O. P., 1956. — The Cambrian stratigraphy of Victoria. *20th Int. Geol. Congr. Mexico, 1956. El Sistema Cambrico* 2: 149-163.

THOMSON, B. P., 1969. — The Kanmantoo Group. *In* PARKIN, L. W., (ed.), *Handbook of South Australian Geology,* Geol. Surv. South Aust., 102-108.

VEEVERS, J. J., 1976. — Early Phanerozoic events on and alongside the Australasian-Antarctic platform. *J. geol. Soc. Aust.* 23: 183-206.

WARRIS, B. J., 1967. — The Palaeozoic stratigraphy and palaeontology of north-western New South Wales. Sydney: University of Sydney, Ph.D. thesis, unpubl.

WEBBY, B. D., 1972. — Devonian geological history of the Lachlan Geosyncline. *J. geol. Soc. Aust.* 19: 99-123.

———, 1978. — History of the Ordovician continental platform and shelf margin of Australia. *J. geol. Soc. Aust.* 25: 41-63.

WILLIAMS, E., 1978. — Tasman Fold Belt system in Tasmania. *Tectonophysics* 48: 159-205.

WILSON, R. B. 1967. — Geological appraisal of the Mootwingee area, New South Wales. *Aust. Petrol. Explor. Assn. J.* 7: 103-114.

WOPFNER, H., 1966. — Cambro-Ordovician sediments from northeastern margin of the Frome Embayment (Mt Arrowsmith, N.S.W.). *J. Proc. R. Soc. N.S. W.* 100: 163-177.