

Eucla Basin, an emerging new heavy mineral province of global significance: old province, new ideas



Baohong Hou and John L Keeling (CRC LEME; Geological Survey, PIRSA)

Introduction

The onshore extent of the Eucla Basin in southern Australia contains remarkably preserved Cainozoic coastal barriers and palaeovalley systems, inland of the vast Nullarbor Plain (Fig. 1). These are attractive for mineral exploration because fluvial and shallow-marine sediments within the basin and palaeovalleys were derived from the surrounding mineral-rich cratons and the sediments host remobilised gold, uranium and heavy minerals. In particular, the preserved palaeoshoreline sequence along the northeastern margin of the Eucla Basin is highly prospective for heavy mineral placer deposits. This is confirmed by the number and quality of new heavy mineral discoveries in the region, which include the world-class zircon deposits of Jacinth and Ambrosia (Table 1). Understanding the history of the Eucla Basin and palaeovalleys provides insights for mineral exploration that can help target these commodities. Tectonics, sea-level change and climate were important controls on the changing physical palaeogeography of the region, the distribution of sediments in the basin and inland valleys, and, consequently, the sites of mineral deposition and accumulation. In a recent review of the evolution of the Eucla Basin, Hou et al. (2008) outline the sequence and timing of major events affecting basin sedimentation. Evidence of topographic variation in key stratigraphic units across the basin is interpreted in terms of new ideas on post-Palaeogene tilting of the Australian continent. The major events and impact of neotectonic activity described in Hou et al. (2008) are summarised here with specific reference to coastal dune development and the significance for heavy mineral exploration.

Landscape and stratigraphy

The modern landscape of the Eucla Basin and associated palaeovalley network is the result of landscape processes and

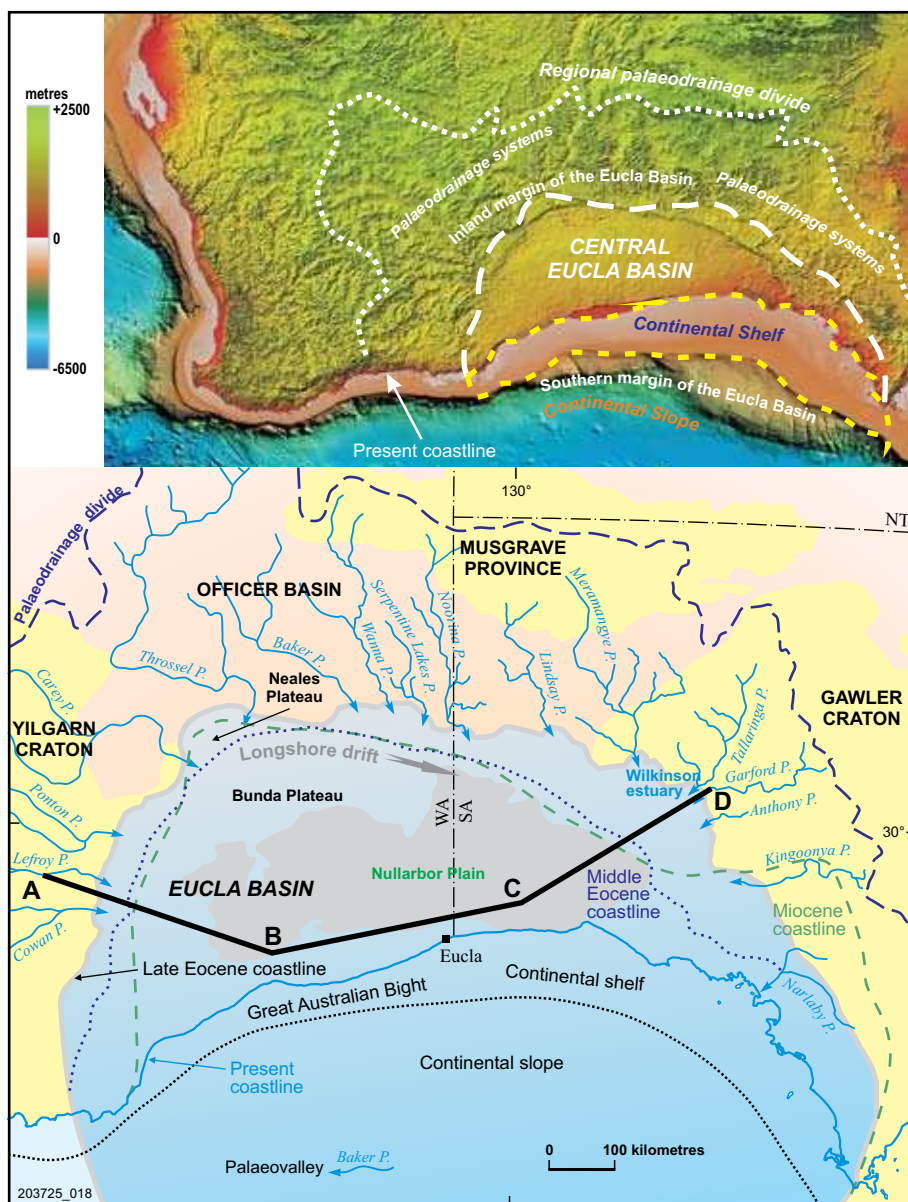


Figure 1 Locality map of the Eucla Basin and major palaeovalleys. Top inset: Interpreted Eucla Basin framework draped over modern digital elevation model for the region (image courtesy of Geoscience Australia). (After Hou et al. 2008.)

