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EARLY CAMBRIAN ARTHROPODS FROM THE EMU BAY SHALE LAGERSTÄTTE, SOUTH AUSTRALIA

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HISTORY OF RESEARCH ON ARTHROPODS FROM THE EMU BAY SHALE LAGERSTÄTTE

The Emu Bay Shale Lagerstätte, located on the north coast of Kangaroo Island, South Australia, is the most important Burgess Shale-type Cambrian fossil locality in Australia. In 1952, R.C. Sprigg first discovered fossils in the Emu Bay Shale near the Emu Bay jetty as part of the Geological Survey of South Australia regional mapping programme (Sprigg *et al.*, 1954; Sprigg, 1955). However, due to an accident, Sprigg was unable to carry out detailed work to the east of Emu Bay. The Emu Bay Shale Lagerstätte site at Big Gully, located 3 km east of Emu Bay (Fig. 1), was discovered along the coastline immediately adjacent to Big Gully by B. Daily during his doctoral studies. The first fossils collected included superb articulated specimens of *Redlichia* up to 25 cm in length. Daily (1956, p. 126) was also the first to publish information on the Lagerstätte, recording the presence of the trilobites *Redlichia* n. sp. and cf. *Lusiatops*, plus *Isoxys* n. sp., an unidentified crustacean and annelids; this represented his Faunal Assemblage 12. The trilobite species referred to as "cf. *Lusiatops*" by Daily (1956) was later described as *Estaingia bilobata* by Pocock (1964), although the illustrated specimens were not sourced from the Lagerstätte. Jell (in Bengtson *et al.*, 1990) formally described specimens of *Redlichia* from Big Gully as *R. takooensis* Lu, 1950. M.F. Glaessner, M. Wade and B. McGowran collected material (including nonmineralised taxa) in December 1956 (B. McGowran, pers. comm., December 2007), but no formal descriptions were published until Glaessner (1979) described the bivalved arthropods *Isoxys communis* and *Tuzoia australis,* the palaeoscolecid priapulid *Palaeoscolex antiquus*, plus *Myoscolex ateles* and *Vetustovermis planus* of uncertain affinities. Glaessner (1979) noted that there were no signs of trace fossils in his material; he suggested deposition as a thanatocoenosis within a reducing environment.

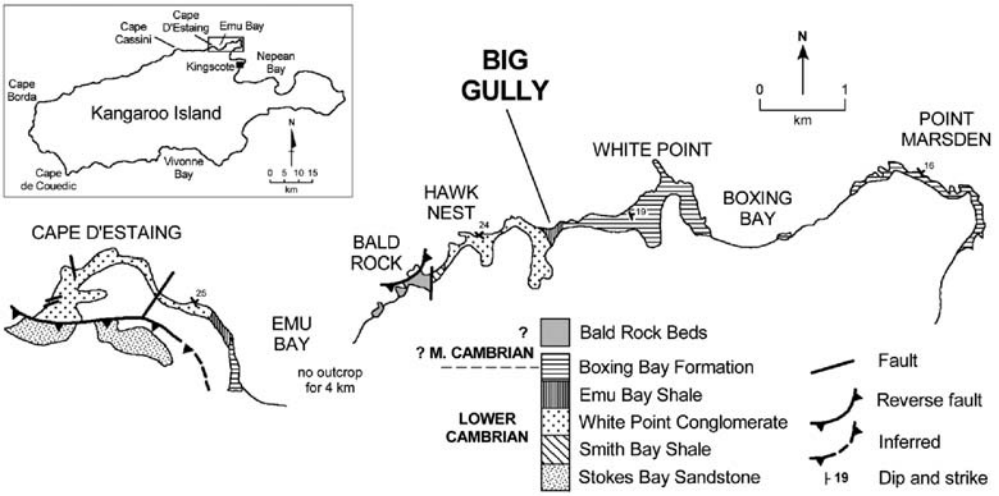


Figure 1. North east coast of Kangaroo Island showing Cambrian outcrop and the location of the Emu Bay Shale Lagerstätte at Big Gully; modified from Paterson and Jago (2006, fig. 1).

