# Eocene bryozoans preserved in chert from the Wilson Bluff Limestone, Eucla Basin, Western Australia

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Fossil bryozoans preserved in cherts of the middle to upper Eocene Wilson Bluff Limestone from the Eucla area, Western Australia, are described. The Wilson Bluff Limestone was deposited in the broad shallow epicontinental Eucla Basin, which underlies the Nullarbor Plain and extends offshore into the Great Australian Bight. It is exposed at the base of the Nullarbor Plain sea cliffs and in caves in the Nullarbor Plain. The Wilson Bluff Limestone is a fine-grained, medium- to thick-bedded, chalky, bryozoan-rich limestone with abundant chert nodules. Volumetrically, the most important fossils are bryozoans. Thin sections from three samples of Aboriginal chert artifacts and two samples of chert from well cuttings were prepared. Due to the lack of frontal wall zooecial morphology, species were determined from zoarial habit, branch width, and zooecium diameter. Sixteen colonies could be assigned to three species: the cheilostomes *Adeonellopsis* sp. and *Cellaria rigida*, and the cyclostome *Idmonea geminata*. This species diversity preserved in chert is far lower than in previous studies of the non-chert component of the Wilson Bluff Limestone. This was attributed to the poor preservation resulting from the silicification process.

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THOUGH the 'Tertiary' bryozoans of Victoria and South Australia (Brown 1958; James & Bone 1991, 2000, 2011; Schmidt & Bone 2003; Sharples *et al.* 2014) have been better studied than those of Western Australia, the bryozoan-rich limestones of southern Western Australia have long been known. Tate (1879) described two bryozoans (*Cellepora hemisphaerica* and *Retepora* sp.) from the 'White Polyzoal Limestone' which is now known as the Wilson Bluff Limestone (Table 1). There were no more published studies of the bryozoan fauna of the Wilson Bluff Limestone for another century. In the interim, Gregory (1916) and Crespin (in Clarke *et al.*1948) identified a few species from the slightly older Norseman Limestone of the Eundynie Group, a lateral equivalent of the Plantagenet Group (Table 1), 700 km to the west of our study site. Cockbain (1970) published a list of 35 species of the Wilson Bluff Limestone cheilostome fauna. Most recently, Sharples *et al.* (2014) examined the bryozoans in an offshore well 350 km southeast of our study site and found that the taxa in the giant Eocene bryozoan reef mounds include eight genera of cheilostomes (*Porina*, *Cellaria*, *Puellina*, *Chondriovelum*, *Foveolaria*, *?Reteporella*, *Nudicella*, and *Exechonella*) and eight of cyclostomes (*Patinella*, *Nevianipora*, *Hornera*, '*Entalophora*,' *Idmidronea*, *Crisia*, *Platonea*, and *Diaperoecia*).

This study significantly adds to our understanding of the Eocene bryozoan fauna of the Wilson Bluff Limestone. The non-silicified cheilostomes from this formation have been listed previously (Cockbain 1970), but not necessarily the species preserved in chert. The limestone was deposited at a time when chert formation was widespread globally. The deposition of silica-rich sediments and formation of bedded biogenic chert has occurred throughout the Phanerozoic but peaked during the early Eocene (~50 Ma) following the Jurassic–Paleogene diatom radiation (Kidder & Erwin 2001; Muttoni & Kent 2007). Biogenic cherts of the Wilson Bluff Limestone formed in the middle to late Eocene, which is after the global 50 Ma peak, but still was a time of elevated biogenic chert formation (Muttoni & Kent 2007, fig. 1D). In southern Australia, McGowran *et al.* (1997) correlated the deposition of the Wilson Bluff Limestone with a period of opaline chert formation they termed the 'Silica Window.'

Biogenic chert has the potential to preserve bryozoan communities which are indicative of different regions and could provide a useful tool for sourcing the origin of raw materials used in stone tool fabrication. It is hoped that the results from this study can in the future be applied to determining the provenance of Aboriginal bryozoan-bearing chert artifacts which are common from archaeological sites in southern Australia (Bates 1921; Johnston 1941; Nicholson & Cane 1991) and Western Australia (Glover & Cockbain 1971; Hallam 1972). Fossils in general (Key *et al.* 2010, 2016) as well as bryozoans in particular (Key & Wyse Jackson 2014; Key *et al.* 2014) are effective tools for discriminating lithic sources of artifacts and dimension stones.