sedimentation operating over 50 million years. Palaeolandforms of Cainozoic age are remarkably well-preserved and are the basis for palaeogeographic reconstructions (Fig. 2). Major continental drainage networks dissect the Musgrave Province and Yilgarn and Gawler cratons into valleys that slope towards the Southern Ocean. The

pattern of palaeovalleys is dominantly sub-dendritic (Fig. 1), reflecting both the pre-Cainozoic land surface gradient and bedrock lithology and structure (e.g. Alley et al. 1999). Sandy marginal-marine sediments underlie the marine carbonate deposits of the Nullarbor Plain and present day offshore Eucla Basin, and extend far inland as sediment fill

deposited in palaeovalley systems during sea-level highstands. Reconstructing the distribution, thickness and sedimentary facies of palaeovalley fills and palaeoshoreline deposits, to identify sites of mineral accumulation, presents a challenge and opportunity for mineral explorers in the region (Figs 1, 2).

The large areal extent of the Eucla Basin and adjacent palaeovalley system, which together cover ~20% of the Australian continent, incorporates a complex succession of marine and non-marine strata, making correlation of stratigraphic units, sedimentary and tectonic events non-trivial. Most important are sediment age determinations, particularly the use of chronostratigraphic and allostratigraphic units in making stratigraphic correlations, recognising regional stages and their boundaries, and in dating tectonic events. The marine-influenced Eucla Basin successions show a remarkably consistent stratigraphy across the entire basin and are lithostratigraphically correlated as shown in Figures 3 and 4. Onshore extrapolation of this stratigraphic framework relies to a large extent on palynological age

determinations and sample examinations from an extensive drillhole data set.

The record of marine, marginal-marine, estuarine, fluvial and lacustrine environments reflects major depositional events during the Paleocene – Early Eocene, Middle–Late Eocene, Oligocene – Early Miocene, Middle Miocene – Early Pliocene and Pliocene–Quaternary. These events reflect the key role of eustatic sea-level variation which, during highstands, inundated the craton margins, flooding palaeovalleys up to 400 km inboard of the present coastline. However, a systematic eastward migration of the depocentre across the Eucla Basin during the Neogene, together with apparent flow reversal in certain palaeovalley systems draining the Gawler Craton, suggest that the Eucla Basin has also been subject to differential vertical movements, expressed as a west-side up, east-side down tilting of ~100–200 m (Fig. 5). This differential movement forms part of a broader north-down – southwest-up dynamic topographic tilting of the Australian continent associated with relatively fast (6–7 cm/y) northward plate motion since fast spreading commenced in the Southern Ocean at ~43 Ma (Sandiford 2007; Hou et al. 2008).

Eucla margins and shoreline record

Along the Eucla margin, the palaeoriver mouths are characterised by deposits that reflect a series of former estuaries (e.g. Neales, Wilkinson, Anthony), lagoons and coastal barriers (e.g. Ooldea, Barton) in which Middle–Late Eocene and Middle Miocene – Early Pliocene deposits dominate. The Barton–Paling barrier/ridge elevation decreases towards the SE, following the longshore drift direction, partly reflecting a decrease in sand supply from the NW, but also a broader scale, relative east-down vertical movement (Hou et al. 2008).

Four constructional phases for coastal barrier and nearshore depositional sequences are identified in the eastern Eucla Basin and can be correlated with major third-order sea-level events in Middle Eocene (~42.5 Ma), late Middle Eocene (39–36 Ma), Late Eocene (36–34 Ma), and the Neogene (15–5 Ma), respectively (Figs 3–5). The Barton and Paling barriers are characterised by a series of Late Eocene (36–34 Ma) coastal sand barriers oriented SW–NE, while the earlier formed Ooldea Barrier was partly drowned by the higher sea level and remained as a series of offshore barrier

Table 1 Recent heavy mineral discoveries in the Eucla Basin barrier dunes

Deposit or prospect	Company	Discovery announced	Resource	Heavy mineral content
Jacinth	Iluka Resources	November 2004	68.1 Mt at 7.3% HM probable reserve 5 Mt HM total	49% zircon, 30% ilmenite, 5% rutile
Ambrosia	Iluka Resources	December 2004	30.3 Mt at 4.8% HM probable reserve 1.5 Mt HM total	55% zircon, 22% ilmenite, 5% rutile
Tripitaka	Iluka Resources – Adelaide Resources Limited	January 2005	42 Mt at 2.4% HM inferred resource 1.0 Mt HM total	65% zircon, 9% ilmenite, 5% rutile
Barton West	Dominion Mining	June 2005	Not available	1–3% HM up to 16 m, extending over 25 km by up to 12 km HM content range: 6–21% zircon, 2–10% rutile, 50–67% ilmenite, 6–24% leucoxene
Gullivers	Iluka Resources	April 2006	Not available	1–3% HM Indicative content: 60% altered ilmenite, 21% zircon, 5% leucoxene, 2% rutile
Willy Willy	Diatreme Resources	April 2007	Not available	Up to 6 m at 4.9% HM
Cyclone	Diatreme Resources	July 2007	60 Mt at 3.1% HM inferred resource 1.8 Mt HM total	41% zircon, 42% leucoxene, 10% ilmenite, 3% rutile
Hurricane	Diatreme Resources	July 2007	Not available	Up to 4.5 m at 3.8% HM
Typhoon	Iluka Resources	July 2007	Not available	2–7% HM (indicative) HM concentrate: 25% ilmenite, 18% zircon, 5% leucoxene and rutile
Dromedary	Iluka Resources	December 2007	Not available	Up to 4.5 m at 8.4% HM Indicative content: 17% zircon, 57% ilmenite, 4% leucoxene

HM = heavy minerals

Source of data is from company announcements to the Australian Securities Exchange available on <www.asx.com.au>. Go to Prices, Research & Announcements; Company research. Note that this includes preliminary exploration data and may be subject to confirmation and update.

