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ARTICLE

Insights into the procurement and distribution of fossiliferous chert artefacts across southern Australia from the archival record

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ABSTRACT
Following from previous research in Western Australia, this study explores the use of embedded microfossils—including bryozoan and foraminiferal fossil assemblages—to help identify source and distribution of fossiliferous chert artefacts from South Australian archives. Artefacts from key archaeological sites include Allen's Cave, Koonalda Cave, Wilson's Bluff, Ooldea and Kongarong. Preliminary analyses indicate a possible differentiation of fossiliferous chert types east and west of the Eyre Peninsula, from Otway Basin and Eucla Basin limestones, respectively. The widespread distribution and trade of fossiliferous chert is supported by ethnographic descriptions of the sources, procurement and trade as recorded by Daisy Bates, Thomas Draper Campbell and Norman Tindale. Further work combining biostratigraphy and lithology with archaeology and ethnography is needed to explore these ideas further.

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Background

Chert, or flint as it is often synonymously termed, has been used for making stone tools for thousands of years, being associated with the earliest fossil remains in Africa (Hershkovitz et al. 2018) through to small, fine artefacts in the Neolithic and later periods of France and England (Beasley 1984; Cunliffe 2001:89–90). It has also been used in more recent times for industrial and armament purposes (e.g. Flint et al. 1989:20). In Australia, chert artefacts are documented in several early sites, most notably Devil's Lair (Dortch 1984) and Allen's Cave (Cane 1995; Marun 1972), and also in sites dating to the early to mid-Holocene (Beasley 1984; Cann et al. 1999; Coutts 1981; McNiven et al. 2012). Indeed in SW Western Australia, fossil-bearing chert has been used, arguably erroneously (see O'Leary et al. 2017), as a chronological divide between early to mid-Holocene age sites (Dortch 1986; Dortch and McArthur 1985; Glover et al. 1993; Hallam 1987; Marwick 2002; Smith 1993).

More important than the chronological context is the spatial context of chert-bearing archaeological sites and in particular those found inland from coastal sources (Beasley 1984; see also below) as these imply human dispersal or trade. Investigations of the WA Museum Archives have already revealed examples of fossiliferous chert artefacts from regions much further north and east than initially assumed (Key et al. 2019; O'Leary et al. 2017; Ward et al. 2019). At the same time, preliminary studies of diagnostic fossil bryozoan assemblages within samples of chert debitage from southwest Western Australia demonstrated that the source could not be offshore in the Perth Basin as previously purported (Glover 1975a, 1975b) but onshore in the Eucla Basin (O'Leary et al. 2017). However, the idea of long-distance trade of fossiliferous chert with Aboriginal groups westward continues to be dismissed due to the apparently large distances involved (Dortch and Dortch 2019; Glover 1975a). This is despite evidence of trade of this material up to 700 km eastward (Bates 1921; Johnston 1941; Nicholson and Cane 1991; see also Bourman et al. 2016:167; Ward et al. 2019), and also the distribution of lithic raw materials, edge-ground axes, wooden items, ochre and baler shell hundreds of kilometres over much of Australia (see McBryde 1997; Munt et al. 2018:79 and references).

Having previously focused on fossiliferous chert archives from Western Australia, this study explores the South Australian archival records[1] and what this

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[1]Attempts were also made to explore the archival record in Victoria. Queries of the Victorian State heritage databases revealed 2889 registered Aboriginal places where chert has been identified across the State. These registers do not discriminate biogenic and non-biogenic chert. Viewing these records is complicated by the need to obtain approval of all registered Aboriginal parties, as well as the approval of the Victorian Aboriginal Heritage Council (VAHC). Hence it was decided just to focus on the South Australian archival collections for this study.