## GEOLOGICAL SETTING

Based on planktonic foram biostratigraphy, the Wilson Bluff Limestone was deposited between 34 and 43 Ma in the middle to late Eocene (Ludbrook 1963; Li *et al.* 2003). The Eocene was a period of widespread carbonate sedimentation in basins along Australia's southern passive

**Table 1.** Eocene stratigraphy of the Eucla Basin. Modified from Quilty (1974, fig. 14), Clarke *et al.* (2003, table 2), O'Connell *et al.* (2012, fig. 3) and Cockbain (2014, fig. 9).

| Period | Epoch | Esperance Shelf stratigraphy | | Nullarbor Shelf stratigraphy |
|---|---|---|---|---|
| Paleogene | Eocene | Plantagenet Group | Pallinup Formation | Wilson Bluff Limestone |
| | | | Werillup Formation | Hampton Sandstone |

margin that formed following Jurassic rifting and Early Cretaceous separation of Australia from Antarctica (Veevers *et al.* 1990). The Wilson Bluff Limestone was deposited in the Eucla Basin as a broad shallow epicontinental sea that extended out into what is currently the Great Australian Bight (McGowran *et al.* 1997; Feary & James 1998). The now offshore section of the Eucla Basin (Fig. 1) in the middle–late Eocene was at 50–55°S paleolatitude (McGowran *et al.* 1997, fig. 2; Molina Garza & Fuller 2002, table 1; Li *et al.* 2003, fig. 8) compared to ~32°S today. In the subsurface of the onshore Eucla Basin, the Wilson Bluff Limestone thickens from its eastern margin at 130–133°E to its thickest (~300 m) in the center of the basin at 126–127°E (300 km southwest of Eucla) and thins again to the western margin at 123–125°E (Lowry 1970, fig. 19; Quilty 1974, fig. 3; Jones 1990, fig. 5; Webb & James 2006, fig. 8; Hou *et al.* 2011, fig. 5; O'Connell *et al.* 2012, fig. 2B). The almost horizontal Wilson Bluff Limestone is exposed at the base of the 50–90 m high sea cliffs at Wilson Bluff and between Point Culver and Point Dover, which extend essentially unbroken for almost 900 km (Lowry 1970). The formation is also exposed in caves in the semi-arid Nullarbor Plain (Webb & James 2006; Miller *et al.* 2012).

The Wilson Bluff Limestone is a fine-grained, medium- to thick-bedded, chalky, bryozoan-rich limestone with abundant chert nodules in a matrix of micrite and silt-sized skeletal fragments (Tate 1879; Singleton 1954; McWhae *et al.* 1958; Lowry 1968, 1970; James & Bone 1991; James *et al.* 1994; Li *et al.* 1996; Gammon *et al.* 2000). In the terminology of Dunham (1962) it is a poorly sorted packstone (Lowry 1970). The formation grades upwards from a whiter, harder, denser, more crystalline brachiopod-rich limestone to a yellower, softer, friable, and more poorly lithified, bryozoan-rich limestone (Lowry 1968; Lindsay & Harris 1975). It was deposited in a low energy, cool-water, normal marine salinity, open shelf, with carbonate muds and little terrigenous input (Lowry 1970; Lindsay & Harris 1975; O'Connell *et al.* 2012). Palaeodepths have been estimated at 50–90 m based on cheilostome bryozoan zoarial habits (Cockbain 1970) to as much as 75–120 m based on the planktonic foraminifera faunal assemblage (Lowry 1970).

Volumetrically the dominant fossils in both the silicified and non-silicified zones are bryozoans. Traces of bryozoans enclosed in the chert indicate the chert formed by diagenetic silicification of the original limestone. Diatoms and radiolarians are the primary source of the silica forming the chert nodules with sponge spicules a ubiquitous minor component (Lowry 1970). Bryozoan-rich chert nodules are scattered throughout most of the formation except for the top 13 m and the base. The nodules are well displayed at Wilson Bluff where waves have weathered the nodules out and concentrated them at the foot of the cliff. In the past, Aborigines collected many of the nodules there for the manufacture of tools (Lowry 1970). Chert nodules can also be found in the Wilson Bluff Limestone exposed in caves around Eucla (Lowry 1970). For example, in Koonalda Cave, 100 km northeast of Eucla (Fig. 1), the chert was quarried by Aborigines for tools (Gallus 1971; Wright 1971a, b).