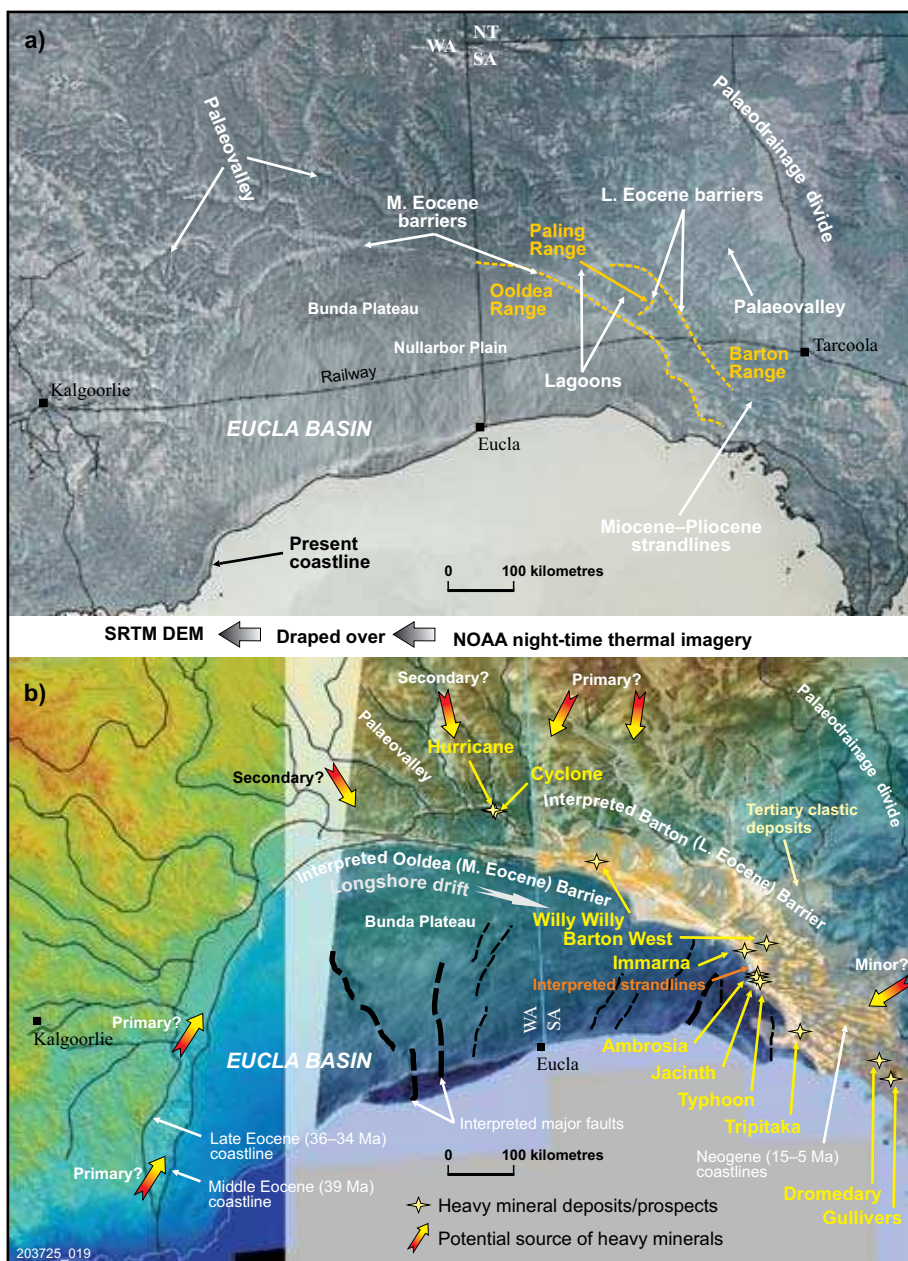


Figure 2 (a) NOAA-AVHRR (National Oceanic and Atmospheric Administration - Advanced Very High Resolution Radiometer) night-time thermal imagery of the Eucla Basin. **(b)** SRTM (Shuttle Radar Topography Mission) imagery, overlain by interpreted Tertiary features, highlighting the Middle Eocene (39 Ma), Late Eocene (36 Ma) and Miocene (15–5 Ma) shorelines and palaeovalleys, and relatively high relief of the Musgrave Province and the Yilgarn Craton/Albany–Fraser Orogen when compared to the Gawler Craton in the east. (After Hou et al. 2008.)

islands. Importantly, the distribution pattern of the Late Eocene coastal barriers is neither parallel to that of the Ooldea Barrier, nor aligned along the present Barton Range (Fig. 2). Thus the ‘Ooldea and Barton barriers’ (characterising Palaeogene morphology) are not strictly equivalent to the ‘Ooldea and Barton ranges’, with the latter reflecting, in part, additional Quaternary aeolian reworking. Landward of the Ooldea Barrier, a series of parallel beach ridges reflects the interaction of localised sediment supply along palaeodrainage networks and continuous, westerly longshore drift

processes operating behind the Ooldea Barrier ‘islands’ (Fig. 2). The Barton–Paling barrier is a morphologically complex, topographically elevated area formed as part of a beach barrier–lagoon system (Fig. 3). Sediments comprise both lagoonal and barrier facies with beach placer potential (Reid and Hou 2006).