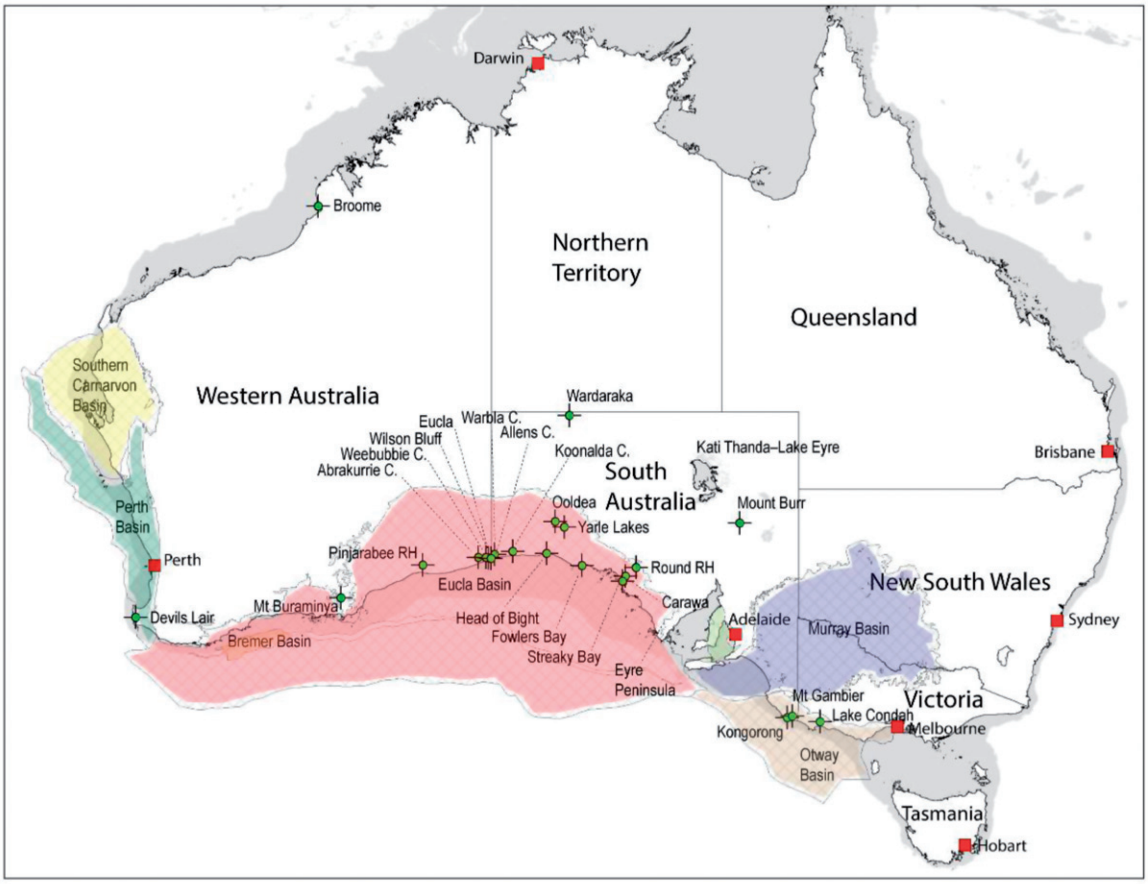

Figure 1. Location of sites and basins mentioned in the text.

might also reveal about the use and distribution of this diagnostic material. In particular, we focus on the records of Norman Tindale, Daisy Bates and Thomas Draper Campbell, each of whom recorded and collected chert artefacts from sites along the Eucla coast and in other parts of South Australia between 1930 and late 1960. As part of this investigation we identify bryozoan fossils on the surface of artefacts from key archaeological sites, including Allen's Cave, Koonalda Cave, Wilson's Bluff, Ooldea and a few other sites in South Australia (Figure 1). This follows a similar study undertaken by Benbow and Nicholson (1992), who also undertook a lithological and microscopic comparison of artefacts from the South Australian Museum and Moeller collections with silicified source material from Wilson's Bluff, Koonalda Cave and Head of the Bight. Whilst distinct lithologies were observed in each of the source materials, and in particular the presence of relict bryozoan clasts in the Wilson Bluff Limestone, it was found that the variation in degree of silicification precluded provenancing artefacts to any of these particular sources (Benbow and Nicholson 1992). We argue that the identification of the embedded fossils is the key to provenancing fossiliferous chert artefacts. We preface this discussion with a brief consideration of the terminology and stratigraphic context of chert-bearing limestones along the southern coastline of Australia.

Terminology

As outlined by Munt et al. (2018) there is some confusion in the use of the terms 'chert' and 'flint' for microcrystalline or cryptocrystalline silica (e.g. Luedtke 1992; Whittaker 1994:70; see also Sieveking and Hart 1986). In Koonalda Cave, Marun (1972) identifies flint and 'numerically insignificant' quantities of chert and limestone, whilst Cane (1995) and Wright (1971) use only the term flint. For the Allen's Cave site, Munt et al. (2018:74) use chert for lighter coloured material and 'flint' for denser, blacker material that is more like the flint from the English chalks from which the term derived (e.g. Rapp 2009:76, 79). Glover (1975a) similarly preferred the term chert over the 'unsatisfactorily defined' flint to describe artefacts from SW Western Australia, including Devils Lair. In the Lake Condah region of Victoria however, McNiven et al. (2012:50) differentiate (non-fossiliferous) chert from cherts that 'contain microfossils consistent with flint'.

Both chert and flint are formed by diagenetic replacement of carbonate by silica under high pressure by burial beneath the seafloor. Flint is generally reserved for material which has originated from chalk deposits (or marl) and chert for material from limestone deposits, the latter usually formed from the skeletons of organisms with a calcium carbonate biomineralogical structure. This explains the description of 'silicified limestone'—or more specifically 'silicified bryozoan limestone'—by Benbow and Nicholson (1992) for artefacts from the Nullarbor Plain. Similarly, in SW Western Australia, Glover (1974, 1975b; see also Martin 1982) makes the distinction between 'fossiliferous cryptocrystalline chert' and 'palaeontologically barren' chert. Indeed Martin (1982) suggests there may be up to five types of chert in SW Western Australia, differentiated by presence/absence, type and abundance of embedded fossil species. Hence the more descriptive terminology, rather than simply chert, is important in terms of characterising the use and provenance of these silicified artefacts. Here we follow Glover's (1975a, 1975b) example and use the term fossiliferous chert to describe archival samples.

Geological stratigraphy of Cainozoic limestones

The Cainozoic sequences of the Eucla Basin have been explored by Benbow (1990), Benbow et al. (1982), Clarke et al. (2003), Cockbain (2014), Gammon et al. (2000), Hou et al. (2003, 2006), James and Bone (1991), Jones (1990), Li et al. (1996), Lowry (1970), McGowran et al. (2004), Miller et al. (2012), O'Connell et al. (2012) and Quilty (1974). The Cainozoic succession is represented by the Middle Eocene to Middle Miocene Eucla Group, which can be divided into four stratigraphic units:

i. the Middle Eocene Hampton Sandstone;
ii. the Middle to Late Eocene marine Wilson Bluff Limestone and time equivalent terrestrial dune deposits;
iii. the Late Oligocene to Early Miocene marine Abrakurrie Limestone and
iv. the Early to Middle Miocene marine Nullarbor Limestone and time equivalent terrestrial sandstones.

There is no record of Early Eocene, Early Oligocene nor Late Miocene units. The two main fossiliferous chert-bearing units within these sequences are the middle-late Eocene Wilson Bluff Limestone, which extends to the inner margin of the Eucla Platform, and the Miocene Nullarbor Limestone. Both units occur together in outcrop and drillcore.

The Wilson Bluff Limestone has a chalky macroscopic aspect and is composed of micrite to microbioclastic carbonate silt with abundant bryozoans and scattered cherts. It accumulated in a cool water, open ocean environment (James and Bone 1991; Lowry 1970). The Nullarbor Limestone is a well cemented sub-tropical limestone with numerous large benthic foraminifera (James and Bone 1991; O'Connell et al. 2012). According to Benbow and Nicholson (1992:3), the younger Miocene limestone has been locally silicified in groundwater environments around the margins of the Nullarbor Plain, such as in the Yarle Lakes—Ooldea area. Further east is the Upper Eocene to Middle Miocene Gambier Limestone within the Gambier and Otway Basins, which also contains fossiliferous chert (Blakemore et al. 2014; Bourman et al. 2016). The latter outcrops east of Naracoorte scarp and in coastal areas near Mount Gambier (Sexton 1965). Eocene chert and silica-rich rocks have also been observed in the Bremer Basin and in the St Vincent Basin (Li et al. 2000).