Studies during the 1980s and 1990s recognised the occurrence of putative stem-group arthropods in the Emu Bay Shale. Based on evidence of healed injuries in specimens of *Redlichia* from Big Gully, Conway Morris and Jenkins (1985) postulated the presence of predators in the fauna. This was confirmed when McHenry and Yates (1993) reported the occurrence of *Anomalocaris* at Big Gully; they also described and figured preserved antennae on a specimen of *Redlichia takooensis.* Nedin (1995a) subsequently recognised two species of *Anomalocaris*, but only formally naming *A. briggsi*. Briggs and Nedin (1997) reinterpreted *Myoscolex* as an *Opabinia*-like animal and stressed the importance of preserved mineralised (i.e., phosphatised) muscle tissue in *Myoscolex* as the oldest known at that time (and remains to hold true), with Nedin (1997) suggesting that early diagenesis was an important factor in preserving the muscle tissue. However, Dzik (2004) has recently swung back to Glaessner's original interpretation of *Myoscolex* in regarding it as the oldest known annelid.

Existence of trilobitomorphs or 'trilobite-allied' arthropods in the Emu Bay Shale Lagerstätte has been known for over 10 years. Nedin (1995b, 1999) reported the presence of two species of *Naraoia,* but recent studies (Lin *et al*., 2006; Zhang *et al*., 2007) have suggested that one of these species (illustrated by Nedin 1999, fig. 2A) has possible affinities to taxa such as *Primicaris* and *Skania*. However, new collections reveal that both of Nedin's species of "*Naraoia*" in fact represent new trilobitomorph taxa (discussed below). Nedin (1995b) also reported a single, poorly preserved specimen of *Xandarella*, but this has never been published.

The most recent research on the Emu Bay Shale Lagerstätte has focused on trilobites. Paterson and Jago (2006) described two new taxa, *Megapharanaspis nedini* and *Holyoakia simpsoni*; the former also representing a new monotypic emuelloid family, the Megapharanaspidae, and the latter representing the first occurrence of the genus outside of Antarctica. They also provided new morphological information on *Redlichia takooensis*, including a description of the hypostome and rostral plate. Paterson and colleagues (Paterson and Edgecombe, 2006; Paterson *et al*., 2007) have also conducted extensive research on emuellids, including material from the Emu Bay Shale type section at Emu Bay, although they have noted the rare occurrence of *Balcoracania dailyi* in the Lagerstätte.

STRATIGRAPHY AND AGE

At Big Gully, the Emu Bay Shale is about 78 m thick (Daily *et al*., 1979). The unit overlies the polymict conglomerates of the White Point Conglomerate that Daily *et al*. (1980) suggested were deposited as fanglomerates with a source area to the north. The Emu Bay Shale at Big Gully represents a minor facies comprising of dark laminated silty shales that were deposited below wave base in a fluctuating dysoxic-anoxic microenvironment (Conway Morris and Jenkins, 1985; Nedin, 1995b), which favoured the preservation of the Lagerstätte. Small scale slumping indicates a local southerly slope. There is at least one thin polymict conglomerate horizon within the unit. The Emu Bay Shale is conformably overlain by the 550 m thick Boxing Bay Formation, which comprises mainly subtidal feldspathic sandstones and arkoses with subordinate shales and thin conglomerate lenses (Daily *et al*., 1979). The lower part of the Boxing Bay Formation contains abundant trace fossils, including burrows and arthropod tracks, as well as exhibiting large scale soft sediment deformation.

The presence of the trilobites *Estaingia bilobata*, *Balcoracania dailyi* and *Redlichia takooensis* in the Emu Bay Shale suggests correlation with the lower Cambrian (Series 2) *Pararaia janeae* trilobite Zone within South Australia, the early-mid Canglangpuan Stage of China and the mid-late Botoman of Siberia (Jell in Bengtson *et al*., 1990; Paterson and Edgecombe, 2006; Paterson and Jago, 2006; Paterson and Brock, 2007). In a global context of lower Cambrian Lagerstätten, the Emu Bay Shale Lagerstätte is approximately coeval with the Balang Lagerstätte of China, but younger than the famous Chengjiang (aka Maotianshan Shale) and Sirius Passet Lagerstätten (Zhu *et al*., 2006).

CURRENT RESEARCH: NEW INSIGHTS INTO THE BIODIVERSITY OF THE EMU BAY SHALE ARTHROPODS

All previous research and collections from the Emu Bay Shale Lagerstätte have been sourced from outcrops along the shore platform and adjacent cliffs to the east of the mouth of Big Gully. A new study commenced in September 2007 with the excavation of a 15 m long trench covering about 8 m true thickness of the Emu Bay Shale, which is located about 500 m inland and along strike from the coastal outcrops. The trench section is highly fossiliferous, although soft-part preservation becomes rarer in the upper part of the section due to a higher frequency of interbedded siltstones and sandstones. The initial excavation has proved to be very successful with the discovery of several taxa previously unrecognised from the biota.