Miocene–Pliocene shorelines mainly followed those of late Middle Eocene in the western, northern and northeastern Eucla margins (Fig. 1), due to the constraint of relatively high cliffs developed along this margin during the Miocene (Fig. 5). However, in the

southeastern Eucla margin, a series of parallel linear ridges at an angle to the Ooldea Barrier represent Neogene strandlines of the Narlaby and Ilkina formations formed from reworking of the Middle Eocene Ooldea Barrier sands (Benbow 1990; Hou, Frakes, Alley and Heithersay 2003; Hou et al. 2006). These palaeoshorelines are highly prospective for heavy minerals that were reworked and concentrated during sea-level change (Hou and Warland 2005).

The Cainozoic shorelines, defined as bodies of coastal sand comprising beach, shoreface, barrier, dune, tidal inlet, washover and lagoonal facies, are associated with an extensive palaeovalley network that drained areas of cratonic basement and supplied sediment to the basin. A series of ‘J-shaped’ segments along the Ooldea and Barton barriers, which are favourable sites for beach placer accumulation, is inferred to have resulted from westerly longshore-drift and wave refraction around headland promontories (Benbow 1990; Hou, Frakes, Alley, Gammon et al. 2003; Fig. 2). It is arguable whether, or how far, the late Middle Eocene coastal sand barrier may have extended westward. A westerly longshore drift model implies that beach placers will accumulate along the northwestern Eucla margin, largely because the longshore drift should preferentially move finer sand away to the east or offshore.

Neotectono-eustatic evolution

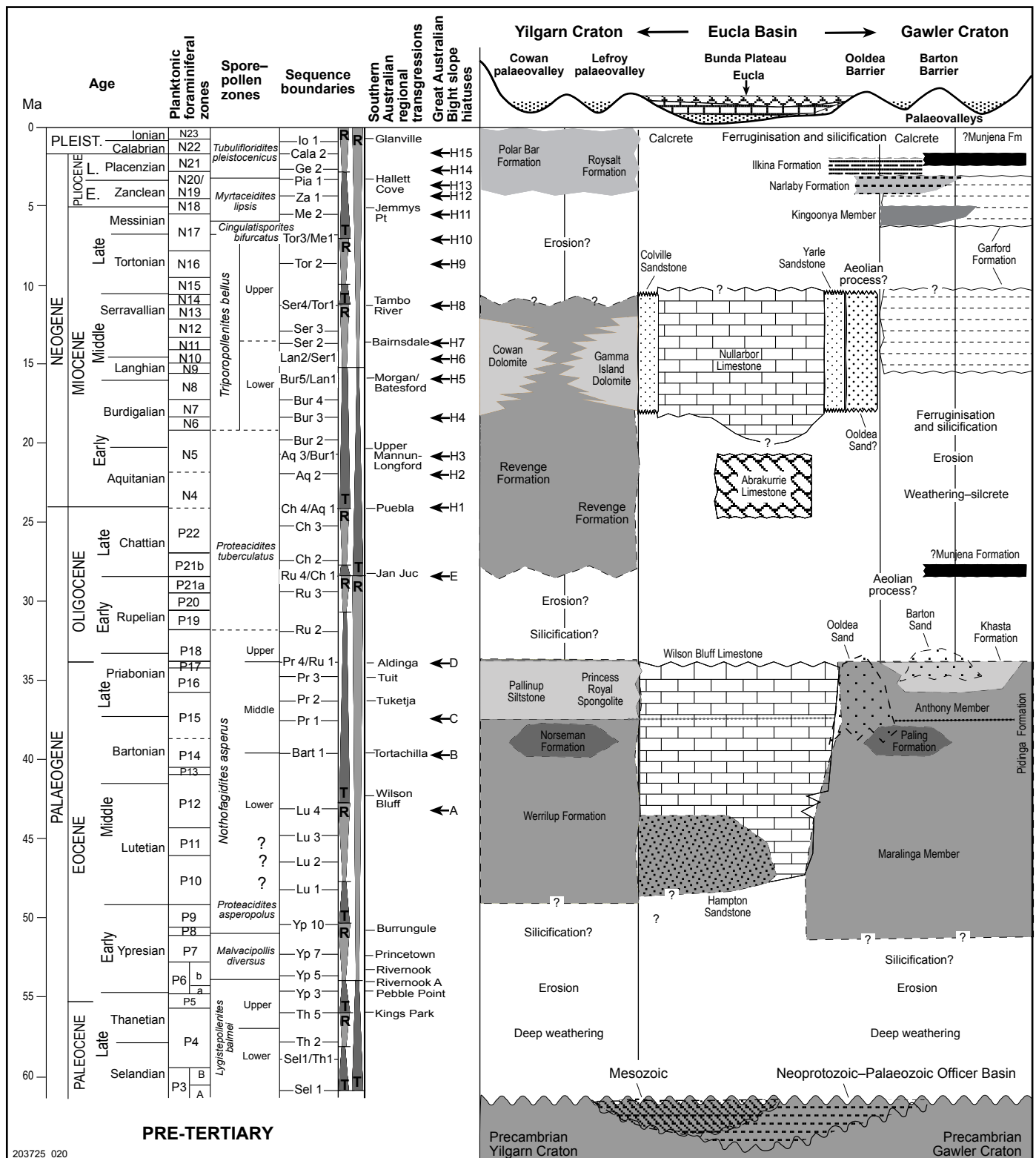
A comparison of the longitudinal gradient of palaeovalleys from western to eastern margins of the basin (e.g. Roe to Garford palaeovalleys) is shown in Figure 5. Although some irregularities in the valley floor are detected, the profiles of the palaeovalley floors overall are remarkably smooth but show significantly different gradients in places. Borehole-controlled transects in the eastern Yilgarn (Mount Morgan) and western Gawler cratons (Garford Palaeovalley) indicate that the irregularities along the palaeovalley floors dominantly occur as bedrock highs with an elevation of ~10–20 m above the regional gradient (Hou, Frakes, Alley and Clarke 2003; de Broekert and Sandiford 2005).

