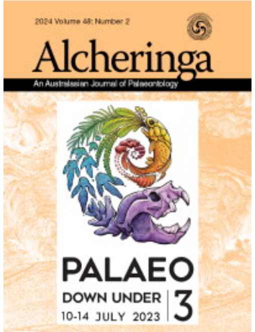

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The quest for an Australian Cambrian stage scale

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ABSTRACT

The chronostratigraphical scale is a hierarchical scheme that is subdivided into increasingly smaller units, from eonothem down to the level of the substage and beyond. Boundaries of chronostratigraphic intervals typically coincide with individual bioevents. As these intervals become smaller, their geographic utility tends to shrink. Typically, where the original interval is inapplicable, the next highest interval in the scale is used for communication. Where appropriate intervals are unavailable, confusion reigns. A stadial subdivision of the Australian mid–late Cambrian (equivalent to the international Miaolingian and Furongian series) was completed in 1993 with the definition of the Furongian Iverian Stage. One stage, the Ordian, was initially suggested as the lowest stage for what is now the Miaolingian, but should be considered to belong to upper Series 2 of the Cambrian. No older Cambrian stages have been proposed in Australia. Indeed, the base of the Ordian has not been defined, due in part to the incompleteness of Series 2 successions in central and northern Australia. A longstanding impediment to the establishment of lower Cambrian stages in Australia arises from the fact that the entire Australian stadial scheme for the Miaolingian and Furongian series was established in the cratonic basins of central-northern Australia, whereas the lower Cambrian is best developed in separate South Australian basins. With the rapid increase in knowledge of the biostratigraphic successions in the South Australian lower Cambrian (Terreneuvian and Series 2) over the last three decades, the time seems ripe for the establishment of such a stadial subdivision. This will require careful correlation between the mostly Terreneuvian and Series 2 succession in South Australia and the mostly Miaolingian–Furongian succession in central and northern Australia. Taxa that can be used for such a stadial subdivision include trilobites, organophosphatic brachiopods, archaeocyaths, small shelly fossils, molluscs and acritarchs, as each has provided the basis of zonations in the South Australian successions.

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THE DEVELOPMENT of the concept of the Cambrian System has been detailed by Cowie *et al.* (1972), and the early history of the discovery and study of rocks from that system in the various parts of Australia has been presented by Shergold (1989, 1995) and Cooper & Jago (2007). In many cases, the Cambrian age of these rocks was suspected before it was known, and it was often Etheridge (1890, 1896, 1897, 1902, 1905) who initially determined their age.

Cambrian rocks are widespread in Australia, being present in every state and the Northern Territory (Fig. 1). However, most of the successions that have been intensively studied palaeontologically are in basins within the middle third of the continent. These include the Stansbury, eastern Officer and Arrowie basins in South Australia; the eastern Amadeus, central and western Georgina, Wiso, Daly and eastern Ord basins in the Northern Territory; the eastern Georgina Basin in western Queensland; the entirely subsurface Warburton Basin at the borders of South

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Australia, Northern Territory and Queensland; the subsurface western Officer Basin and the Bonaparte and western Ord basins in northern Western Australia; the Koonenberry Belt in northwestern New South Wales; and the Dundas, Adamsfield and Dial Range troughs and Smithton Basin in western Tasmania.

In Australia, rocks of possible Cambrian age were first reported by Burr (1846) in South Australia (*fide* Cooper 1984); Selwyn (in Fairfax 1859) in Victoria; Gould (1867) in Tasmania; Hardman (1884, 1885) in Western Australia; Brown (1895) in the Northern Territory; Saint-Smith (1924) in Queensland; and Warner & Harrison (1961) in New South Wales. Despite many of these discoveries being made well over a century ago, a comprehensive biostratigraphic framework for the Cambrian has been long in the making (Shergold 1995, p. 6). Activity has been intermittent; it was initially exploratory and descriptive, and was subsequently followed by research conducted largely in support of regional mapping programs. It is only in the last few decades that much more detailed work has been undertaken, building upon the seminal work of Etheridge (1880–1919), Whitehouse (1927–1945) and Öpik (1956–1982).

Much remains to be done; specifically, the completion of an Australian stadial subdivision of the Terreneuvian Series and unnamed Series 2 of the Cambrian. Previously, correlations in the Australian lower Cambrian have often resorted to potentially imprecise correlations to the Siberian stadial scheme. A regional stadial scheme is needed to allow more precise correlations within Australia.

Towards the current stadial subdivision

Etheridge's (1890, 1896, 1897, 1902, 1905) work was largely descriptive and occurred during a period of initial discoveries of Cambrian rocks as exploration of the continent expanded and a gross stratigraphy developed. At this time, a distinction between Cambrian and younger systems was more important than establishing an accurate position within the Cambrian (Shergold 1995).

Whitehouse (1927, 1930) was the first to begin the subdivision of the Cambrian System in Australia, using fossils to identify the middle and upper Cambrian rocks of the Georgina Basin in northwestern Queensland. Whitehouse (1930) created a Templeton Series, which was initially deemed to contain two faunal stages: the *Dinesus* Stage and the *Redlichia* Stage (Fig. 2). The following year, Whitehouse (1931) added the *Leiagnostus* Stage to the middle Cambrian, and additionally recognized two upper Cambrian stages

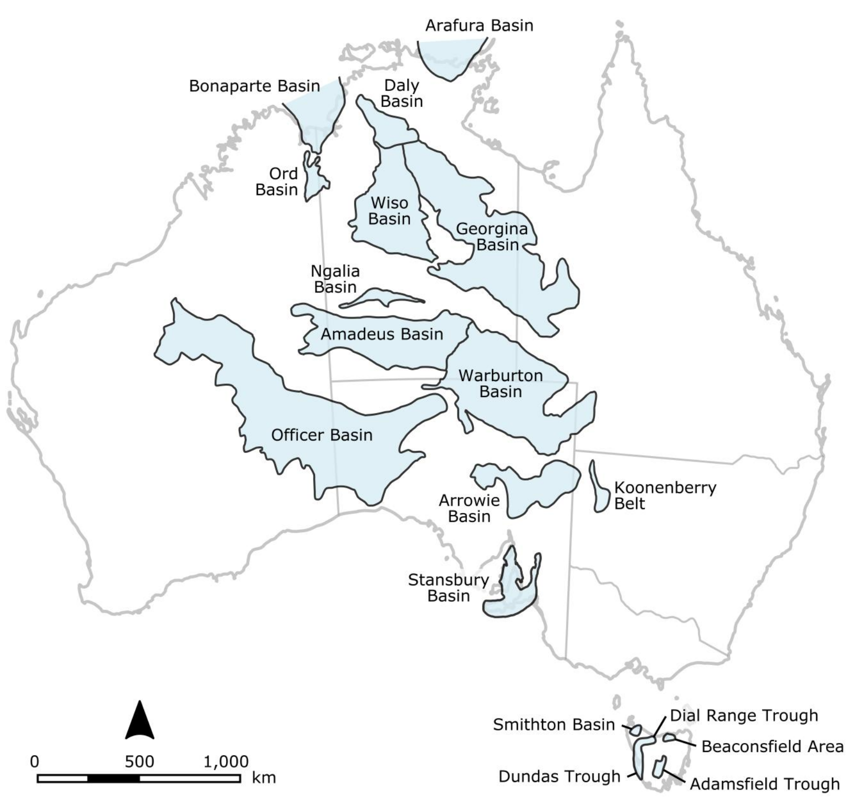

Fig. 1. Map of Australian basins and provinces containing Cambrian sedimentary rocks.