Fossiliferous chert occurs as horizontal seams within these limestone sequences, which are present along coastal cliffs (Figure 2) and in some cave profiles. Shallow caves are formed within the Miocene Nullarbor Limestone and deeper caves penetrate into the underlying Upper Eocene Wilson Bluff Limestone (Jennings 1963; Miller et al. 2012; Sexton 1965; Webb and James 2006). The former is present in Abrakurrie Cave and at Wilson Bluff as well as along the Nullarbor Plain and at Lower Calcrete Pit (Johnson 2015) (Figure 1). Wilson Bluff Limestone is present within Abrakurrie Cave and at Wilson Bluff (Johnson 2015; Miller et al. 2012) and also at Koonalda, Warbla and Weebubbie caves (Davey and Frank 1984; Nicholson 1994; Webb and James 2006) (Figure 1).

Potential sources and Aboriginal procurement of fossiliferous chert

At Koonalda Cave, there is evidence that chert quarrying extended vertically about 75 m below the surface and laterally up to 300 m from the entrance of the cave. Archival records on the 1967 Koonalda Cave expedition by Dr Eustace Couper Black (Black 1967) state

Figure 2. Band of nodular flint in Wilson Bluff cliff-face as photographed by Norman Tindale (Tindale 1965 [from South Australian Museum archives AA338-50-3]).

> …the flint occurs as round boulders of varying size, seen on the side walls of the cave, sometimes in a horizontal stratum, sometimes showing as black stones, sometimes as white. Plenty of broken flint on the floor, some showing conchoidal fracture. The idea seems to be that it was a flint mine; the rather inaccessible parts where it is mined being associated with myth of totemic ancestors, as it was procurable in more easily reached parts.

In his diaries, Tindale (1965) references another major native flint mine, 'n.n. *Njinjitjokolba* (?)' [sic], just over 100 km further west at Wilson's Bluff that is accessed from the west via a sand ridge:

> The flint outcrops in horizontal bands up to 9 inches high at intervals through about 70 feet of chalk cliff. All the accessible seams as high as one can reach have been battered off flush with the chalk by Aborigines; those seams which are beyond reach project from to eight inches [sic].

This is presumably the same flint quarry known to the Mirning People in the west as *Kardilyerra* (Gara and Cane 1988:81).

Whilst there is archaeological evidence that these underground sources were used by the people who lived on the Nullarbor Plain (Davey and Frank 1984:16; Flood 2004; Gara and Cane 1988:173; Marun 1972; Wright 1971), the main source of flint according to Bates (1918:164) was a quarry at Wilson Bluff near Eucla on the South Australia/Western Australia border. The flint outcrops about half-way down the 90 m cliff face, although apparently little evidence of quarrying remains on the face itself (Cane and Gara 1989:26). The flint is described as translucent and honey-coloured, with inclusions of coarse-grained white-grey opaque material. A small, more inaccessible flint outcrop is located at Sponge Cove at Head of the Bight and this may also have been used by Aboriginal people as a source of flint (Eyre 1845 in Nicholson and Cane 1991).

Weathered nodules of flint also occur as beach gravel deposits and storm shingle beaches along much of the southern coastline of Australia (e.g. Beasley 1984, their Figure 5.13; see also Bourman et al. 2016; Flint et al. 1989). T.D. Campbell's diaries (AA52-4-5, South Australian Museum Archives) record that

> …vast mounds of flint pebbles occur on parts of the South coast of the state. On the South East shoreline occur minor headlands of Miocene limestone…these eroded remnants of limestone were the source of vast masses of flint pebbles on some beaches.

Beach gravels may have provided a more accessible (secondary) source of fossiliferous chert for Aboriginal people. These secondary sources have a very distinctive cortex, which is smooth and waterrolled as opposed to those from primary, outcropping sources found in the cliff faces. At Wilson's Bluff, Campbell (AA52-4-7E, South Australian Museum Archives) notes that 'Aboriginals carried the pebbles to the sheltered side of the coastal dunes, where they broke them up and made implements which were the transported to inland sites'. However, access to the cliff faces or beach gravels was limited due to the sheer nature of the cliffs, with only six identified and named routes to the sea along the whole 200 km stretch of Nullarbor coastline (Bates 1918; Gara and Cane 1988). In addition, where both Miocene and Eocene sequences outcrop, both could have contributed to the beach deposits at the base of the cliffs. These could further have been mixed together through successive sea-level changes (Collins 1988; Lambeck et al. 2014; Wright 1971). Nevertheless, cortex types may at least provide a useful distinction between primary and secondary sources of fossiliferous chert.

Less useful as a guide to source is colour, yet both Tindale and Bates specifically note a distinction between 'white' and 'black' flint, with Tindale highlighting a darker band of flint in the cliffs at Wilson's Bluff in his field notes (Figure 3).[2] Bates (1930, 1932b) further ascribes a different value to the darker flint (see also below):

> A certain species of hard black flint, called jee'mari in the border of South and West Australia, was also specially valued by men in far areas, owing to the tradition, which went along with the jee'mari, that the sharpened and finished weapon was produced from the stomach of the jeemari totem men.