Changes in the basinward gradients of the western and eastern palaeovalleys are evident (Fig. 5), for example: from ~0.33% between Zuleika Pit and borehole KRA8 to ~0.01% east of borehole J10 in

the Roe Palaeovalley (de Broekert and Sandiford 2005); but from ~0.1% between the drainage divide and borehole TPS3 to ~0.001% at borehole 5638–253 and to ~0.01% west of borehole WL55 in the Garford Palaeovalley (Hou, Frakes and Alley 2001; Hou, Frakes, Alley and Clarke 2003). Changing sediment patterns and flow reversal observed within the

eastern Eucla palaeovalley fills suggest that the palaeovalleys were affected by post-Eocene tectonic movements. A negative gradient in the lower reach of the Garford Palaeovalley (between boreholes P63 and west of borehole WL59, -0.16‰) is attributed to post-Eocene uplift along the northeastern margin of the Eucla Basin (Hou, Frakes,

Alley and Clarke 2003), as is 'reverse' flow observed in the pattern of Neogene valley fills in the Garford Palaeovalley (Hou, Frakes and Dodds 2001; Hou, Frakes, Alley and Clarke 2003). A similar progression of gradients occurs within the Kingoonya Palaeodrainage system, which drained the western Gawler Craton. Here, marine influence in the Neogene channels



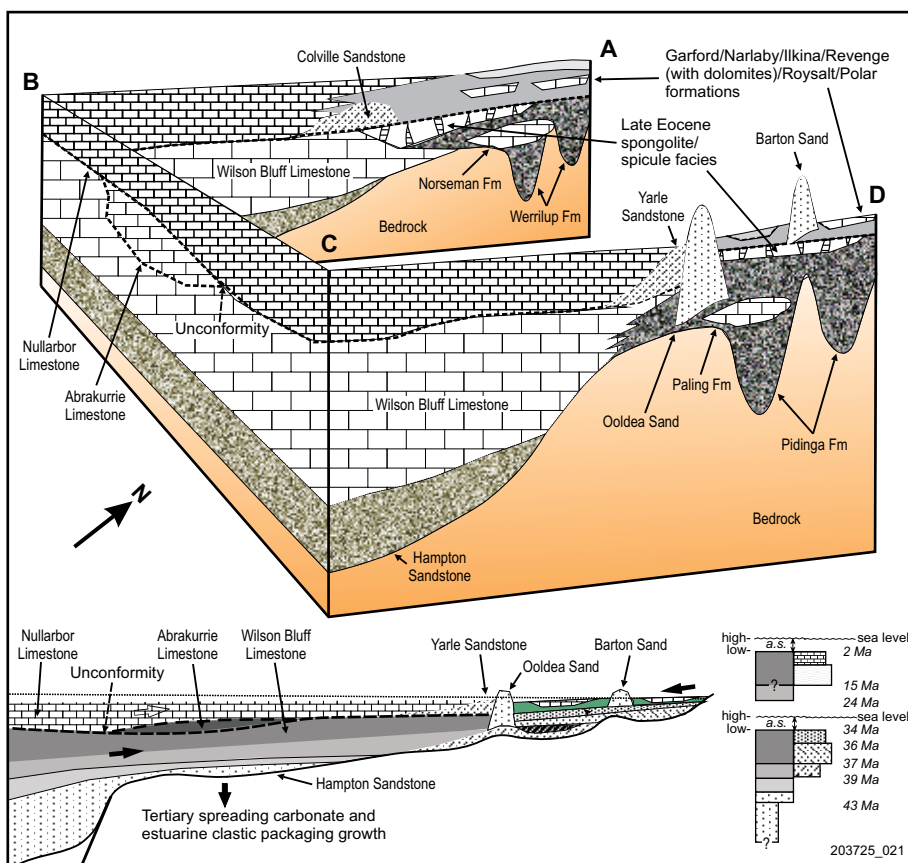


Figure 4 Schematic stratigraphic relationships across the Eucla Basin and palaeovalleys, showing regional extensive Cainozoic marine and non-marine cross-sectional sedimentary reconstruction. Section is located in Figure 1. (After Hou et al. 2008.)

was greater than that in the Palaeogene channels (Hou 2004), in contrast to the western and northern Eucla margins (see Tertiary shorelines in Fig. 1).