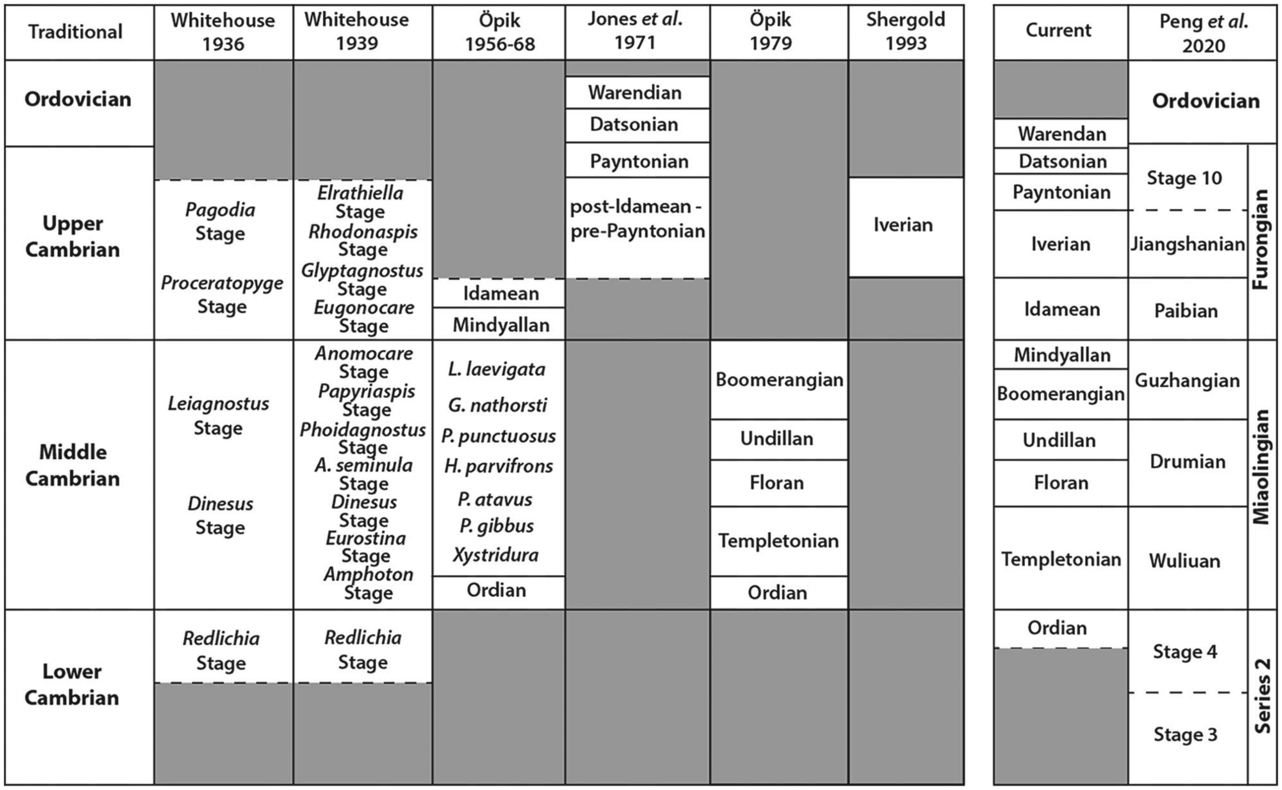

Fig. 2. Development of current stadial scheme. The columns showing the schemes devised by Whitehouse (1936, 1939), Öpik (1956, 1961, 1963, 1967, 1968), Jones *et al.* (1971), Öpik (1979) and Shergold (1993) are calibrated against the 'traditional' tripartite division of the Cambrian in the left-hand column, and are plotted where the various authors suggested they belonged at the time of publication. The current scheme, which is in the column second from right, is calibrated against the most recent global scheme of Peng *et al.* (2020), which is shown in the right-hand column. Zone abbreviations: *A. seminula* = *Agnostus seminula*; *L. laevigata* = *Lejopyge laeviagata*; *G. nathorsti* = *Goniagnostus nathorsti*; *P. punctuosus* = *Ptychagnostus punctuosus*; *H. parvifrons* = *Hypagnostus parvifrons*; *P. atavus* = *Ptychagnostus atavus* (= *Acidusus atavus*); *P. gibbus* = *Ptychagnostus gibbus*.

based on *Pagodia* Walcott, 1905 and *Proceratopyge* Wallerius, 1895, separated by the occurrence of *Glyptagnostus reticulatus* (Angelin, 1851). All of these names were used by Whitehouse (in David 1932) in an attempt to provide a framework within which to integrate successions in South Australia, Victoria, Tasmania and Queensland. The lower Cambrian was divided into three stages: *Archaeocyathus*, Protolenoid and *Redlichia*; the middle Cambrian into three: *Obolella*, *Dinesus* and *Leiagnostus*; and the upper Cambrian into four: the *Pagodia* and *Proceratopyge* stages of Queensland overlain by the Florentine Valley and Caroline Creek faunas of Tasmania (both of which are now known to be Ordovician). Subsequently, Whitehouse (1936, 1939) recognized the Georgina, Pituri and Ninmaroo series succeeding the Templeton Series in the Georgina Basin. At this time, the Templeton Series was expanded to contain the *Redlichia*, *Amphoton*, *Inouyella*, *Dinesus*, *Phoidagnostus*, *Anomocare* and *Solenopleura* stages in the middle Cambrian, whereas the upper Cambrian contained the *Anorina*, *Glyptagnostus*, *Pagodia* and *Elrathiella* stages (Shergold 1995, p. 6).

In 1939, Whitehouse proposed further modification of his stratigraphic scheme for the Georgina Basin. In this, the *Redlichia* Stage was retained in the lower Cambrian; the middle Cambrian contained, in ascending order, the *Amphoton*, *Eurostina*, *Dinesus*, *Agnostus seminula*, *Phoidagnostus*, *Papyriaspis* and *Anomocare* stages; and in the upper Cambrian, the *Eugonocare*, *Glyptagnostus*, *Rhodonaspis* and *Elrathiella* stages (Fig. 2). Subsequently, David & Browne (1950) combined the first three of Whitehouse's middle Cambrian stages into a *Xystridura* Stage, retaining the *Redlichia* Stage in the lower Cambrian (Shergold 1995, p. 7).

Regional mapping, initially (1947–1948) by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and subsequently (1949–1980) by the Bureau of Mineral Resources, Geology and Geophysics (BMR), indicated that there were problems with Whitehouse's (1939; in David & Browne

1950) understanding of the Cambrian succession in the Georgina Basin. These problems included the inability of some of the stages to be identified with certainty, and the unclear or erroneous position of some relative to others (Öpik 1956, p. 6). For example, the *Amphoton* Stage was considered by Whitehouse (1939) to be immediately above the *Redlichia* Stage, whereas Öpik (1956, p. 7) determined that it belonged in the uppermost middle Cambrian; the *Phoidagnostus* Stage was the 'top of the Middle Cambrian' (Öpik 1956, p. 7); and the position of the *Anomocare* Stage in the sequence of stages was 'not yet identifiable', but was not the topmost division of the middle Cambrian (Öpik 1956, p. 8).

An indication of where Öpik was likely to proceed is given in the left column of his middle Cambrian correlation chart (Öpik 1956, fig. 3). In this 'time scale' column, he mostly lists agnostides above the *Redlichia* and *Xystridura–Dinesus* stages, and in the caption to the figure notes that it is based on Acado–Baltic agnostides, and 'reflects the sequence of the species as constructed from observations of about 300 field stations' in the eastern Georgina Basin (Öpik 1956, p. 16) (Fig. 2).