Characterising fossiliferous chert

Geoarchaeologists use various palaeontologic, lithologic, geochemical and geophysical parameters to determine the source of chert/flint and other lithic artefacts. The key is to choose an approach with sufficient discriminating features for the various possible source localities to be distinguished. Both destructive and non-destructive methods have been used to try and characterise physical and chemical properties of chert/flint (Colao et al. 2010; Högberg et al. 2012; Ray 2007), with most studies still often based on petrographic analysis due to wider availability, lower cost and sometimes better discrimination (e.g. Dreesen & Dusar 2004; Flügel & Flügel 1997; Martin 1982). A number of studies focus on, or at least include as part of a wider study, the fossil content of the lithic artefact in an attempt

[2]Black flint was also preferred for calcining applications in industry as it produced a whiter product. Freshly broken surfaces of black flint, waterworn pebbles and museum specimens of black flint rapidly lose their dark colour and develop a white patina (Flint et al. 1989:26).

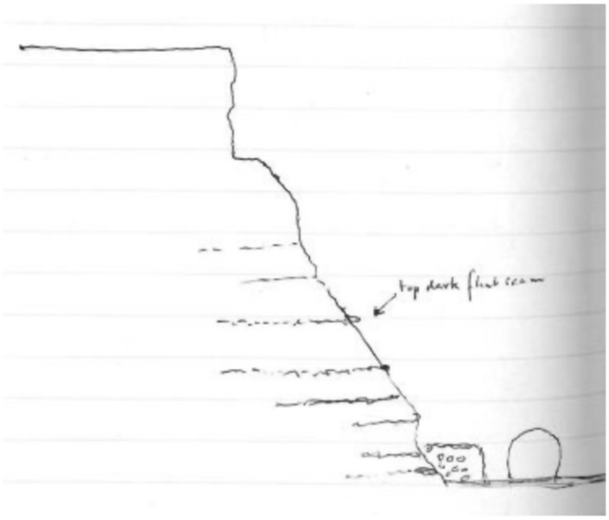

Figure 3. Sketch of flint/chert seams within Wilson's Bluff from Tindale's diary, 1965, with arrow marking 'top dark flint seam' (AA338-1-43-3_0552, South Australian Museum Archives).

to fully characterise it and determine its source (e.g. Key et al. 2014, 2019; Morris 2010; O'Leary et al. 2017).

For fossiliferous chert/flint, physical properties, colour, texture and microfossil assemblages can vary within and between samples even in a limited area (Högberg and Olausson 2007; Meeks 2000; Ray 2007). However, it may be possible to attribute it to a particular stratigraphic formation (or biostratigraphic unit). Studies elsewhere, particularly in Europe, have shown that the origins of chert in limestone are most commonly related to the occurrence and dissolution of sponge spicules (Knauth 1979). Others have used foraminiferal assemblages to characterise limestone sequences (e.g. Haig et al. 1997; Riera et al. 2019). The presence of the benthic foraminiferoid *Maslinella chapmani* in chert artefacts from SW Western Australia was used to ascribe a Middle to Upper Eocene age of this material (Glover and Cockbain 1971). The common presence of this same foraminiferoid in marine core samples was the main reason to propose an offshore source for these artefacts (Quilty 1978). However, the subsequent work of O'Leary et al. (2017) on the bryozoan assemblages have helped reject this long-held hypothesis.

Identification of embedded foraminifera

Here we continue the work of O'Leary et al. (2017) to argue that the characterisation of both the embedded bryozoan and foraminiferal microfossil assemblages within both the chert artefacts and chert-bearing limestone sequences are the key to provenancing artefacts manufactured from this material. Foraminiferal assemblages can be characterised at the order, genus and species level. Characterising the assemblage at the order level can provide information on the characteristics of the marine environment in which the facies accumulated, such as water temperature, salinity and water depth, and thus help to trace the regional scale geographic origin of the outcrop from which the chert artefacts were collected. Thirty percent of the Cainozoic species of benthic foraminifera from Southern Australia are endemic or semi-endemic (Li et al. 1996), and the identification of endemic species would confirm the *geographic origin* of the chert. Identifying key genera and species of planktonic foraminifera through serial sections could also be used to constrain the *age* and hence stratigraphic interval of the chert-bearing facies with a precision below one million years, as the living range of key species is calibrated to the geomagnetic polarity and to the astronomical time scales (Wade et al. 2011). Finally, the foraminiferal assemblage of outcrops could be identified to aid in the determination of the potential source of the chert artefact. Outcrops with similar ages accumulated in similar environment and in similar large scale geographic areas and can extend over long distances; for example, outcrops with Eocene cherts extend over more than 1,700 km along the southern Australian coast (Gammon et al. 2000; Li et al. 2000) and there is no existing precise description of the lateral variation of this outcrop. The latter could be precisely described in order to create index characteristics of the microfacies over several kilometres. This could be used to identify the relatively precise origin of each chert artefact.

Preliminary analyses of the fossiliferous chert material analysed in the Western Australian study (O'Leary et al. 2017) indicate the cherts contain a mixed assemblage of small benthic foraminifera of the orders Rotaliida, Bulimida and Textulariida, and of planktonic foraminifera (Figure 4). Small Rotaliida and planktonic forms are the dominant type of foraminifera, whereas large foraminifera and Miliolida have not been identified at this stage of the study. This suggests that most of the cherts examined during the preliminary survey are coming from limestone formed in cold to temperate oceanic waters, at water depths >50 m, following the general criteria outlined by Murray (1991) and Grimsdale and Van Morkhoven (1995). It is unlikely that the Nullarbor Limestone, which was accumulated in sub-tropical waters, is the source of the chert artefacts. However, the Wilson Bluff Limestone, which accumulated in cool, open mesophotic waters, could be the source but additional analyses are necessary to validate the origin of these and other chert artefacts.

