Heavy mineral sands potential of the Eucla Basin in South Australia

— a world-class palaeo-beach placer province

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Introduction

The eastern Eucla Basin is characterised by Tertiary coastal-barrier systems containing highly prospective beach placers with great economic potential (e.g. Benbow et al., 1995; Hou et al., 2003c). Of particular importance has been the recognition of Eocene coastal-barrier systems; their distribution is now reasonably well known from regional investigations in the topographically elevated Ooldea, Barton and Paling Ranges (e.g. Benbow, 1986, 1990; Benbow and Crooks, 1988). Exploration for heavy mineral sands (HMS) in the region followed work on sedimentary uranium and coal during the 1970s to early 1980s, that revealed numerous HMS anomalies (Ferris, 1994). In some areas of the Ooldea Range, HMS exploration was carried out from the mid-1980s until the early 1990s.

HMS in this region have now become an important exploration focus, as several generations of HMS-bearing shorelines have been recognised recently (Hou et al., 2003b,c). The widespread development of strandlines within the extensive sand dunes, and their possible role as major heavy mineral carriers, make them an important target for further exploration.

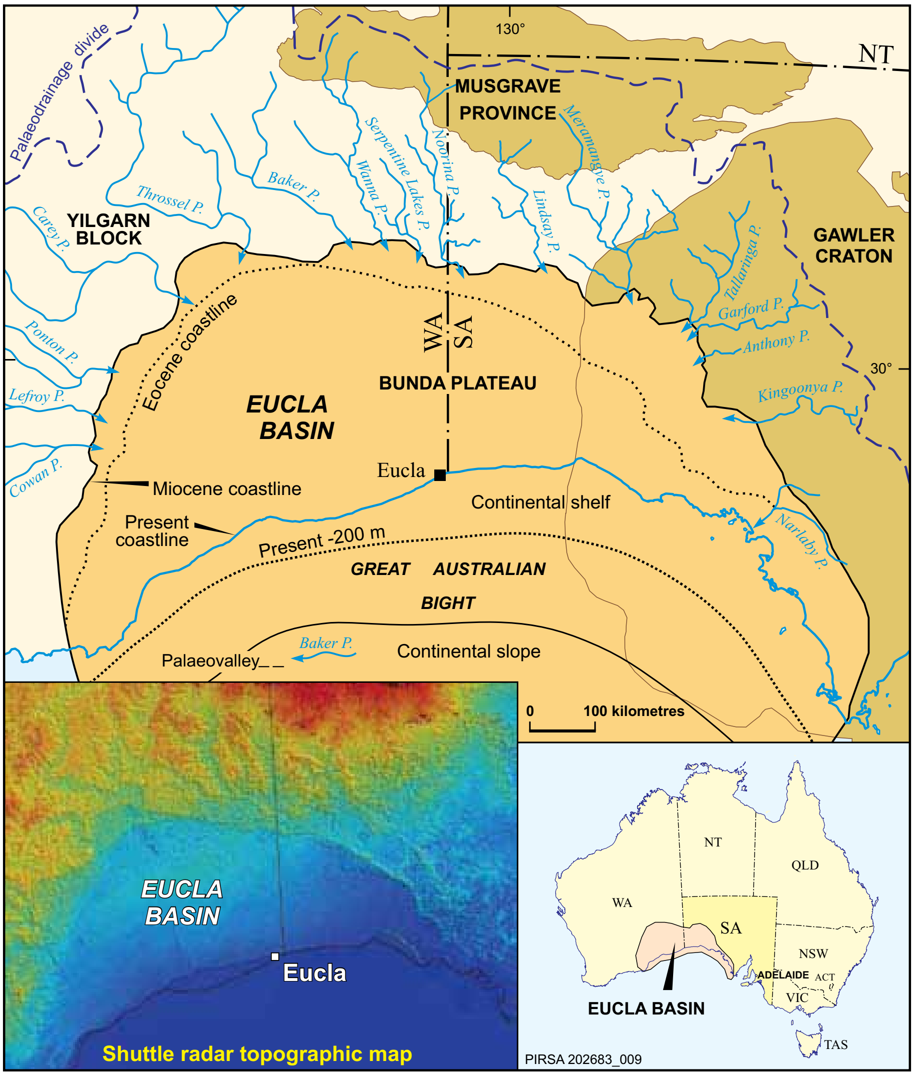


Fig. 1 *Eucla Basin and major adjacent palaeovalleys (after Hou et al., 2003c).*

Regional setting

The Eucla Basin contains a sequence up to 300 m thick of Tertiary marine, coastal and palaeochannel sediments (Benbow et al., 1995; Hou et al., 2003a). Its northern margin extends ~2000 km from Western Australia to South Australia and contains a large onshore province of Tertiary sediments characterised by a number of palaeovalleys that drained the Precambrian Yilgarn Block, Gawler Craton and Musgrave Province (Alley et al., 1999; Fig. 1).

The ~1000 km long eastern margin of the Eucla Basin contains a large nearshore and onshore region of Tertiary sediments characterised by a number of palaeovalleys extending landward in the Gawler Craton (Fig. 2). On the eastern basin margin, linear coastal landforms are preserved that include coastal dunes, dune ridges and possible beach ridges, which have a morphology similar to the Quaternary coastal dunes of southeastern Australia (Benbow, 1990). The present landscape is dominated by extensive tracts of Quaternary deposits, largely superimposed on preserved Tertiary landscape elements including palaeovalleys, lagoons, estuaries and coastal barriers (Figs 1, 2).

Investigative methods

Examination of lithofacies, together with creation of palaeontological, allo-stratigraphic and sequence stratigraphic frameworks from selected drillholes and minor outcrop across the eastern Eucla Basin, has shed new light on the sedimentary history of the sequence of Tertiary marine transgressions and deposition in the region (Hou et al., 2001, 2003a,b,c, in prep.). Palaeogeographic reconstruction was processed in a