Öpik (1956, pp. 21–23) made note of Whitehouse's (1939) upper Cambrian *Eugonocare*, *Glyptagnostus*, *Rhodonaspis* and *Elrathiella* stages, but did note that the *Elrathiella* stage may be below the *Glyptagnostus* stage and that the correlation of some localities with any of these stages may be doubtful.

Öpik began his numerous monographic contributions on Cambrian agnostides and trilobites with his 'Geology and palaeontology of the headwaters of the Burke River, Queensland' (Öpik 1961), but did not subdivide the Cambrian beyond establishing a few zones in the late middle and earliest upper Cambrian. In fact, to denote the early part of the upper Cambrian he used the North American Stage name Dresbachian, albeit in inverted commas (Öpik 1961, fig. 14).

It was in a later paper on trilobites in which he (Öpik 1968, p. 135) erected the Ordian and Templetonian stages, maintaining both to be middle Cambrian. The Ordian was proposed as a name for the '*Redlichia*-bearing beds, or strata', whereas the Templetonian was stated to have not been 'stabilized', but referred to the *Xystridura templetonensis* fauna in Queensland and the *Xystridura browni* fauna in the Northern Territory, with the 'Zone of *Ptychagnostus gibbus*' being taken as the topmost zone of the Templetonian. The base of the Templetonian was eventually defined at the first appearance datum (FAD) of *Pentagnostus anabarensis* Lermontova in Vologdin, 1940 by Laurie (2006a), based on faunas from the southern Georgina Basin in the Northern Territory.

Öpik (1963, p. 7–8) defined two more stages, which he proposed were within the upper Cambrian: the Mindyallan and overlying Idamean (Fig. 2). The Mindyallan was vaguely defined as comprising the *Glyptagnostus stolidotus* Zone and an unnamed pre-*stolidotus* Zone (later defined as the *Erediaspis eretes* and *Cyclagnostus quasivespa* zones; Öpik 1967, pp. 9, 10), whereas the base of the Idamean was defined at the base of the *Glyptagnostus reticulatus* Zone. Given that the basal zone of the Idamean contains *Glyptagnostus reticulatus*, its base is therefore now known to be coeval with the base of the global Furongian Series. The uppermost zone in the Mindyallan is that of *Glyptagnostus stolidotus*, so it is now part of the Miaolingian Series.

Further, Jones *et al.* (1971) defined three overlying conodont-based stages: the Payntonian, Datsonian and Warendian (now Warendan; Kruse *et al.* 2009) (Fig. 2). Only the Payntonian Stage was considered Cambrian, with the base of the Datsonian being drawn at the first appearance of the *Cordylodus proavus* assemblage. However, with the definition of the global Cambrian–Ordovician boundary now defined as the FAD of *Iapetognathus fluctivagus* Nicoll, Miller, Nowlan, Repetski & Ethington, 1999, the Datsonian is now considered to be Furongian, and the Cambrian–Ordovician boundary lies within the early Warendan (Peng *et al.* 2020). The base of the Payntonian was redefined by Shergold *et al.* (1991) and Shergold & Nicoll (1992) as the first appearance of the conodont *Hispidodontus resimus* Nicoll & Shergold, 1991 (Shergold 1993).

Öpik (1979) completed the subdivision of the Australian Miaolingian with the erection of the Floran, Undillan and Boomerangian stages (Fig. 2). The base of the Floran was effectively defined at the FAD of the agnostide *Acidusus atavus* (Tullberg, 1880), which coincides with the base of the global Drumian Stage (Peng *et al.* 2020). The base of the Undillan was effectively defined at the FAD of the agnostide *Ptychagnostus punctuosus* (Angelin, 1851), and the base of the Boomerangian at the FAD of the agnostide *Lejopyge laevigata* (Dalman, 1828), the latter of which coincides with the base of the global Guzhangian Stage (Peng *et al.* 2020).

Shergold (1993, see also Laurie *et al.* 2023) completed the subdivision of the Australian Furongian with the erection of the Iverian Stage, the base of