Foraminifera (and other fossils) have not been specifically identified in the cherts of the Wilson

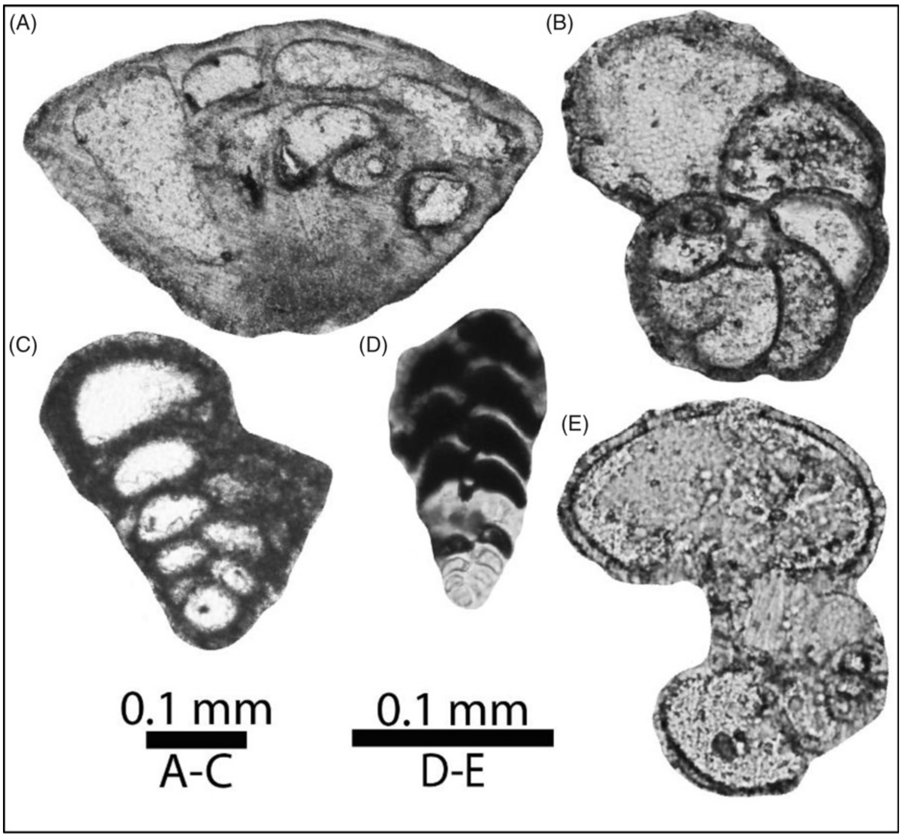

Figure 4. Examples of foraminifera observed in the thin sections of cherts from Western Australia, (A and B) Axial and equatorial sections of Rotaliida benthic foraminifera; (C) section through the biserial plan of a carbonate-cement agglutinated benthic foraminifera belonging to Textulariida; (D) biserial-plan section of Buliminida and (E) axial section of planktonic foraminifera.

Bluff Limestone and Nullarbor Limestone but only in the limestone unit more generally. The Wilson Bluff Limestone contains abundant bryozoan and planktonic foraminifera fossils and is characterised in the biostratigraphy by the first appearance of *Turborotalia pomeroli* (McGowran et al. 2004). *Globigerapsis index* is also another diagnostic foraminiferoid of this formation (McGowran et al. 2004). Based on MacGillivray's (1895) monograph on Australian Cainozoic bryozoans, five Eocene species of bryozoans occur in the Middle-Late Ecoene Wilson Bluff Limestone. Three are cheilostomes, *Adeonellopsis* sp., *Cellaria rigida*, *C. australis,* and two are cyclostomes, *Idmonea incurva* and *I. geminata*.

According to Gillespie (2010) benthic foraminifera are the most conspicuous components of the Nullarbor Limestone and include miliolines (e.g. *Marginopora vertebralis, Sorites* spp., *Austrotrillina howchini, Flosculinella* sp.) and rotaliines (*Miogypsina* spp., *Gypsina* spp., *Operculina* spp.). In contrast bryozoans, particularly delicate branching bryozoans, are rare in the Nullarbor Limestone (Gillespie 2010; Lowry 1970). Large encrusting celleporiform bryozoans (*Celleporaria*) do occur often in association with corals, some of which have been locally replaced by chert (e.g. see Figure 4.5 in Gillespie 2010). From this basic differentiation of foraminifera and other fossils, differentiation of fossiliferous chert artefacts sourced from the Nullarbor Limestone and Wilson Bluff Limestone may be possible.

Identification of embedded bryozoa

Due to the destructive nature of thin sectioning, it is not desirable (nor allowed by the museum) to undertake thin section analysis of artefacts. Hence investigations and identifications (by MK) of bryozoan fossils from South Australian archives were restricted to those visible on the surface of artefactual material using a Dino-Lite digital camera. These indicate similar species to those observed in the West Australian artefact samples (Table 1). As found by Benbow and Nicholson (1992), artefacts from Wilson's Bluff, Koonalda Cave, Head of the Bight and those identified here from Eucla and Allen's Cave tend to be, but are not exclusively, more translucent. It is notable that both the fossiliferous chert and also the chalky limestone were used in the manufacture of artefacts from Koonalda Cave. Embedded bryozoan fossils which form the bulk of the chert matrix are best identified using polarised light both on the surface (e.g. Figure 5(A–P)) and also in thin section (Figure 5(G,H); see also Benbow and Nicholson 1992). Benbow and Nicholson (1992) identified a further five sites in