New collections from the trench are dominated by articulated trilobites (Fig. 2A, B). This faunal dominance was also noted in the assemblage from the coastal outcrops by Nedin (1995b) and Briggs and Nedin (1997). They proposed that trilobites constitute between 50 and 60% of the fossils, but our recent observations suggest that this percentage may be underestimated. Even considering the occurrence of a small percentage of moult remains, trilobites appear to dominate the biota. The trilobite fauna from the trench collections is dominated by *Estaingia bilobata* (Fig. 2A) and to a lesser extent by *Redlichia takooensis* (Fig. 2B), a few specimens of the latter possess antennae and poorly preserved biramous appendages. The other trilobite taxa known from the Emu Bay Shale are quite rare or absent in the new collections. For example, of the hundreds of trilobite specimens found, we uncovered only two specimens of *Balcoracania dailyi*. These specimens of *B. dailyi* are regarded as vagrants because this species is typically found in marginal marine environments (Paterson *et al*., 2007).

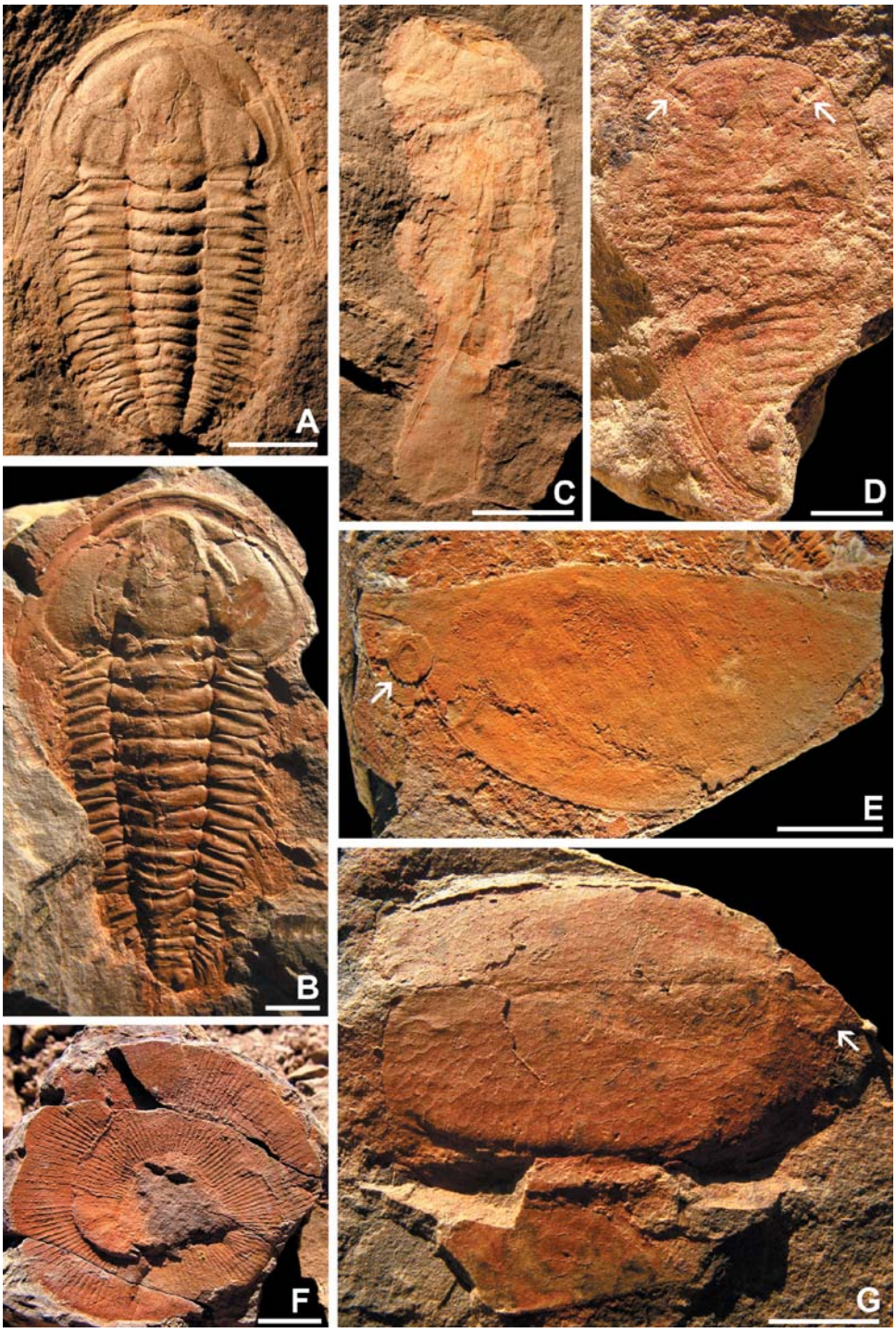
The excavation has also revealed an increased diversity of nonmineralised arthropods. The most common of these are the bivalved arthropods (Fig. 2E, G). Species include: numerous specimens of *Isoxys communis* (Fig. 2E), with considerably large cardinal spines, humped dorsal hinge line and hitherto undescribed very fine reticulated carapace, together with stalked eyes, alimentary canal and possible appendages; and a new species of *Isoxys* with straight dorsal hinge line and very short cardinal spines, also presenting soft-body preservation of eyes and gut; several specimens, including some in "butterfly" and dorsal orientation, of *Tuzoia australis* (Fig. 2G), three of which also possess eyes – a very uncommon occurrence (Vannier *et al*., 2007); and a few large fragments of a possible new species of *Tuzoia*.