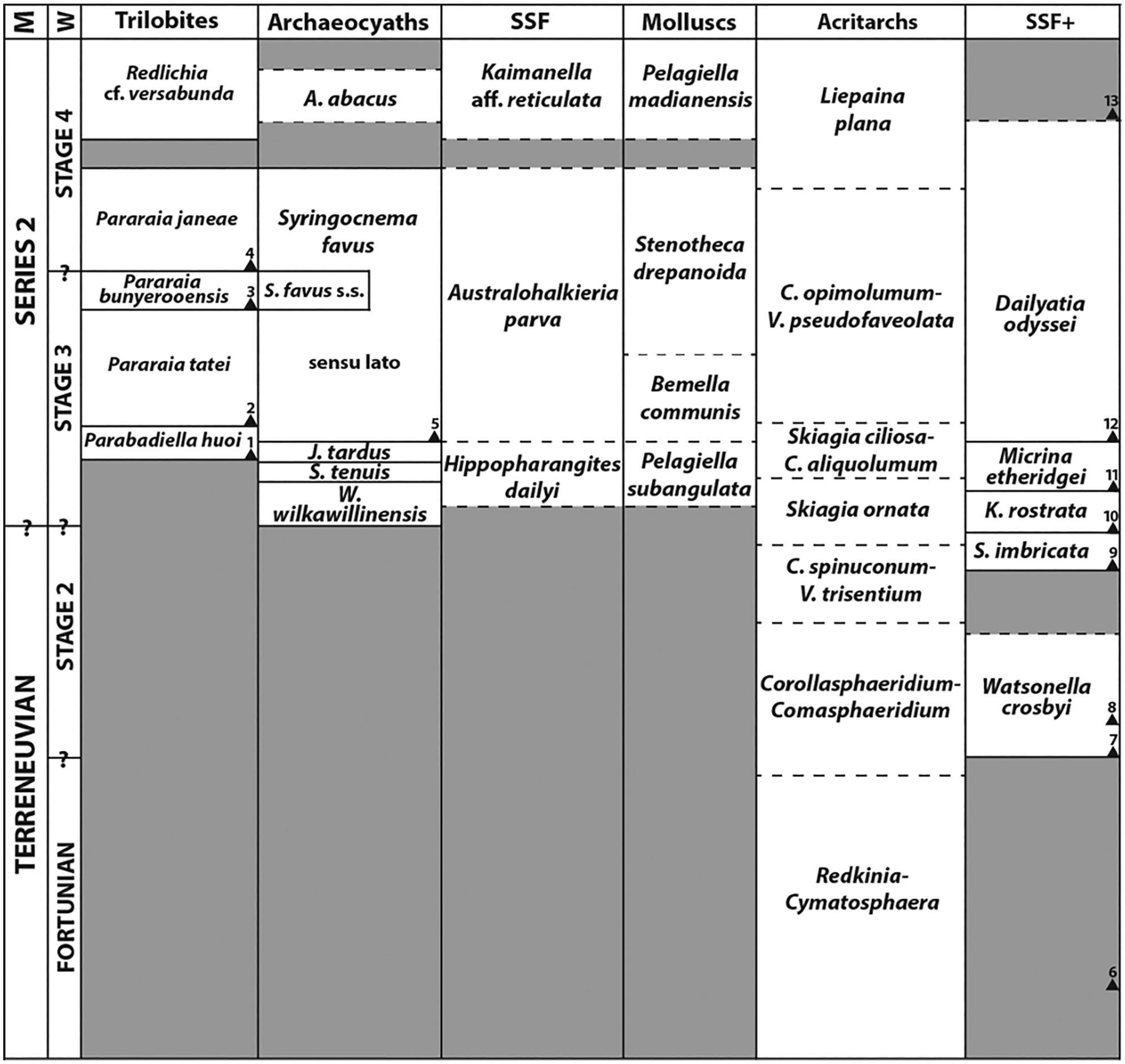

Fig. 3. Development of South Australian Cambrian biozonations and suggested First Appearance Datum points. Columns from left to right are: global series and stages; trilobite zonation modified from Jell (in Bengtson *et al.* 1990); archaeocyath zonation of Zhuravlev *et al.* (1994) based on Gravestock (1984), modified after Kruse & Debrenne (2020); small shelly fossil (SSF) and mollusc zonations of Gravestock *et al.* (2001), which have been shown to be poorly characterized and to lack usable definitions (see Jacquet *et al.* 2016, p. 6–7); acritarch zonation of Zang *et al.* (2007); small shelly fossil zonation (SSF+) of Betts *et al.* (2016b). Suggested First Appearance Datum points are: 1, *Parabadiella huoi* Zhang, 1966; 2, *Pararaia tatei* (Woodward, 1884); 3, *Pararaia bunyerooensis* Jell in Bengtson *et al.*, 1990; 4, *Pararaia janeae* Jell in Bengtson *et al.*, 1990; 5, *Syringocnema favus* Taylor, 1910; 6, ichnotaxa *Treptichnus pedum* (Seilacher, 1955) and *Sabellidites* isp.; 7, *Watsonella crosbyi* Grabau, 1900; 8, ichnotaxa *Skolithos* isp. and *Diplocraterion* isp.; 9, *Sunnaginia imbricata* Missarzhevskiy in Rozanov *et al.*, 1969; 10, *Kulparina rostrata* Conway Morris & Bengtson in Bengtson *et al.*, 1990 and brachiopod *Askepasma saproconcha* Topper, Holmer, Skovsted, Brock, Balthasar, Larsson, Petterson Stolk, & Harper, 2013; 11, *Micrina etheridgei* (Tate, 1892) and brachiopod *Askepasma toddense* Laurie, 1986; 12, *Dailyatia odyssei* Evans & Rowell, 1990 and *Stoibostrombus crenulatus* Conway Morris & Bengtson in Bengtson *et al.*, 1990; 13, brachiopods *Kostjubella djagoran* (Kruse, 1990) and *Schizopholis napuru* (Kruse, 1990). Abbreviations: M = Miaolingian; W = Wuliuan; *A. abacus* = *Archaeocyathus abacus*; *S. favus* s.s. = *Syringocnema favus* sensu stricto; *J. tardus* = *Jugalicyathus tardus*; *S. tenuis* = *Spirillicyathus tenuis*; *W. wilkawillinensis* = *Warriootacyathus wilkaillinensis*; *C. opimolumum* = *Corollasphaeridium opimolumum*; *V. pseudofaveolata* = *Vulcanisphaera pseudofaveolata*; *C. aliquolumum* = *Corollasphaeridium aliquolumum*; *C. spinuconum* = *Ceratophyton spinuconum*; *V. trisentium* = *Veryhachium trisentium*; *K. rostrata* = *Kulparina rostrata*; *S. imbricata* = *Sunnaginia imbricata*.

which was defined at 'the first appearance of elements of the *Irvingella tropica* Trilobite Zone' (Fig. 2). Hence, all the constituent stages of the Australian Miaolingian and Furongian were defined in central-northern Australia. This stadial scheme from central-northern Australia has been applied in Victoria (Paterson & Laurie 2004, Jell 2013, and references therein), Tasmania (Jago *et al.* 2016a, Bentley *et al.* 2020), New South Wales (see overview in Percival *et al.* 2011), the Warburton Basin of northeastern South Australia (Sun *et al.* 2021 and references therein), New Zealand (Smith *et al.* in press) and northern Victoria Land, Antarctica (Jago *et al.* 2019).

South Australian biostratigraphy

At the time of Shergold's (1995) overview of the Cambrian in Australia, the stadial nomenclature used for the lower Cambrian was that of Siberia, with Tommotian, Atdabanian, Botoman and Toyonian being used in his Fig. 1. Alongside this was a zonation based on archaeocyaths established by Zhuravlev *et al.* (1994), based primarily on the work of Gravestock (1984). These latter authors established a succession of three archaeocyath zones in the lower Hawker Group of the Arrowie Basin—in ascending order, the *Warriootacyathus wilkawillinensis*, *Spirillicyathus tenuis* and *Jugalicyathus tardus* zones—beneath a widespread horizon known as the Flinders Unconformity (James & Gravestock 1990).

Daily (1956, 1972, 1976a, b) had earlier introduced twelve faunal assemblages based on various taxa including trilobites, archaeocyaths and small shelly fossils, but most of these faunas remained undescribed and lacking accurate biostratigraphic information; as such, they could only be used as informal 'yardsticks' for intercontinental correlations. Bengtson *et al.* (1990) described some of the shelly fossils from the Stansbury and Arrowie basins, but did not attempt to construct a biostratigraphic scheme from their data. In that same publication, Jell (in Bengtson *et al.* 1990) described trilobites from the Stansbury and Arrowie basins and erected four zones based on their ranges, though these were largely based on collections from spot localities (Fig. 3).

Daily (1972, 1990) and Gravestock *et al.* (1990, 2001) outlined the basic biostratigraphy of the Stansbury Basin, with the last of these publications describing key phosphatic fossils from two short surface sections and several drill cores. As a result, three small shelly fossil zones (Demidenko in Gravestock *et al.* 2001), four molluscan zones (Parkhaev in Gravestock *et al.* 2001), and seven acritarch zones (Zang in Gravestock *et al.* 2001, Zang *et al.* 2007) were erected (Fig. 2). However, Jacquet *et al.* (2016) later contended that the molluscan biozones of Gravestock *et al.* (2001) had very poorly defined boundaries and were based on poorly preserved, long-ranging steinkerns that Jacquet *et al.* (2019) considered, with a few exceptions, to have weak taxonomic validity. In addition, Jacquet *et al.* (2016) also noted that biostratigraphic data presented by Gravestock *et al.* (2001) revealed clear temporal discrepancies between the sections on Yorke and Fleurieu peninsulas (see also Betts *et al.* 2016b), indicating major problems with these basin-wide correlations.

Detailed taxonomic treatment of key lower Cambrian taxa collected systematically from more than 15 stratigraphic sections and subsurface cores in the Arrowie Basin was initiated in the 1990s and expanded during the 2000s, with comprehensive descriptions of small shelly fossils (Brock & Cooper 1993, Holmer *et al.* 2008, 2011b, Skovsted *et al.* 2008, 2009a, 2009b, 2011a, 2011b, 2015a, 2015b, 2016, Topper *et al.* 2009, Larsson *et al.* 2014), trilobites (Jell *et al.* 1992, Paterson & Edgecombe 2006, Paterson & Brock 2007, Paterson *et al.* 2007a, 2007b), bradoriide arthropods (Skovsted *et al.* 2006, Topper *et al.* 2011b, Betts *et al.* 2014, 2016a, 2016b), lobopodians (Topper *et al.* 2010, 2011a), brachiopods (Holmer *et al.* 2006, 2011a, Topper *et al.* 2013, Betts *et al.* 2019) and molluscs (Brock & Paterson 2004, Paterson *et al.* 2007a, 2009, Skovsted *et al.* 2007, 2012, 2014, Jacquet & Brock 2016, Jacquet *et al.* 2014, 2016). This comprehensive taxonomic dataset, together with new collections and illustrations of key taxa, resulted in a new high-resolution biostratigraphic scheme (Betts *et al.* 2016b, 2017) and the erection of three new shelly fossil biozones: in ascending order, these are the *Kulparina rostrata*, *Micrina etheridgei* and *Dailyatia odyssei* zones (Fig. 3). The two lower zones approximately correspond to the three archaeocyath zones of Zhuravlev *et al.* (1994), whereas the *D. odyssei* Zone correlates broadly with the *Syringocnema favus* beds of those authors. The integration of $\delta^{13}C$ and $\delta^{18}O$ isotope data (chemostratigraphy) from the sections that provided the new biozonation, together with several $^{238}U/^{206}Pb$ dates derived from ID-TIMS analyses of zircon grains from ash beds in the Mernmerna Formation and overlying Billy Creek Formation, facilitated the development of a new multiproxy chronostratigraphic scheme for the lower Cambrian succession in the Arrowie Basin (Betts *et al.* 2018).