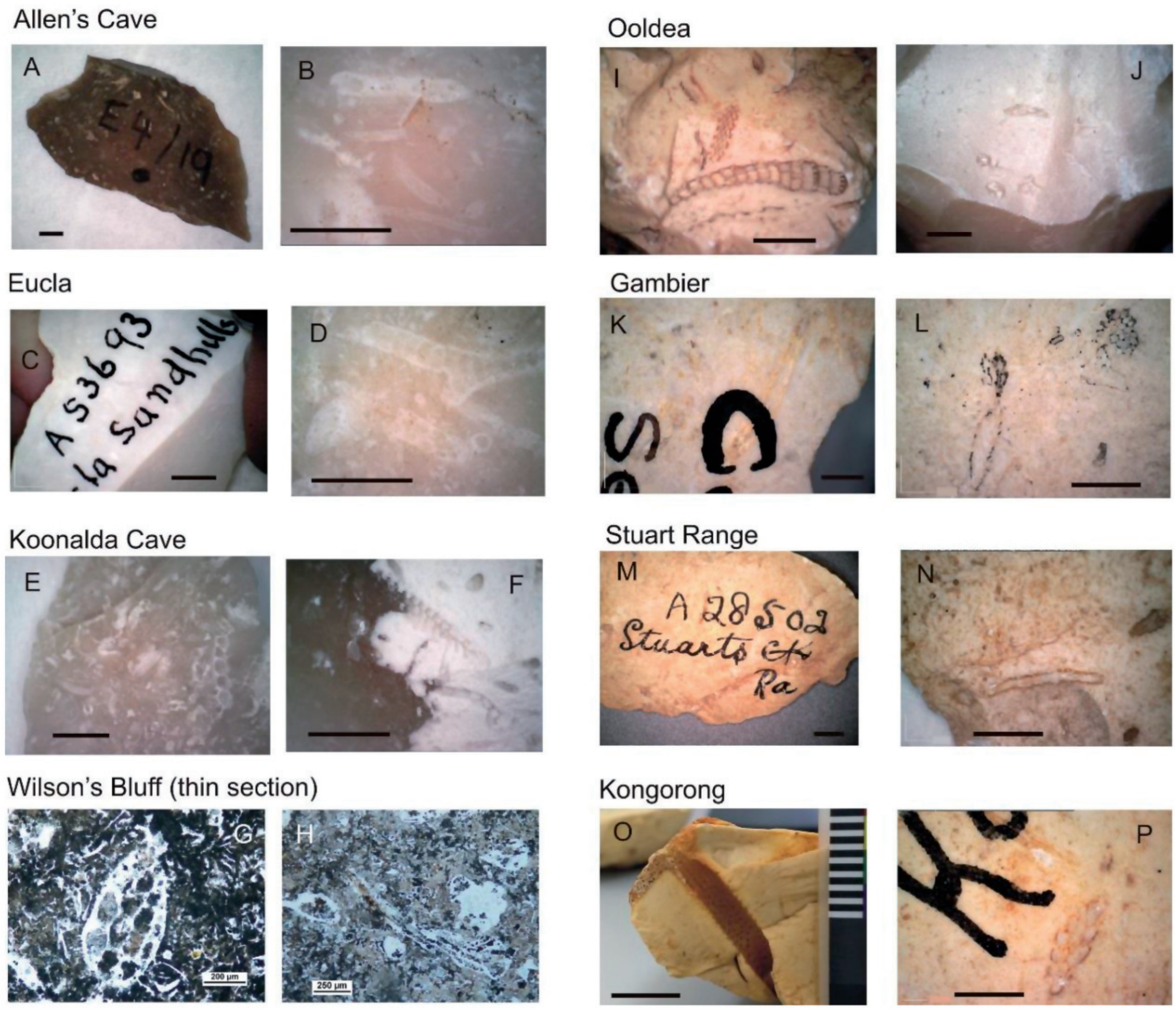

Figure 5. Photos of bryozoans within fossiliferous chert artefacts and geological thin sections. (A) Black fossiliferous chert (B) *Porina* sp. in white chert (C). Utilised flake fragment (D). *Siphonicytara* sp. (E) *Adeonellopsis* sp. (?) (F) *Porina* sp. (?) (G) *Cellaria* sp. (?) (H, I) *Siphonicytara* sp. (J) n.d. (K) *Porina* sp. (L) *Trigonopora* sp. (M) Complete flake (N) *Cellaria* sp. (O) Invertebrate fossil impression (P) *Adeonellopsis* sp.(?). Black scale bar is approximately 1 cm.

the Great Victorian Desert with artefacts similar to the fossiliferous chert from Wilson's Bluff, including Pinjarra Rock Hole, Round Rock Hole, Yallabinna Rocks, OTC Rock Hole. Both black (Figure 5(A)) and white (Figure 5(B)) fossiliferous chert was identified in the Allen's Cave artefacts.

In contrast, artefacts from Ooldea, Stuart Range, Gambier and Kongorong tended to be more weathered and opaque in colour with bryozoan fossils clearly evident on the surface of many artefacts from iron staining (e.g. Figure 5(I–P)). Those from Kongorong also preserved surface remnants of larger marine fossils, including echinoderm and crustaceans (Figure 5(O)).

Benbow and Nicholson (1992) did not identify these fossiliferous cherts but they did observe black-desert varnish on some of younger (Miocene) Nullarbor Limestones. This black varnish is evident in the artefacts from the Gambier region (e.g. Figure 5(L)), implying they may derive from the Nullarbor Limestone or other inland sources. At nearby Mount Burr rockshelter, Campbell (AA-52-4-7E South Australian Museum Archives) argued that the supply of flint (*sic*) was locally derived:

> …from deposits occurring in the old beach strands which can be seen in the lower levels encircling Mt Burr and Mt Graham highlands. [But even here] the majority of flint from the Burr shelter does not appear to have the compact, clean texture of that in the vast Kongorong deposits.

Campbell's diaries dating 1940–1960 (AA52-4-8N) document many other sites in the southeast of South Australia where flint (*sic*) artefacts were found but he does not specifically identify them as fossiliferous chert, noting only that it formed in the 'Coraline limestone underlying most of Lower SE South Australia and was traded east into Victorian Wimmera region'.

These preliminary analyses indicate a possible differentiation of fossiliferous chert distribution east and west of the Eyre Peninsula. Broadly, artefacts found west of the Eyre Peninsula and along the coastal

Table 1. Summary of features of artefacts from South Australian archives.