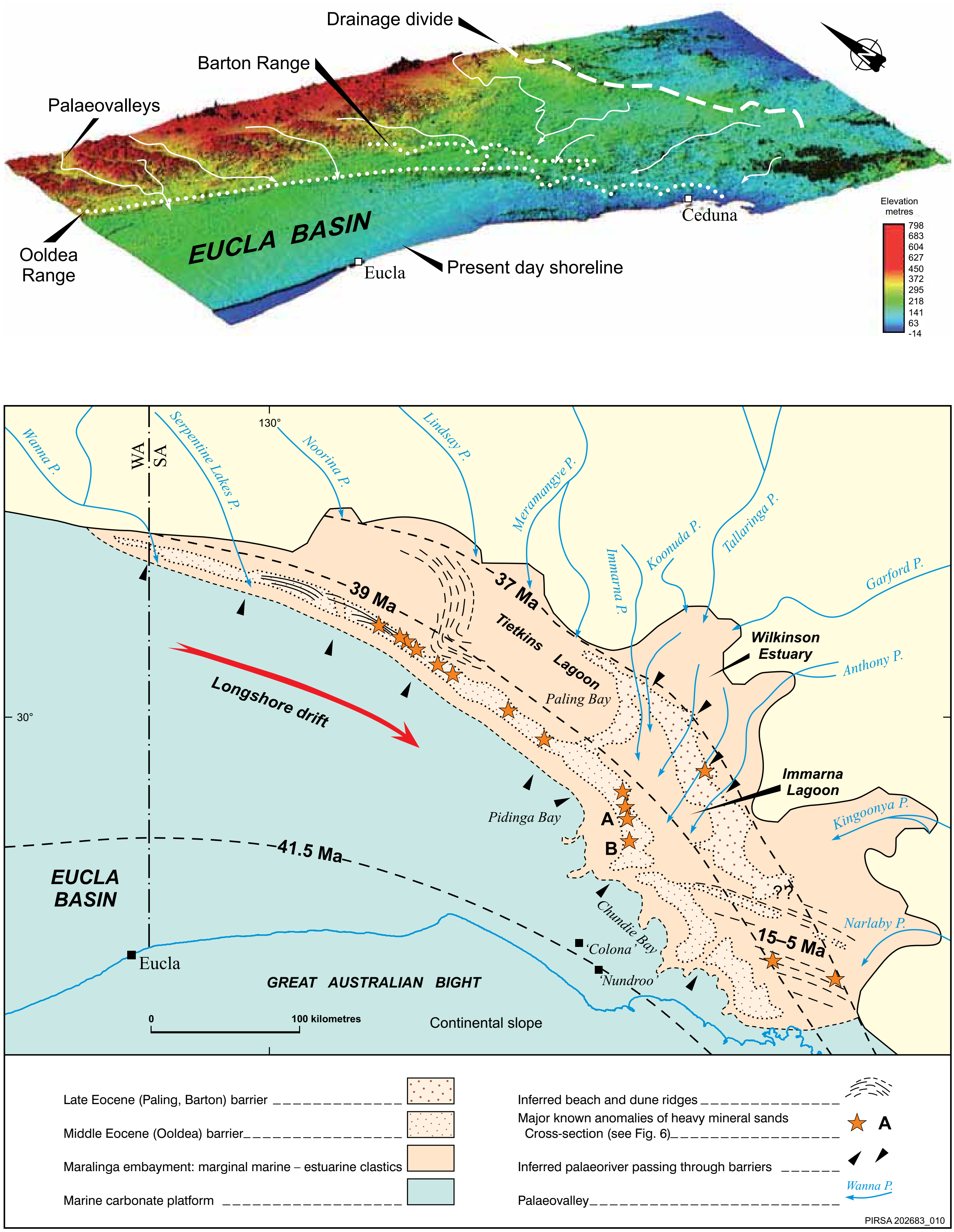


Fig. 2 Regional relief interpreted from DEM and Tertiary geographical and lithofacies frameworks of the eastern Eucla Basin (after Hou et al., 2003c).

geographic information system based on a digital elevation model (DEM), remotely sensed imagery, surface geological and drillhole data, and sedimentological analysis in which key sedimentary surfaces (disconformities, tidal and/or wave ravinement surfaces, transgressive surfaces, and maximum ooding surfaces) bounding the sedimentary packages were recognised. This new work provides better resolution of significant features as shown in Figure 3. A number of HMS-bearing transects were created, based on detailed drillhole descriptions, including microscopic study, to show the distribution of mineralisation.

Stratigraphic units

The stratigraphy of the eastern Eucla basin margin has recently been revised (Clarke et al., 2003; Hou et al., 2003c). Detailed re-examination of the onshore lithostratigraphy of the eastern Eucla Basin, based on field and borehole observations, has revealed a record of stepwise evolution of marine and non-marine environments for these potentially economic sediments (Hou et al., in prep.). Four third-order eustatic cycles resulted in four generations of marine and non-marine deposits across this region (Fig. 4):