Further dates from these ash beds should improve definition of the scheme (Langsford & Jago 2023).

Modern taxonomic treatment of key shelly fossil groups from the Stansbury Basin has been provided by Paterson *et al.* (2007a), Jacquet *et al.* (2017), Betts *et al.* (2019) and Holmes *et al.* (2021b). Importantly, Jacquet *et al.* (2017) formally described *Watsonella crosbyi* Grabau, 1900 and the sinistral conchs of *Aldanella* sp. cf. *golubevi* Parkhaev, 2007 from the lower units of the Normanville Group, and reported new occurrences of the widespread tommotiide *Sunnaginia imbricata* Missarzhevskiy in Rozanov *et al.*, 1969 from the Sellick Hill Formation, suggesting that the lower Cambrian package in the Stansbury Basin is older than the shelly fossil biozones established in the Arrowie Basin. This is supported by initial chemostratigraphic data presented by Betts *et al.* (2018) for the Wangkonda and Sellick Hill formations, interpreted by those authors to correlate with major global Zhujiaqing Carbon Isotope Excursion (ZHUCE) and Shiyantou Carbon Isotope Excursion (SHICE) events—reinforcing an older Terreneuvian, Stage 2 age for this package.

The Kangaroo Island Group on the north coast of Kangaroo Island includes the Emu Bay Shale *Konservat-Lagerstätte*, which contains over 50 species of panarthropods, molluscs, brachiopods, sponges, vetulicolians and other taxa (Paterson *et al.* 2016, 2023, Jago *et al.* 2016b, Edgecombe *et al.* 2017, Schroeder *et al.* 2018, Yun *et al.* 2019, Holmes *et al.* 2020, and references therein). The biostratigraphically important trilobites *Estaingia bilobata* Pocock, 1964, *Balcoracania dailyi* Pocock, 1970 and *Redlichia takooensis* Lu, 1950 are known from the Emu Bay Shale (Pocock 1964, 1970, Paterson & Jago 2006, Holmes *et al.* 2020, 2021a), with *B. dailyi* Pocock, 1970 also recognized from the underlying Marsden Sandstone (Gehling *et al.* 2011), and from the Smith Bay Shale further to the west, where it co-occurs with *R. takooensis* Lu, 1950 (Jago *et al.* 2021). These trilobites indicate correlation with the Series 2, Stage 4 *Pararaia janeae* Zone of the Arrowie and Stansbury basins.

Correlation between central-northern and South Australia

A longstanding impediment to the establishment of lower Cambrian stages in Australia arises from the historical fact that the entire Australian stadial scheme for the Miaolingian and Furongian series was established in the cratonic basins of central and northern Australia, whereas the lower Cambrian is best developed in South Australia (Laurie *et al.* 2023). Uppermost Series 2 (Ordian) rocks are widespread in central-northern Australia, but correlation with the succession in South Australia has proven difficult. Biostratigraphic studies targeting rocks of this age in central and northern Australia and South Australia will be essential for correlating these areas (Castle-Jones *et al.* 2023, Birksmith *et al.* 2023, Betts *et al.* 2023, Smith *et al.* 2023).

Among the existing Australian stages, the Ordian (Öpik 1968)—the stratigraphically lowest Australian stage recognized at present—is the only one that remains undefined. A base for the Ordian needs to be designated before any lower stages can be identified and formally defined. However, a suitable base for the Ordian Stage cannot be defined in central-northern Australia because the classical Ordian of Öpik (1968) in many places rests on the widespread Kalkarindji Volcanic Group (Glass 2002, Glass & Phillips 2002, Kruse in Rawlings *et al.* 2008), which extends from northern Western Australia across the Northern Territory into western Queensland, thereby underlying the Ord, Bonaparte, Daly and Wiso basins and much of the northern Georgina Basin. This extrusive flood-basalt province has been dated by Jourdan *et al.* (2014) at 510.7 ± 0.6 Ma, placing it within the unnamed and undefined global Stage 4.

In the southern Georgina Basin where this volcanic unit is absent, Ordian rocks rest upon the Red Heart Dolostone (assigned to the *Micrina etheridgei* Zone of Betts *et al.* 2016b) or older units. Hence, a lengthy hiatus lies beneath the classical Ordian succession. In the northeastern Amadeus Basin, the *M. etheridgei* Zone interval of the Todd River Dolostone is directly overlain by the Giles Creek Dolostone. The Giles Creek Dolostone likely straddles the Ordian–Templetonian boundary (e.g., Öpik 1968, 1982, Shergold 1986, Smith *et al.* 2023). Previously, Smith *et al.* (2014, 2015b, 2016) had assigned the unit's type section entirely to the Templetonian. However, an update to the range for *Pagetia silicunda* Jell, 1975, as well as the likely synonymy of *Xystridura gayladia* Öpik, 1975 and *Xystridura fracta* Öpik, 1975, supports a latest Ordian age for the lower portion of the formation (Smith *et al.* 2023). In the central Amadeus Basin, the Ordian Tempe Formation is disconformably underlain by the unfossiliferous Chandler Formation or, where this is absent, the Arumbera Sandstone of latest Ediacaran to earliest Cambrian age (Smith *et al.* 2015a). A similar (albeit shorter) hiatus is also seen in the Koonenberry Belt of northwestern

New South Wales. Here, the Ordian Coonigan Formation rests disconformably on the 'late Botomian' Cymbric Vale Formation (Roberts & Jell 1990, fig. 2 'second trench'), which is placed low in the *Pararaia janeae* Zone (Jago *et al.* 1997, Paterson 2005, Jell & Smith unpublished data). The basal part of the Pincally Formation (of likely Ordian to early Templetonian age) near Mount Arrowsmith, further northwest, is entirely covered by unconsolidated colluvium and impossible to access (Brock & Percival 2006, Percival in Greenfield *et al.* 2010, p. 68, Percival *et al.* 2011, p. 9).

For the above reasons, most, if not all, central-northern Australian sections are unsuitable for defining the Ordian base as traditionally conceived. Recourse to South Australian sections is unavoidable.

The youngest known trilobite occurrence in the entire South Australian succession is represented by four partial pygidia assigned to *Pagetia* cf. *edura* Jell, 1975, recorded from the Coobowie Limestone in Port Julia 1A well in the Stansbury Basin (Jago & Kruse 2020). Three relatively poorly preserved cephala of a taxon comparable to *P. edura* have also recently been reported in the Stansbury Limestone in the CUR-D 9 core (Birksmith 2022, Birksmith *et al.* 2023). *Pagetia edura* Jell, 1975 has previously been recorded from the Templetonian *Xystridura templetonensis* Zone by Jell (1975), and *P.* aff. *edura* has been recorded from the early Templetonian Jigaimara Formation in the Arafura Basin, Northern Territory (Laurie 2006b). Accordingly, Jago & Kruse (2020) assigned the Coobowie Limestone occurrence to the global Wuliuan Stage, the basal stage of the Miaolingian.