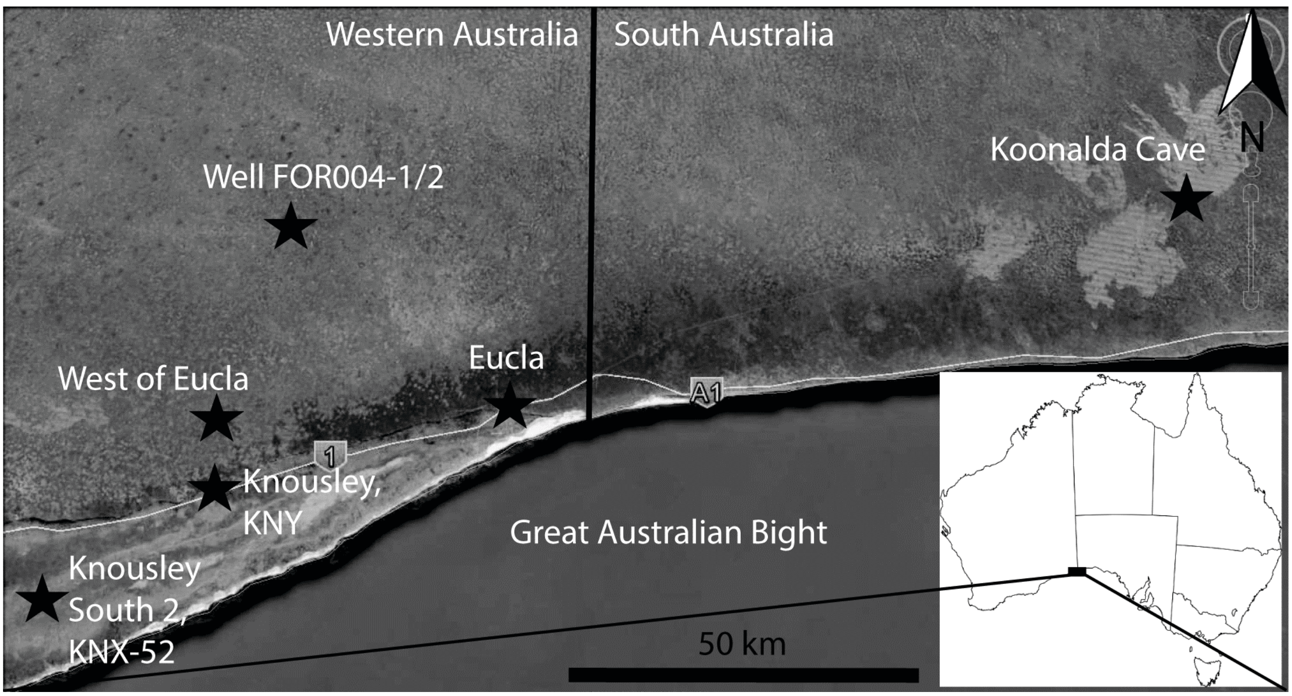


**Figure 1**. Map showing locations of chert samples analyzed in this study relative to Eucla, Western Australia and Koonalda Cave, South Australia. Modified from Google Earth.

**Table 2.** Chert samples examined in this study from the Eocene Wilson Bluff Limestone from around Eucla, Western Australia.

| Site | Type of sample | Munsell (2009) colour | Weight (g) | Latitude (°S) | Longitude (°E) |
|---|---|---|---|---|---|
| Knousley South 2, KNX-52 | surface scatter artifact | 2.5Y 7/1 Light grey | 9.56 | 31.906052 | 128.2698392 |
| Knousley, KNY | surface scatter artifact | 7.5YR 8/3 Pink | 4.94 | 31.7790141 | 128.4832551 |
| West of Eucla | surface scatter artifact | 7.5YR 6/2 Pinkish grey | 3.73 | 31.7224935 | 128.4832551 |
| Well FOR004-1, unweathered core of a 60.1 g chert nodule | nodule from well cuttings, 180m depth | mottled, mostly 2.5Y 6/1 Grey | 10.78 | 31.28008 | 128.55396 |
| Well FOR004-2, weathered rind of a 60.1 g chert nodule | nodule from well cuttings, 180m depth | 7.5YR 8/1 White | 4.95 | 31.28008 | 128.55396 |