The northeastward migration of the depocentre across the Eucla Basin during the Mesozoic–Cainozoic, together with time-slice features such as the ‘reverse flow’ of Neogene systems draining the Gawler Craton as well as the Cainozoic uplift of the Yilgarn Craton, are consistent with a post-Palaeogene tilting of southern Australia (Figs 3, 5; Sandiford 2007).

Implications for heavy mineral exploration

The evolving dynamic topographic field has likely played a key role in facilitating development of placer deposits, largely through multistage, eastward reworking of nearshore sequences during highstand transgressive cycles on a progressively tilting platform under the influence of persistent westerly weather systems (Hou et al. 2008).

Sediment provenance studies in both the Ooldea Barrier (e.g. Jacinth and Ambrosia deposits; Hou and Warland 2005) and Barton Barrier (e.g. Barton

West prospect; Reid and Hou 2006) suggest that zircon and rutile were derived mainly from the Musgrave Province and possibly the Albany–Fraser Orogen, with minor contribution from the Gawler Craton. This is consistent with westerly longshore drift during Eocene to Miocene times. The absence of zircons with ages between c. 2800 and 2600 Ma, which are prominent within the Albany–Fraser Orogen, indicates that the Musgrave Province was the most likely, or dominant, source region (Fig. 2; Reid and Hou 2006).

New models of landscape evolution of the Eucla Basin margin and associated shorelines can be used to develop improved understanding of how to search for beach placers in the region. Information provided on heavy mineral source and tilting of the Eucla Basin indicates that heavy mineral accumulations are expected to be found further to the west than the initial batch of discoveries, since a major source of the zircons is not in the immediate vicinity, but probably lies far to the west and north (Fig. 2). A detailed understanding of the sedimentary architecture and transport systems of the Eocene Eucla Basin is

important for assisting discovery of new heavy mineral accumulations within this emerging mineral sands province. While the Eocene shorelines along the inland margin of the Eucla Basin extend over the entire ~2000 km from east to west, heavy mineral concentration is not known to have occurred continuously along this shoreline. The role of local control on sediment supply and dynamics leading to localised heavy mineral concentrations in specific regions is essentially unknown. Given the predominant eastward longshore drift in the Eocene beach system (Fig. 1), knowledge of the cratonic source region for the heavy minerals is an important predictive exploration tool. For example, if a solely Gawler Craton origin could be shown, then mineralisation would not be expected to extend for any significant distance westward, as this is not supported by the present models derived from the landscape evolution, including source of supply, Eocene longshore drift, and epeirogenic tilting of the basin. In contrast, a source solely from the Yilgarn/Albany–Fraser region would significantly extend the prospective area of the Eucla Basin palaeobeach placer province. Therefore, although our studies indicate a predominantly Musgrave Province source for the zircon fraction, multiple source regions for other heavy minerals remain a possibility. Future work must consider dating of other mineral fractions such as titanite, rutile and monazite to provide a clearer picture of the source region.

Since 2004, exploration of Tertiary shorelines along the eastern and northeastern margin of the Eucla Basin has discovered high-grade heavy mineral deposits at Jacinth, Ambrosia, and Tripitaka with further prospects at Gullivers, Typhoon, Barton West, Dromedary, Willy Willy, Cyclone, and Hurricane (Fig. 2; Table 1). The region today is an important exploration focus for heavy mineral sands with several generations of shorelines recognised as potential heavy mineral targets. Studies such as Hou et al. (2008) provide a framework of climatic and tectonic controls on sedimentation along the Eucla Basin margins against which recent heavy mineral discoveries can be interpreted. The location and stratigraphic context of individual deposits provides the basis for assessing the potential for reworking, dispersion and reconcentration. This will be a factor in developing strategies to explore for additional deposits. Such