Öpik (1968) recorded species of *Onaraspis* Öpik, 1968 from the Ordian of central-northern Australia, specifically from localities Rd10 and AS33 (see Smith *et al.* 2015b) in a unit that he attributed to the Giles Creek Dolostone of the Amadeus Basin; locality CG51/1 in the Tarrara (= Blatchford) Formation in the Bonaparte Basin; the First Discovery Limestone Member of the Coonigan Formation (Roberts & Jell 1990, Smith *et al.* 2023) in the Koonenberry Belt; and in an unknown formation at locality M262 in the northeastern Georgina Basin. In South Australia, *Onaraspis rubra* Jell, 1990 is known from several localities in the Moodlatana Formation in the Arrowie Basin (Jell in Bengtson *et al.* 1990, p. 13) and is assumed to be of similar age.

In addition, *Redlichia* cf. *versabunda* Öpik, 1970 (= *R. guizhouensis* of Jell in Bengtson *et al.*, 1990) is known from the Ramsay Limestone in the Stansbury Basin, and the Wirrealpa Limestone (and probably Aroona Creek Limestone) in the Arrowie Basin (Paterson & Brock 2007, Holmes *et al.* 2021b). *Redlichia versabunda* Öpik, 1970 has been described from several localities in the northeastern Georgina Basin, including the 'chertified dolostone' of the Yelvertoft Bed (locality M426, now considered within the Thorntonia Limestone; Southgate & Shergold 1991), as well as from what Öpik (1970) stated was an equivalent chert bed at Cornford Bore ~40 km east of Mount Isa (locality M262, mentioned above), and from the Thorntonia Limestone ~110 km south of Mount Isa (locality D41) (Öpik 1970, fig. 1).

Below these isolated occurrences, the South Australian early Cambrian trilobite zones erected by Jell (in Bengtson *et al.* 1990) comprise, in ascending order, the *Parabadiella huoi*, *Pararaia tatei*, *Pararaia bunyerooensis* and *Pararaia janeae* zones (Fig. 3). Regrettably, none of the representative taxa have yet been found in central-northern Australia (although *P. janeae* Jell, in Bengtson *et al.* 1990 is known from the Cymbric Vale Formation in New South Wales; Jell & Smith unpublished data). Hence, correlation between these two regions is difficult using available trilobite faunas. This apparent rarity of trilobites in the upper parts of the South Australian Cambrian means that other fossil groups are required to correlate between the central-northern Australian basins and those in South Australia.

Small shelly fossils are abundant and diverse in South Australian successions (e.g., Skovsted *et al.* 2007, 2008, 2011a, 2011b, 2015a, 2015b), with the *Kulparina rostrata*, *Micrina etheridgei* and *Dailyatia odyssei* zones erected (Betts *et al.* 2016b, 2017, 2018). In central-northern Australia, these fossils are known only from one unit each in the Amadeus (Todd River Dolostone; Laurie 1986) and southern Georgina (Red Heart Dolostone [= Errarra Formation]; Laurie & Shergold 1985) basins, both of which are bounded by disconformities that likely represent considerable intervals of time. The small shelly fossils indicate that both formations lie within the *Micrina etheridgei* Zone, and these are the only two units in the Amadeus and Georgina basins from which archaeocyaths have been recorded (Walter *et al.* 1979, Kruse & West 1980).

Brachiopods also appear to be a viable option for correlation, as several species are widespread. For example, *Kostjubella djagoran* (Kruse, 1990), widely reported from central-northern Australian cratonic sedimentary basins (Kruse 1990, 1991a, 1998, Percival & Kruse 2014), is also found in the Ramsay, Stansbury and Coobowie limestones in the western

Stansbury Basin (Holmer & Ushatinskaya in Gravestock *et al.* 2001, Jago & Kruse 2020, Birksmith 2022, Birksmith *et al.* 2023), and the Wirrealpa Limestone in the Arrowie Basin (Brock & Cooper 1993, fide Holmer *et al.* 1996, but see Claybourn *et al.* 2020). Indeed, Brock (in Jago *et al.* 2006, 2012) recognized four informal brachiopod assemblages in the Arrowie and Stansbury basins, the uppermost of which was the *K. djagoran* assemblage. In central-northern Australia, *Kostjubella djagoran* is known from the Thorntonia Limestone in the southern Georgina Basin (Percival & Kruse 2014), Top Springs Limestone in the northern Georgina Basin (Kruse 1991a), Tindall Limestone in the Daly Basin (Kruse 1990), Montejinni Limestone in the eastern Wiso Basin (Kruse 1998), and Tempe Formation in the Amadeus Basin (Smith *et al.* 2015a). Further afield, it is also reported from erratics on King George Island in the South Shetland Islands, Antarctica (Holmer *et al.* 1996).

Other brachiopods widely distributed in South Australia include *Askepasma toddense* Laurie, 1986, *Askepasma saproconcha* Topper, Holmer, Skovsted, Brock, Balthasar, Larsson, Petterson Stolk & Harper, 2013, *Schizopholis yorkensis* (Holmer & Ushatinskaya in Gravestock *et al.*, 2001) and *Kyrshabaktella davidi* Holmer & Ushatinskaya in Gravestock *et al.*, 2001; whereas the Ordian *Kyrshabaktella mudedirri* Kruse, 1990, *Westonia nyapungensis* Kruse, 1990 and *Schizopholis napuru* (Kruse, 1990, fide Popov *et al.*, 2015) among others, are widespread in central and northern Australia. *Schizopholis yorkensis* (Holmer & Ushatinskaya in Gravestock *et al.*, 2001) is also known from the Transantarctic Mountains, Antarctica (Claybourn *et al.* 2020), and the Xinji Formation of South China (Pan *et al.* 2020). Uniquely among these species, *S. napuru* (Kruse, 1990) is represented in both central-northern and South Australia (where it often partially overlaps the range of *Kostjubella djagoran* [Kruse, 1990]). *Schizopholis napuru* (Kruse, 1990) has also been reported from King George Island, Antarctica (Holmer *et al.* 1996) and the Himalayas (Popov *et al.* 2015).

Although acritarch studies have been carried out in the South Australian Cambrian, resulting in the identification of seven assemblages (Zang in Gravestock *et al.* 2001, Zang *et al.* 2007), work on acritarchs in the central-northern Australian Cambrian has been limited, with a single assemblage identified from two units—the Adam Shale, which was considered to be 'Tommotian' (i.e., latest Terreneuvian) in age (Walter *et al.* 1979), and the Ordian Tempe Formation (Zang & Walter 1992).

Carbon isotope excursions, when integrated with biostratigraphy, are another useful tool for correlation. Smith *et al.* (2015c) identified a strong negative δ^{13}C excursion in the lower Arthur Creek Formation of the southern Georgina Basin, first reported by Lindsay *et al.* (2005), as the Redlichiid–Olenellid Extinction Carbon Excursion (ROECE), although the weak correlation of C and O isotopes in the crossplot data (Smith *et al.* 2015c, p. 19) suggests a potential diagenetic signal for this event. Lindsay *et al.* (2005) interpreted this excursion as due to microbial alteration. In the Stansbury Basin, the ROECE has been identified by Birksmith (2022, see also Birksmith *et al.* 2023) in two cores in the upper Stansbury Limestone. Lower in the succession, a negative event in the Ramsay Limestone is also captured in the correlative Wirrealpa Limestone in the Arrowie Basin (GAB, unpublished data) and may represent the Archaeocyath Extinction Carbon Excursion (AECE) event. The youngest archaeocyaths in the entire Australian succession, which are correlated with the equivalent youngest archaeocyaths in the Toyonian Stage of Siberia (e.g., Debrenne *et al.* 1989, 1990), are found in the medial Wirrealpa Limestone (Kruse 1991b).