## MATERIALS AND METHODS

Five chert samples from the Wilson Bluff Limestone were obtained from the vicinity of Eucla in the very southeastern corner of Western Australia (Fig. 1; Table 2). They ranged from 3.73 to 10.78 g (mean 6.79 g). Three were prehistoric debitage artifacts (i.e. conchoidally fractured, residual flakes from tool making) found as surface scatter that were obtained by Aborigines from the only biogenic chert-bearing formation in the area, the subsurface Wilson Bluff Limestone. This formation was accessible to Aborigines via caves and the coastal cliff outcrops (Gallus 1971; Wright 1971a, b). Caves occur along the coastline of the Nullarbor Plain (Webb & James 2006; Miller *et al.* 2012). The remaining two samples were from a 60.10 g chert nodule in well cuttings at a depth of 180 m in well FOR004, drilled as part of the Eucla basement stratigraphic drilling program (Spaggiari & Smithies 2015). Other than the subsurface well sample, all the samples come from within 20 km of the Wilson Bluff Limestone chert sources exposed in the Nullarbor Plain sea cliffs. All are geological samples, not registered artifacts requiring permits.

To provide another independent character for determining provenance, the colour of the chert was described using the Munsell (2009) rock color book. The chert samples were set in epoxy resin and standard (46×27×0.03 mm) petrographic thin sections were prepared from each. Species were identified with reference mainly to MacGillivray (1895) and Brown (1958) with the help of taxonomists listed in the acknowledgements. Species identifications were difficult due to (1) the random orientation of the colonies in relation to the thin-sectioned chert samples, and (2) the lack of access to the rich frontal wall morphology essential to many species identifications. As a result, not all colonies could be identified and some identifications are only to the genus level. We relied on zoarial habit, branch width, and zooecium diameter. All measurements were made with a Nikon Labophot-2 transmitted light petrographic microscope using ImagePro Express 5.0 software (Media Cybernetics 2004). All measurements were made to the nearest micron with a measurement error of <3%. All measurements were made in the most transversely oriented colonies. To determine true colony branch width, we measured the maximum width of the cross sectional view of the branch perpendicular to the growth direction of the branch. To determine true zooecium diameter, we measured the maximum zooecium width perpendicular to the growth axis of the zooecium. As silicification can degrade skeletal morphology, as many colony branch diameters and zooecium diameters as possible were measured in each thin section to maximize our sample size.

## RESULTS AND DISCUSSION

Our Wilson Bluff Limestone chert samples were white to grey (Table 2). This agrees with Lowry's (1970) determination of the colours of Wilson Bluff Limestone chert nodules as ranging from opaque white to translucent pale grey. Likewise, Dortch & Glover (1983) reported Wilson Bluff Limestone cherts as ranging from white through light brownish-grey. We identified three bryozoan species (Fig. 2, Table 3), including two cheilostomes (*Adeonellopsis* sp. and *Cellaria rigida* MacGillivray, 1885) and one cyclostome (*Idmonea geminata* MacGillivray, 1895). The cellariiform *Idmonea geminata* had the smallest branches and zooids, the adeoniform *Adeonellopsis* sp. was intermediate, and the cellariiform *Cellaria rigida* the largest (Fig. 3).

*Adeonellopsis* has been widely reported in the literature from the Eocene of Australia (Alroy 2015), and specifically *Adeonellopsis yarraensis* occurs in the Wilson Bluff Limestone (Cockbain 1970). We were unable to confidently assign our *Adeonellopsis* colonies to this species. *Cellaria rigida* has been reported from the Wilson Bluff Limestone (Cockbain 1970). Species level identification of

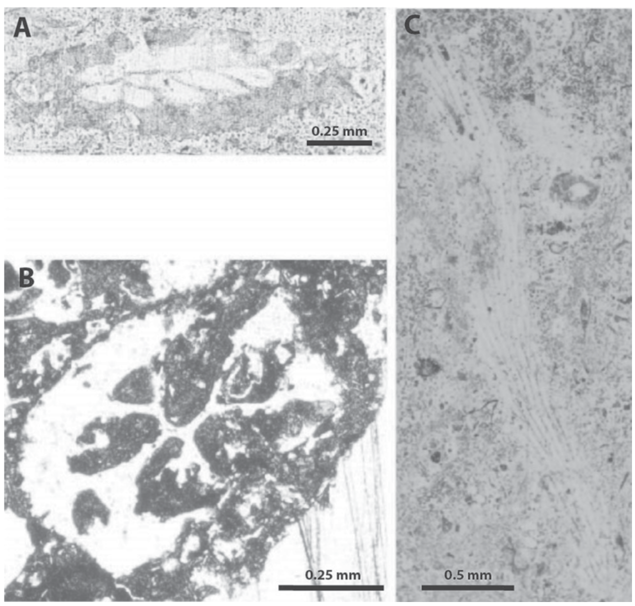


**Figure 2**. Silicified fossil bryozoan species identified in chert samples from the Eocene Wilson Bluff Limestone from the vicinity of Eucla, Western Australia. **A**. *Adeonellopsis* sp. from Knousley, KNY. **B**. *Cellaria rigida* from Well FOR004-2. **C**. *Idmonea geminata* from Knousley South 2, KNX-52.