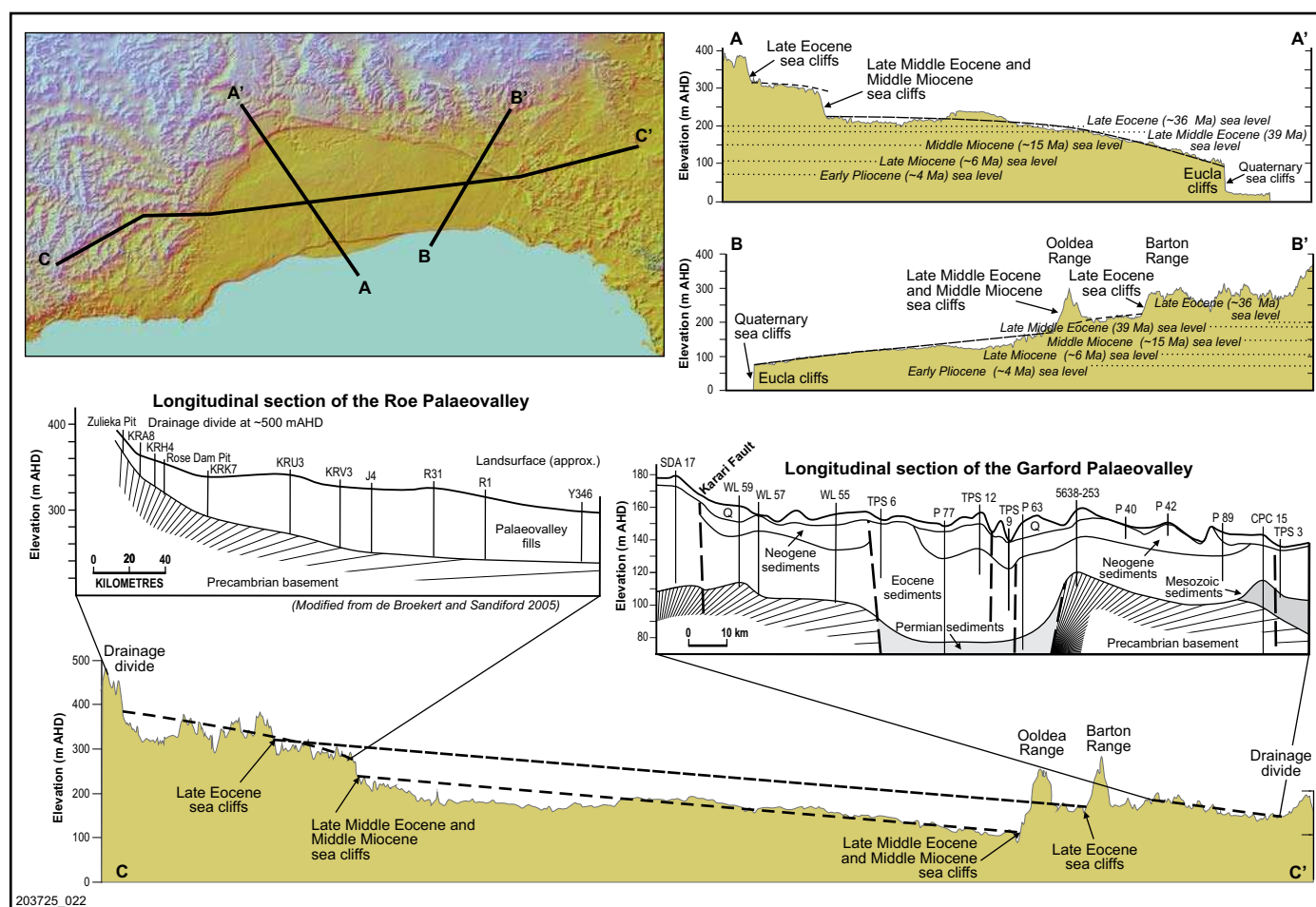


Figure 5 The topographic difference between cratonic elevated terrains and the major incised palaeovalleys and the basin is apparent, as are the Musgrave Province and Yilgarn and Gawler cratons. Also apparent is the down-tilting to the east (section C–C') and the sand ranges (Ooldea and Barton) in the eastern margin of the basin. Note that Quaternary accumulation was not taken into account for the palaeolandscape interpretation. (After Hou et al. 2008.)

strategies need to consider the impacts of later sea-level change, predominant wind and longshore drift directions, and the effect of dynamic tilting on reworking and realigning beach and barrier deposits during marine transgressions, particularly during Neogene times.

Conclusion

The Eucla Basin nearshore coastal barrier systems, coastal lagoons and palaeovalleys contain remarkably well-preserved and varied sedimentary facies of mainly Cainozoic age. Stratigraphic correlation of the sediments across the Eucla Basin and palaeovalleys shows that the marginal basin and adjacent palaeovalleys include at least three main phases of sedimentation: Middle–Late Eocene, Middle Miocene – Early Pliocene, and Quaternary. Progressive (relative) east-down tilting in combination with persistent westerly weather systems explains: the absence of large coastal barriers in the western margin of the basin; the smoothly curved Ooldea Barrier; a western and northern source of sediment supplies indicated by sediment

provenance studies; the series of parallel J-shaped (Barton) barriers of Late Eocene age; ‘reverse flow’ features of Neogene channels draining the Gawler Craton; and progressive reworking of older Eocene barriers during the Neogene along the western Eyre Peninsula. This provides new insights into the geological history of the entire Eucla Basin and associated palaeovalleys that establishes a basis for future investigations of the landscape and tectonic history of the southern part of the Australian continent. This has particular relevance to exploration for heavy mineral placer deposits along the northern and eastern margins of the basin.

Acknowledgements

This paper is a revised version of a poster presented at the 2008 South Australian Resources and Energy Investment Conference held in Adelaide on 30 April – 2 May 2008. Information is drawn largely from that published in *Sedimentary Geology* in 2008 (see Hou et al. 2008) and has benefited from various discussions with university and industry personnel including Larry Frakes, Mike Sandiford,

Neville Alley, Brian McGowran and Lisa Worrall. Studies of the Eucla Basin and palaeovalley system have been supported from various sources including IGCP (International Geoscience Programme) Project 514, PIRSA, University of Adelaide, Geoscience Australia, Iluka Resources Limited, Dominion Exploration Limited, Diatreme Resources Limited and Red Metal Limited, mostly coordinated through projects in CRC LEME (Cooperative Research Centre for Landscape Environments and Mineral Exploration). Remotely-sensed data was processed with the assistance of Alan Mauger and Stephen Petrie (SRTM using raw data from the United States Geological Survey) and Luisa Ruperto.

References

- Alley NF, Clarke JDA, Macphail M and Truswell EM 1999. Sedimentary infillings and development of major Tertiary palaeodrainage systems of south-central Australia. In M Thiry and R Simon-Coincepn, *Palaeoweathering, palaeosurfaces, and related continental deposits*, Special Publication 27. International Association of Sedimentologists, pp. 337–366.