The quest for regional lower Cambrian stages in Australia

Despite possessing a series of world-class and well documented lower Cambrian (Terreneuvian–Series 2) successions, no regional stages have been defined for this interval in Australia. As outlined above, such stages will need to be defined in South Australia, likely within the Arrowie and Stansbury basins. The Arrowie Basin in particular has one of the best-exposed successions of lower Cambrian sedimentary packages anywhere in the world, as summarized by Jago et al. (2020). Calcareous and organophosphatic shelly fossils '… are ubiquitous across carbonate-dominated parts of the basin and have been described in a series of papers' (Betts *et al.* 2016b, p. 177). In addition, the Stansbury Basin has well-documented successions on the Fleurieu Peninsula, Kangaroo Island, and Yorke Peninsula (the last largely from drill core).

In erecting an internally consistent succession of six named regional stages for North America, Palmer (1998, see also Babcock *et al.* 2011) stated that the value of regional stages was in their utility for communication. Similarly, Siberia (Spizharskiy *et al.* 1983, Rozanov & Varlamov 2008), South China (Peng *et al.* 2020) and Iberia/Morocco (Gozalo *et al.* 2003, Geyer & Landing 2004) also have well-developed stadial schemes. The Siberian scheme was long used as a proxy for the lower Cambrian in Australia (Shergold 1995, Kruse *et al.* 2009).

Given that we now have a well-developed understanding of the distribution of numerous taxa (archaeocyaths, trilobites, bradoriides, brachiopods, tommotiides, molluscs, acritarchs, etc.; Zhuravlev *et al.* 1994, Betts *et al.* 2016b, 2018, Kruse & Debrenne 2020), it is time to consider the introduction of a regional stadial scheme for the lower Cambrian in Australia.

When the remaining global stages for the Terreneuvian and Cambrian Series 2 are ratified, there is no guarantee that the definitions will be easily applicable in Australia. As an example, the base of the Miaolingian Series and conterminous Wuliuan Stage is defined (Zhao *et al.* 2019) by the FAD of *Oryctocephalus indicus* (Reed, 1910), which has not been found in Australia despite the record of numerous oryctocephalid species from the Amadeus, Arafura and Georgina basins, and the Koonenberry Belt (Shergold 1969, Laurie 2004, 2006a, 2006b, Smith *et al.* 2015b, 2023). As a consequence, a local stadial scheme should be based on multiple independent chronological datasets to allow successful correlation of Cambrian packages across regional and intercontinental scales.

Ideally, a local stadial scheme should be based on features that can be shown to be most useful in correlating as widely as possible within a broad sequence stratigraphic context. With regard to the Cambrian Terreneuvian and Series 2 in South Australia, usable taxa include trilobites, brachiopods, small shelly fossils (tommotiides, molluscs, etc.), archaeocyaths, acritarchs and ichnofossils, could be integrated with robust chemostratigraphy based on stable isotope data ($\delta^{13}C$ and $\delta^{18}O$) and, wherever possible, radiometric dates based on ID-TIMS analysis of zircon grains from volcanic-ash beds.

The obvious levels to define stadial boundaries are where the potential for correlation is the greatest, and therefore where taxa are the most diverse and numerous. Previously established biozones, correlatable across multiple successions and facies, are likely to provide the best options in this case. At stratigraphically higher levels in the South Australian Cambrian successions (i.e., above the Hawker Group of the Arrowie Basin and equivalents), trilobite abundance and diversity are limited, with only four species known (Bengtson *et al.* 1990, Jago & Kruse 2020, Jago et al. 2020). Thus, in this interval, other shelly fossils are likely to be more useful in defining biozones and stage boundaries; however, trilobites can still be used as auxiliary index taxa, as genera such as *Redlichia* Cossmann, 1902 *sensu lato* are fairly widespread in Gondwana (Álvaro *et al.* 2013).

Below this, trilobites of the *Parabadiella huoi*, *Pararaia tatei*, *Pararaia bunyerooensis* and *Pararaia janeae* zones are found in the Wilkawillina and Ajax limestones, Mernmerna Formation and Oraparinna Shale of the Arrowie Basin and equivalents in the Stansbury Basin (e.g., Parara Limestone on Yorke Peninsula), and the Marsden Sandstone, Emu Bay Shale and Smith Bay Shale on Kangaroo Island (Bengtson *et al.* 1990, fig. 7, Jell *et al.* 1992, Paterson & Jago 2006, Paterson & Brock 2007, Betts *et al.* 2018, fig. 17, Holmes *et al.* 2020, 2021a, Jago *et al.* 2021). At least the *P. janeae* Zone fauna (including the eponym) are also found in the Cymbric Vale Formation of the Koonenberry Belt in New South Wales (Jago *et al.* 1997, Paterson 2005, Jell & Smith unpublished data). However, their numbers and occurrence are limited relative to those of small shelly fossils recovered from acid digestion.

Brachiopods are limited in diversity, but are relatively numerous and can be found in several horizons within units such as the Wilkawillina Limestone. Small shelly fossils are very diverse and are found in numerous horizons in many formations, such as the Wilkawillina, Ajax, Wirrapowie, Wirrealpa and Aroona Creek limestones and Mernmerna Formation (Arrowie Basin), as well as the Sellick Hill Formation and Fork Tree, Parara, Kulpara, Ramsay, Stansbury and Coobowie limestones (Stansbury Basin), among others (e.g., Gravestock *et al.* 2001, Betts *et al.* 2016b, 2017, 2018). This makes them probably the most useful taxa for correlation throughout the Arrowie Basin, Stansbury Basin, Stuart Shelf and other areas. However, their zonation only extends a short distance above the base of the *Pararaia janeae* Zone. Above this, zones will need to be established based on different taxa. Work currently in progress within the 'Ordian' interval in the Stansbury, Arrowie and Georgina basins will help to refine the biostratigraphy of these successions and correlations between them.

The base of the Templetonian was defined by Laurie (2006a), which implicitly placed an upper boundary on the Ordian, and is at the tail end of what has been suggested to be the ROECE event. This event is recorded in the Stansbury Limestone

(Birksmith 2022, Birksmith *et al.* 2023). Lower in the Wirrealpa (Arrowie Basin) and Ramsay (Stansbury Basin) limestones are the brachiopods *Hadrotreta primaeva* (Walcott, 1902) (= *Kostjubella djagoran* [Kruse, 1990] according to Holmer *et al.* 1996, *fide* Percival & Kruse 2014), *Schizopholis napuru* (Kruse, 1990) and a possible *Kyrshabaktella* Koneva, 1986 species (Brock & Cooper 1993). The FAD of *K. djagoran* (Kruse, 1990) as reported by Brock & Cooper (1993) is only some 11–14 m above the base of the Wirrealpa Limestone. In the Ramsay Limestone—and presumably above the medial Wirrealpa Limestone, as there are archaeocyaths in the medial interval of that unit—is a $\delta^{13}C$ excursion that may represent the AECE event (Birksmith *et al.* 2023). The first appearance of such brachiopod taxa near the AECE event could be a potential datum to define the base of the Ordian Stage. Such a horizon is most likely to be identified in the Wirrealpa Limestone or Ramsay Limestone. It is noteworthy that Öpik (1968) listed the Wirrealpa Limestone among the units included in his Ordian Stage.