**Table 3.** Bryozoan species found in chert from the Eocene Wilson Bluff Limestone around Eucla, Western Australia.

| Class | Order | Species | No. of colonies | Localities |
|---|---|---|---|---|
| Gymnoalemata | Cheilostomata | *Adeonellopsis* sp. | 2 | Knousley, KNY |
| | | *Cellaria rigida* | 11 | Knousley South 2, KNX-52<br>Knousley, KNY<br>West of Eucla<br>Well FOR004-2 |
| Stenolaemata | Cyclostomata | *Idmonea geminata* | 3 | Well FOR004-1<br>Well FOR004-2 |

the *Adeonellopsis* colonies would have been more useful for the provenance study (O'Leary *et al.* 2017).

The cyclostome *Idmonea geminata* has been reported from the Eocene of Victoria, Australia (MacGillivray 1895). If the poor preservation of what we interpreted as kenozooid pores on the dorsal side was incorrect, this species could alternatively be assigned to the genus *Exidmonea*. Cockbain (1970) did not report this species as his study only included the cheilostomes. This species richness of three is far less than the 35 cheilostomes reported by Cockbain (1970). We attribute this to our smaller sample size and the poorer preservation of our silicified bryozoans in chert relative to the well preserved matrix-free colonies reported by Cockbain (1970) from the easily cleaned-off chalky matrix of the unsilicified beds of the Wilson Bluff Limestone. Preservation is also degraded by diagenetic dolomite rhombs that cut across the bryozoan fragments and gypsum infilling of some zooecial cavities (Lowry 1970). There were additional indeterminate cheilostome bryozoan fragments that probably represent other species due to their encrusting growth form.

Bryozoan-rich chert is a common material for Aboriginal artifacts from Western Australia. For example, fossil bryozoans (especially *Cellaria*) preserved in chert Aboriginal artifacts throughout Western Australia have been frequently figured by previous researchers (e.g. Gallus 1971, pl. 14; Glover 1974, fig. 3; Glover 1975, fig. 4B; Glover *et al.* 1993, fig. 3; Smith 1993, fig. 5.1.1).

## CONCLUSIONS

Volumetrically, bryozoans are the dominant fossils in the chert portion of the middle to upper Eocene Wilson Bluff Limestone from the Eucla area, Western Australia. The Wilson Bluff Limestone is a fine-grained, medium- to thick-bedded, chalky, bryozoan-rich limestone with abundant chert nodules. The cheilostomes from the unsilicified zones have been studied previously, but this is the first study to focus on the chert horizons. From thin sections of the chert, we were able to identify three species: the cheilostomes *Adeonellopsis* sp. and *Cellaria rigida* and the cyclostome *Idmonea geminata*. None are endemic to the Wilson Bluff Limestone. Hopefully this information can be applied in the future to constrain the sources of bryozoan-rich chert Aboriginal artifacts, which are common in South and Western Australia (O'Leary *et al.* 2017).

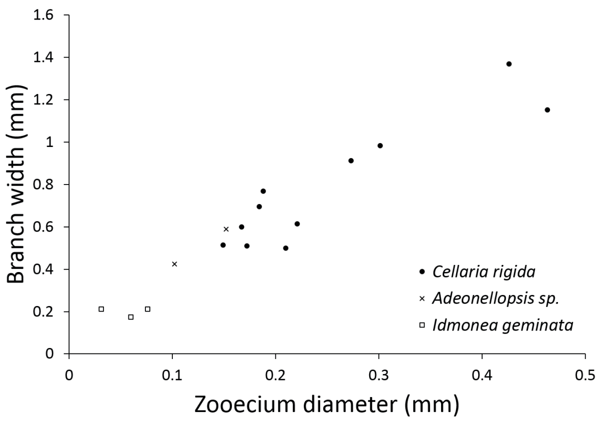


**Figure 3**. Plot of branch width versus zooecium diameter for the three bryozoan species identified in this study.

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