Location	Macroscopic	Microscopic*	Example artefacts	Identified bryozoa
Allen's Cave	Light to dark grey, mainly translucent chert rock with numerous embedded fossils (byrozoa) visible as white traces	Not determined	**30–18 ka**: E4/35/1, E4/37/1 **18–11 ka**: E4/22/23, E4/22/51, E4/26/4 **11–8 ka**: 14/16/11, E4/19/15, E4/19/13 **8–5 ka**: E4/10, D3/8/2	*Adeonellopsis* sp., *Cellaria* sp., *Porina* sp., *Reteporella* sp., *Trigonopora* sp.
Eucla	Mainly white translucent to transparent chert rock, with numerous fossils (bryozoa) visible as white outline (or as transparent outline in chalk)	Not determined	A1364, A53693, A41881, A54328	??
Koonalda Cave	Similar to Eucla material	Not determined	C15-3, C14-15, C15-25	*Adeonellopsis sp.*, *Cellaria* sp., *Porina* sp., *Idmonea* sp., *Trigonopora* sp.
Wilson's Bluff (thin section)	Zonation - inner fossiliferous core; middle translucent to transparent zone; outer white crust with fossil fragments	Relict bioclasts (especially bryozoans) in fine-grained chalcedonic matrix. Some bioclasts replaced by fibrous chalcedony.		*Adeonellopsis sp.*, *Cellaria* sp., *Idmonea* sp., *Trigonopora* sp.
Ooldea	White, pale yellow to orange, non-translucent chert rock with numerous embedded fossils (bryozoa, coral, etc.) visible as white/translucent traces or from discolouration	Not determined	A28517, A28834, A57350	*Cellaria* sp., *Idmonea* sp., *Siphonicytara* sp.
Stuart Range	Pale brown, non-translucent chert rock, with embedded fossils outlined from discolouration (iron staining)	Not determined	A28502	*Quadracellaria* sp., *Cellaria sp.*
Koorongarong	Pale brown - yellow, non-translucent chert rock, with skeletal fossils on surface crust or embedded and visible through discolouration (iron-staining)	Not determined	A36895, A39696, A30416	*Cellaria* sp.
Gambier	Pale brown, non-translucent chert rock, with embedded fossils (bryozoa, coral, etc.) often visible through black discolouration	Not determined	A37108	*Trigonopora* sp.

Bold value signifies the age ranges (ka) for the different units sampled from this site.

Nullarbor tend to conform to the Eucla Basin limestones, whilst those to the east and northeast conform more to the Otway Basin limestones (e.g. Gambier Limestone). To this end, Nicholson and Cane (1991:6) document a proportional decrease in number and size of flint (*sic*) artefacts and proportional increase in the use of local carbonate rock 'further east along the coast (away from the source)'. Nicholson (1994:31) writes:

> The material described as flint [on the West Eyre Peninsula] is considered to be derived from the fine-grained silica enriched nodules contained within the Wilson Bluff formation in the Nullarbor Limestone series of the Eucla Basin. Microscopic examination has so far been unable to confirm that the 'flint' artefacts found on the West Coast sites are made of Wilson Bluff limestone. However, in the absence of an alternative source and on the basis of field identifications, this material is considered to be derived from the Wilson Bluff formation.

Evidence for a formal trade route

There is no doubt that Wilson's Bluff (known to the Mirning as *Kaldiyerra*) was an important mythological, ceremonial and quarry site (Gara and Cane 1988). Tindale and George (1976:27) indicated that Aboriginal people sometimes travelled across the Nullarbor Plain to obtain flint from the cliffs at Wilson's Bluff, and more than once referred to a song line (specifically a bush turkey dreaming myth) that lists a series of waters across the plain leading to the mine (Tindale 1965:559, 1982:99). Kim Akerman (cited in Cane and Gara 1989:26) has documented references to the same song line as far away as Fitzroy Crossing over 2,500 km to the north, implying a further significance of the Wilson Bluff site in the past. Indeed Tindale (1982:99) suggests this elaborate turkey song line preserves a memory of one of the latest effects of the Post-Glacial sea level rise, implying a long antiquity to this song line and to Wilson's Bluff itself.

Earlier letters (e.g. Bates 1932b) and a newspaper publication (Figure 6 from Bates 1930) of Bates imply the flint mine was a focal site for an Aboriginal trade route which ran around the whole continent from the Kimberley, through central Australia and the Eyre region, along the southern coast and west via the Wheatbelt region.

According to Bates (1930):

> … special white flints [of the Eucla district] … were taken along the traditional trade route north-north-east by the Fowler's Bay and Streaky Bay remnants, who bartered them with some Gawler range survivors, whence they were sent towards Lake Eyre … , zigzagging east or west as trade or occasion offered, the goods being bartered by each group.

Figure 6. Map of Australia showing Aboriginal trade route as published by Bates (1930). Points of the line are Darwin, Springvale (Qld), Carawa (SA), Mount Buraminya (WA) and Broome (WA).

> The white flints became magic objects in distant areas and were either used as specially prized initiation knives or were polished and brightened and called jal'yimurra, jarra murra, darr mrra, jaly'ir djula meaning 'magic spirit stones'.

Bates describes the transport of this flint:

> … visiting groups brought big lumps … on their heads or their women carried them in water scoops or in bags, and these were chipped and bartered until the very last portion was so bartered. … the white flint becoming more valuable the further it went.

Further to this evidence, Tindale and Noone (1941:116; see also Tindale 1982) describe a discovery in the coastal dunes,

> … [a] hoard or trade parcel which was in transit from the known flint sites on the coastal cliffs one day's journey to the East … [that] represents a collection of material made during a flint knappers expedition …. An example [of worked stone tools] made of similar material to this hoard has been found 180 miles away to the north at Wardaruka (Boudary Dam), and other examples have been noted at Ooldea (200 miles east, Bates (1930).

The key implication is the suggestion that some fossiliferous chert may have been stockpiled along parts of trading route(s).

Trade of flint from Wilson's Bluff in exchange for spears, shields, ochre and pearl-shell—including from as far north as the Pilbara and Kimberley—is also described by Gara and Cane (1988:81–82 and references) with Ooldea noted as a centre for trade. However, subsequent studies could find no artefactual evidence to corroborate widespread trading of Nullarbor Plain artefacts (Benbow and Nicholson 1992; Cundy 1990). However, there was some evidence from museum archives of movement of Wilson Bluff flint over distances of at least 300 km across the Plain and beyond (Nicholson 1994:32). Benbow and Nicholson (1992:5) suggest that it is possible that flint from this source was traded because of its ritual or mythological significance rather than as a commercial stone resource. Indeed, according to Bates (1944:124), some goods were valued just because they came from distant locations.