- Benbow MC 1990. Tertiary coastal dunes of the Eucla Basin, Australia. *Geomorphology* 3:9–29.
- de Broekert PP and Sandiford M 2005. Buried inset-valleys in the eastern Yilgarn Craton, Western Australia: geomorphology, age, and allogenic control. *The Journal of Geology* 113:471–493.
- Hou B 2004. *Palaeochannel studies related to the Harris Greenstone Belt, Gawler Craton, South Australia: Architecture and evolution of the Kingoonya Palaeochannel System*, Report Book 2004/1. Department of Primary Industries and Resources South Australia, Adelaide.
- Hou B, Alley NF, Frakes LA, Stoian L and Cowley WM 2006. Eocene stratigraphic succession in the Eucla Basin of South Australia and correlation to major regional sea-level events. *Sedimentary Geology* 183:297–319.
- Hou B, Frakes LA and Alley NF 2001. *Development of geoscientific models for the exploration in Tertiary palaeochannels draining the Gawler Craton, SA*, Report Book 2001/021. Department of Primary Industries and Resources South Australia, Adelaide.
- Hou B, Frakes LA, Alley NF and Clarke DA 2003. Characteristics and evolution of the Tertiary palaeovalleys in the NW Gawler Craton, South Australia. *Australian Journal of Earth Sciences* 50:215–230.
- Hou B, Frakes LA, Alley NF, Gammon P and Clarke JDA 2003. Facies and sequence stratigraphy of Eocene valley fills in Eocene palaeovalleys, the eastern Eucla Basin, South Australia. *Sedimentary Geology* 163:111–130.
- Hou B, Frakes LA, Alley NF and Heithersay P 2003. Development and placer potential of the eastern Eucla Basin, South Australia. *Australian Journal of Earth Sciences* 50:955–965.
- Hou B, Frakes LA and Dodds AR 2001. Recent drilling in the Garford Palaeochannel, the Gawler Craton — testing of a model derived from interpreted geological, geophysical and spectral methods. *MESA Journal* 20:24–27. Department of Primary Industries and Resources South Australia, Adelaide.
- Hou B, Frakes LA, Sandiford M, Worrall L, Keeling J and Alley NF 2008. Cenozoic Eucla Basin and associated palaeovalleys, southern Australia — climatic and tectonic influences on landscape evolution, sedimentation and heavy mineral accumulation. *Sedimentary Geology* 203:112–130.
- Hou B and Warland I 2005. Heavy mineral sands potential of the Eucla Basin in South Australia — a world-class palaeo-beach placer province. *MESA Journal* 37:4–12. Department of Primary Industries and Resources South Australia, Adelaide.
- Reid AJ and Hou B 2006. Source of heavy minerals in the Eucla Basin palaeobeach placer province, South Australia: age data from detrital zircons. *MESA Journal* 42:10–14. Department of Primary Industries and Resources South Australia, Adelaide.
- Sandiford M 2007. The tilting continent: a new constraint on the dynamic topographic field from Australia. *Earth and Planetary Science Letters* 261:152–163.

For further information contact Baohong Hou, phone +61 8 463 3038, email <hou.baohong@saugov.sa.gov.au>.

Geoscience Library

The PIRSA Geoscience Library now provides a more comprehensive literature and reference searching service.

In addition to the library's own extensive catalogue and that of the Australian Libraries it now has access to GeoRef, the most comprehensive online bibliographic geoscientific database in the world.

Established by the American Geological Institute, GeoRef contains over 2.8 million references to geoscientific books, journals, CDs and maps, conference papers, reports and theses and continues to grow by more than 90 000 references a year.

PIRSA Geoscience Library catalogue <www.minerals.pir.sa.gov.au/sarig>
The catalogue contains over 20 000 references to geoscientific books, journals, CDs and audiovisual material held in the collection. Items can be requested online via the catalogue: link to SARIG → Information → Geoscience Library Catalogue.

Libraries Australia catalogue <http://librariesaustralia.nla.gov.au>
Maintained by the National Library of Australia, the Libraries Australia catalogue contains references to all published material held in Australian libraries. If a particular item is required, items can be borrowed on interlibrary loan.

The PIRSA Geoscience Library can provide literature searches on any subject required.

For searches and library service, please contact:
Pam Aagaard, Librarian Ph: +61 8 8463 3345
Email: pirsamerlib@saugov.sa.gov.au

AGI AMERICAN GEOLOGICAL INSTITUTE

AGI Home | About AGI | Contact Us | Search

GeoRef
INFORMATION SERVICE

GeoRef Providers

- DIALOG
- Ebsco
- Engineering Information
- GeoScienceWorld (GSW)
- NERAC
- OCLC
- Ovid Technologies, Inc.
- ProQuest
- STN International
- GeoRef Homepage

GeoRef Contact:
Monika Long
(703) 379-2480
ext. 230
ml@agiweb.org

The GeoRef database, established by the American Geological Institute in 1966, provides access to the geoscience literature of the world. GeoRef is the most comprehensive database in the geosciences and continues to grow by more than 90,000 references a year. The database contains over 2.8 million references to geoscience journal articles, books, maps, conference papers, reports and theses. You can gain access to this vast amount of information through searching on the web, online, or on GeoRef CDs.

Check out the GeoRef Preview Database!

This special database highlights references to geoscience publications which have recently been added to our GeoRef production system. Each weekend, completed references are removed from the Preview database and transferred to GeoRef, new references are added, and changes are made in the remaining data.

Online Database Products

Cold Regions Bibliography Project

Groundwater and Soil Contamination Database

Geologic Guidebooks of North America

Ocean Drilling Citation Database