Putative stem-group arthropods are relatively rare in the new collections. We have uncovered frontal appendages and lateral flaps of *Anomalocaris*. Specimens of *Myoscolex ateles* are also relatively uncommon. Previous studies (Nedin, 1995b; Briggs and Nedin, 1997) have indicated that *M. ateles* is the most abundant nonmineralised taxon from the coastal outcrops at Big Gully. The rarity of *M. ateles* at the new inland site could simply represent lateral and/or vertical stratigraphic variation of the assemblage; recent reconnaissance work indicates that the Lagerstätte extends across a greater stratigraphic range than previously thought (Briggs and Nedin, 1997).

The new excavation has revealed a number of previously undescribed arachnomorphs. Taxa include both 'trilobite-allied' arachnomorphs or Trilobitomorpha and 'chelicerate-allied' arachnomorphs or Cheliceramorpha (*sensu* Cotton and Braddy, 2004). The most common of these is a cheliceramorph taxon with probable megacheiran affinities (Fig. 2C). Body size and trunk morphology, especially the possession of 11 trunk segments and a spatulate telson, resemble forms such as *Alalcomenaeus* and *Leanchoilia*, but also *Utahcaris* and *Sanctacaris*. Many specimens also show gut traces and/or longitudinal carinae. Unfortunately, there are no preserved 'great appendages' in the specimens recovered to date. Other cheliceramorphs from the new site are rare and/or too fragmentary to make comment at this stage. Trilobitomorphs include two new taxa with preserved cephalic appendages that are likely allied to naraoiids because both have a natant hypostome, a short thorax, and a pygidium that is much longer than the head shield. One taxon has three thoracic segments and strong intersegmental furrows on the pygidium (Fig. 2D), whereas the other has a four-segmented thorax and effaced furrows on the pygidial pleurae. Discovery of articulated thoracic segments in the latter disproves its assignment to *Naraoia* or close affinities to *Primicaris* and *Skania* (discussed above). A few specimens represent a xandarellid, which is most likely to be conspecific with Nedin's (1995b) unpublished *Xandarella*.

Other (non-arthropod) fossils from the new collections include: several palaeoscolecid taxa (Fig. 2F), including *Palaeoscolex antiquus* and another with similarities to *Acosmia*; a variety of sponges, including leptomitid demosponges; an enigmatic form resembling *Eldonia*; hyoliths; chancelloriids; filamentous algae; a banffozoan; and several other problematic forms. Unfortuntately, we have not uncovered new material of the unusual *Vetustovermis planus* – now considered to share characteristics with molluscs, flatworms and nemertines (Chen *et al*., 2005) – but it is hoped future excavations will reveal important specimens to provide new information on the affinities of this taxon.

Figure 2. A, *Estaingia bilobata* Pocock, 1964, SAMP 14955; scale bar is 0.5 cm. B, *Redlichia takooensis* Lu, 1950, SAMP 14956. C, megacheiran arachnomorph, SAMP 14957. D, new trilobitomorph taxon with arrows indicating preserved antennae, SAMP 14958; scale bar is 0.5 cm. E, *Isoxys communis* Glaessner, 1979, with arrow indicating preserved eye, SAMP 14658. F, coiled palaeoscolecid, SAMP 14932. G, *Tuzoia australis* Glaessner, 1979 showing dorsal compression and arrow indicating preserved eyes, SAMP 14677. All scale bars are 1 cm, unless otherwise stated.


A
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