Similar to Bates's own studies, a more recent investigation by Nicholson (1994) of the western part of the Eyre Peninsula implies that movement of lithics was not just unidirectional.

> Other stone materials found on these sites support the movement of exotic raw materials into this coastal area … The presence of artefacts made on volcanics suggests the movement of material from the Gawler Ranges, over 100 km to the east. (Nicholson 1994:32).

If the movement of fossiliferous chert from the Nullarbor cliffs across hundreds of kilometres is assumed, then the question is over what period this occurred, i.e. whether this network was sustained throughout the late Pleistocene and early Holocene. Our investigations of the Allen's Cave artefacts at least confirm fossiliferous chert did occur throughout at least one part of the excavation, namely E4, from the earlier deposits dated to 30–18 ka through to the later deposits dated to 8–5 ka. Bryozoan fossils were most visible on the Holocene age artefacts, which included one black fossiliferous chert artefact (E4/19/15). Fossiliferous chert artefacts are also abundant in Pleistocene age deposits from Devil's Lair and Tunnel Cave, only declining in the early to mid Holocene (Worrell 2008; see also O'Leary et al. 2017). Thus, the possibility of long-distance trade of fossiliferous chert in the Late Pleistocene is theoretically possible, noting that the geomorphology of the Nullarbor coastline would have been different.

Nicholson and Cane (1991) questioned the role of the coast in Aboriginal economies, and specifically why there is so little evidence of marine exploitation along the Nullarbor coastline. Preservation and visibility were amongst several potential explanations, with the sheer cliffs clearly a geographic obstacle. There is an inherent assumption in some of these explanations that people were restricted to the modern coast. However, based on modern bathymetry (Figure 1; see also Wright 1971, Figure 1) the southern coastline would have been up to 300 km further south at the peak of the Last Glacial, and still up to 100 km further south until the terminal Pleistocene. Hence it is possible that people were occupying and traversing the now drowned coastal plain, accessing gravel beaches and exploiting any springs and soaks. Even the seams of fossiliferous chert may have been more accessible with climbing dunes abutting the cliff faces (Figure 7).

Figure 7. Photograph of Norman Tindale standing on top of the Wilson Bluff cliffs (South Australian Museum archive reference 338-50-005). Note the climbing dunes in the background.

Unfortunately, any evidence for this will be almost certainly lost through erosion, with the only possibly hint of this provided from remnant dunes and offshore islands such as the Recherche Islands WA that would have been cut off by the post-glacial transgression (see also Dortch and Morse 1985). Chert artefacts have been identified on at least two of the islands (Ward et al. 2019) but these are surface finds and have no chronological context. Hence what is needed is a systematic investigation of fossiliferous chert both spatially across southern Australia and also temporally from a number of excavations.

Conclusion—Wider significance and future research

As with previous work on fossiliferous chert (O'Leary et al. 2017; Key et al. 2019; Ward et al. 2019), this study demonstrates the potential for using microfossil assemblages to help identify possible source(s) and distribution of this iconic material. Our preliminary investigation of the South Australian archives indicates a possible differentiation of fossiliferous chert sources east and west of the Eyre Peninsula, with the former conforming more to the Otway Basin limestones and the latter to the Eucla Basin limestones. It remains unknown whether the preliminary lithological distinction in fossiliferous chert relates in any way to the different territorial groups along the South Australian coast, which include the Mirning of the South West region, and the Wirangu, Nauo (Nawu), Banggarla and other groups of the Spencer Gulf (east of Eyre Peninsula) region.

In order to better delimit the provenance, distribution and use of biogenic cherts across mainland southern Australia, the different assemblages of fossil fragments—in particular the bryozoan and foraminiferal elements—in the chalk and limestone stratigraphy of the Eucla Basin, and also the Perth and Otway Basins need to be fully characterised. However, the Nullabor cliffs are the primary focus because of the potential to characterise the chert-bearing limestone sequences and because of the importance given to this coastline, especially the Wilson Bluff/Eucla region, for the procurement and exchange of fossiliferous chert by Aboriginal peoples. Geological collections relating to the Nullabor cliff stratigraphy are available from both the South Australian and Western Australian Geological Survey but comparative fossiliferous chert source material from other locations is also needed. This information can be compared with the microfossil assemblages in the artefacts, perhaps aided by other artefactual characteristics (e.g. cortex type, core size, etc.), as a means to identify potential primary and/or secondary source(s).

The assessment of artefact assemblages that contain fossiliferous chert remains a whole area of research in itself not least because of the way source characteristics can influence the extraction, use and distribution of artefacts and what that may indicate about mobility and trade (Andrefsky 1994; Brantingham 2006; Ditchfield 2016). Characteristics of retouch may also inform us about recycling and possible associated value given to fossiliferous chert artefacts over space and time (e.g. Worrell 2008). These are important questions for future research and beyond the scope of this study.

However, the possibility of continental-scale trade of fossiliferous chert from a major source(s) along the southern coast is given credence from ethnographic descriptions by scholars, including Bates, Campbell and Tindale. Furthermore, fossiliferous chert is just one indicator of a potential widespread exchange network that included the exchange of axes, shields, spears and totem boards from the north (Kimberley) with groups from the Bibbulmen in Western Australia (Bates 1932a).

The questions that this and previous studies of the fossiliferous chert artefacts in Australia open up by virtue of considering long-distance trade are numerous. Such questions include how the accessibility of these sources (including potential submerged ones) have changed over time, how the different fossiliferous cherts are represented in the archaeological record, the processes that are involved in the preservation of that record, and what the available record indicates about mobility and exchange across Australia (see also McBryde 1997). These are questions that need to be investigated further through the same kind of a 'teaming up' of anthropology, archaeology and geology as exemplified in many of the early expeditions of Thomas Draper Campbell and Norman Tindale (Anon. 1947).

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