If the base of the Ordian is defined at the FAD of *K. djagoran* (Kruse, 1990) and/or *S. napuru* (Kruse, 1990) (or a related taxon), then horizons lower in the Cambrian that potentially lend themselves to stage definitions include the following (in descending order):

- FAD of *Pararaia janeae* Jell in Bengtson *et al.*, 1990, which appears very late in the *Dailyatia odyssei* Zone.
- FAD of *Pararaia bunyerooensis* Jell in Bengtson *et al.*, 1990, which occurs late in the *D. odyssei* Zone.
- FAD of *Pararaia tatei* (Woodward, 1884), which occurs just above the base of the *D. odyssei* Zone.

Note that data on the geographic distribution of the above three species are currently limited (Jell in Bengtson *et al.* 1990, Paterson & Brock 2007, Betts *et al.* 2018).

- FAD of *Dailyatia odyssei* Evans & Rowell, 1990 and/or *Stoibostrombus crenulatus* Conway Morris & Bengtson in Bengtson *et al.*, 1990, which define the base of the *D. odyssei* Zone (Betts *et al.* 2016b). Betts *et al.* (2018) interpreted a positive $\delta^{13}C$ peak in the Mernmerna Formation and Ajax Limestone as the Cambrian Arthropod Radiation Event (CARE, or excursion IV), which straddles the boundary between the *Micrina etheridgei* and *Dailyatia odyssei* zones. However, new data from the Parara Limestone in the western Stansbury Basin suggest that this positive event could represent the younger MICE event (Castle-Jones *et al.* 2023).
- FAD of archaeocyathan fauna of the *Syringocnema favus* assemblage *sensu lato* (Zhuravlev *et al.* 1994, Kruse & Debrenne 2020). This assemblage coincides with the base of the *D. odyssei* Zone and with the widespread Flinders Unconformity of James & Gravestock (1990). The *S. favus* assemblage is known from Yorke Peninsula and Kangaroo Island, South Australia (Zhuravlev *et al.* 1994, Kruse & Moreno-Eiris 2013), the Mount Wright Volcanics and Cymbric Vale Formation in the Koonenberry Belt of western New South Wales (Kruse 1978, 1982), at numerous localities along the Transantarctic Mountains and adjacent seas and islands (Gordon 1921, Debrenne & Kruse 1986, 1989, Stone *et al.* 2012), as well as in southern Africa (Debrenne 1975, Perejón *et al.* 2019). In addition to *S. favus* Taylor, 1910, Kruse & Debrenne (2020) proposed the FADs of *Stapicyathus stapipora* (Taylor, 1910), *Tumuliolynthus irregularis* (Bedford & Bedford, 1934) and *Sigmofungia flindersi* Bedford & Bedford, 1936 as potential guide species for the base of this assemblage.
- FAD of *Parabadiella huoi* Zhang, 1966, which occurs late in the *M. etheridgei* Zone, and which also represents the eponymous zone in South China (Betts *et al.* 2018).
- FAD of *Micrina etheridgei* (Tate, 1892) and/or *Askepasma toddense* Laurie, 1986, which defines the base of the *M. etheridgei* Zone (Betts *et al.* 2016b). This is interpreted by Betts *et al.* (2018) to be generally coincident with $\delta^{13}C$ excursions II and III, which, according to those authors, straddle the boundary between the *Kulparina rostrata* and *Micrina etheridgei* zones, but peak in the lower part of the *M. etheridgei* Zone. New data suggest that this boundary may be coincident with the CARE $\delta^{13}C$ excursion (Castle-Jones *et al.* 2023).
- FAD of *Kulparina rostrata* Conway Morris & Bengtson in Bengtson *et al.*, 1990 and/or *Askepasma saproconcha* Topper, Holmer, Skovsted, Brock, Balthasar, Larsson, Petterson Stolk & Harper, 2013, which define the base of the *K. rostrata* Zone (Betts *et al.* 2016b). This assemblage is reported from the upper part of the Sellick Hill Formation and co-occurs with an archaeocyathan fauna (Debrenne & Gravestock 1990) that was correlated with the Atdabanian Stage of Siberia (lower global Stage 3) by Gravestock *et al.* (1995, p. 4); it is stratigraphically above negative $\delta^{13}C$ data that

Betts *et al.* (2018) interpreted as the SHICE, although is more likely to be negative values below the CARE. SHICE is a negative $\delta^{13}C$ excursion in the Shiyantou Member of the Chiungchussu (Qiongzhusi) Formation in eastern Yunnan, China, and is associated with the extinction of many shelly taxa around the middle of Stage 2.

- FAD of *Watsonella crosbyi* Grabau, 1900 in the Mount Terrible Formation (Jacquet *et al.* 2016). This species is a candidate indicator for the base of global Stage 2. The ZHUCE (I' in Siberia, 6p of Maloof et al. [2010], L4 of Landing *et al.* [2013]) is a positive $\delta^{13}C$ excursion and follows a major radiation of the first biomineralized organisms in the Cambrian. Elsewhere, positive ZHUCE $\delta^{13}C$ values occur just after the probable transition between the as yet undefined Fortunian – Stage 2 boundary. A peak within the Sellick Hill Formation is interpreted by Betts *et al.* (2018) as ZHUCE; it is within the stratigraphic range of *Watsonella crosbyi.*
- FAD of vertical burrows of *Skolithos* Haldeman, 1840 and *Diplocraterion* Torell, 1870 in the Parachilna Formation, which is also a potential proxy for the onset of Stage 2 (Mángano & Buatois 2014) in the global scale. These traces are also known from the Wangkonda Formation in the eastern Stansbury Basin (Betts *et al.* 2018). *Skolithos* Haldeman, 1840 is also present in Arumbera Sandstone 4 in the Amadeus Basin, and the Neutral Junction Formation [= Donkey Creek beds of Walter (1980)] in the Georgina Basin; *Diplocraterion* Torell, 1870 is reported from the Octy Formation and/or Neutral Junction Formation, Red Heart Dolostone and Mount Birnie beds in the Georgina Basin (Walter *et al.* 1989, Haines *et al.* 1991).
- FAD of *Treptichnus pedum* (Seilacher, 1955) in the Uratanna Formation (Droser *et al.* 1999, Jago et al. 2020). This ichnospecies is the primary indicator taxon for the global base of the Cambrian. It is also present in Arumbera Sandstone 4 in the Amadeus Basin, and the Octy and Neutral Junction formations of the Georgina Basin (Walter *et al.* 1989, Haines *et al.* 1991). The first occurrence of *Sabellidites* Yanishevskiy, 1926 'worms' immediately above *Treptichnus* Miller, 1889 is also within the Uratanna Formation, and the genus is additionally present in the Mount Terrible Formation. *Sabellidites* Yanishevskiy, 1926 is globally widespread among basal Cambrian terranes (e.g., South China, Norway, Iran and elsewhere; see Ebbestad *et al.* 2022).

Concluding remarks

After nearly 100 years of development of the Cambrian stage scale in Australia, and with the Miaolingian and Furongian regional stages completed in 2006 and much new information on Terreneuvian and Series 2 faunas now available, a workable lower Cambrian stage scale is at last in view. Brachiopods appear to be best suited to establishing the base of the Ordian Stage, after which several faunal levels offer scope for proposing new lower Cambrian stages, thereby facilitating the completion of a comprehensive Australian Cambrian stage scale.

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