- mid-Middle Eocene calcareous, glauconitic and gritty shallow marine sandstone (Hampton Sandstone) and limestone (lower Wilson Bluff Limestone)
- late Middle Eocene marine limestone (lower Wilson Bluff), lagoonal carbonaceous limestone (Paling Formation), and marginal marine – uvial carbonaceous clastics (Maralinga Member of the Pidinga Formation)
- a complex sequence of Late Eocene marine limestone (upper Wilson Bluff), marginal marine – uvial carbonaceous clastics (Anthony Member of the Pidinga Formation), and estuarine clastics (Khasta Formation)
- Middle Miocene – Early Pliocene marine limestone (Nullarbor Limestone), lacustrine mudstone and dolomitic limestone (Garford Formation), and marginal marine – estuarine (carbonaceous) clastics (Kingoonya Member of the Garford Formation, and Narlaby Formation).

Shoreline features

A new model of the shoreline evolution, based on major third-order sea-level events, provides valuable geological information on the Tertiary landscape and defines four generations of shorelines — mid-Middle Eocene (41.5 Ma), late Middle Eocene (39 Ma), Late Eocene (37 Ma), and Neogene (15–5 Ma; Hou et al., 2003c; Fig. 2). These shorelines are highly prospective for beach-sand-hosted heavy minerals related to wave-

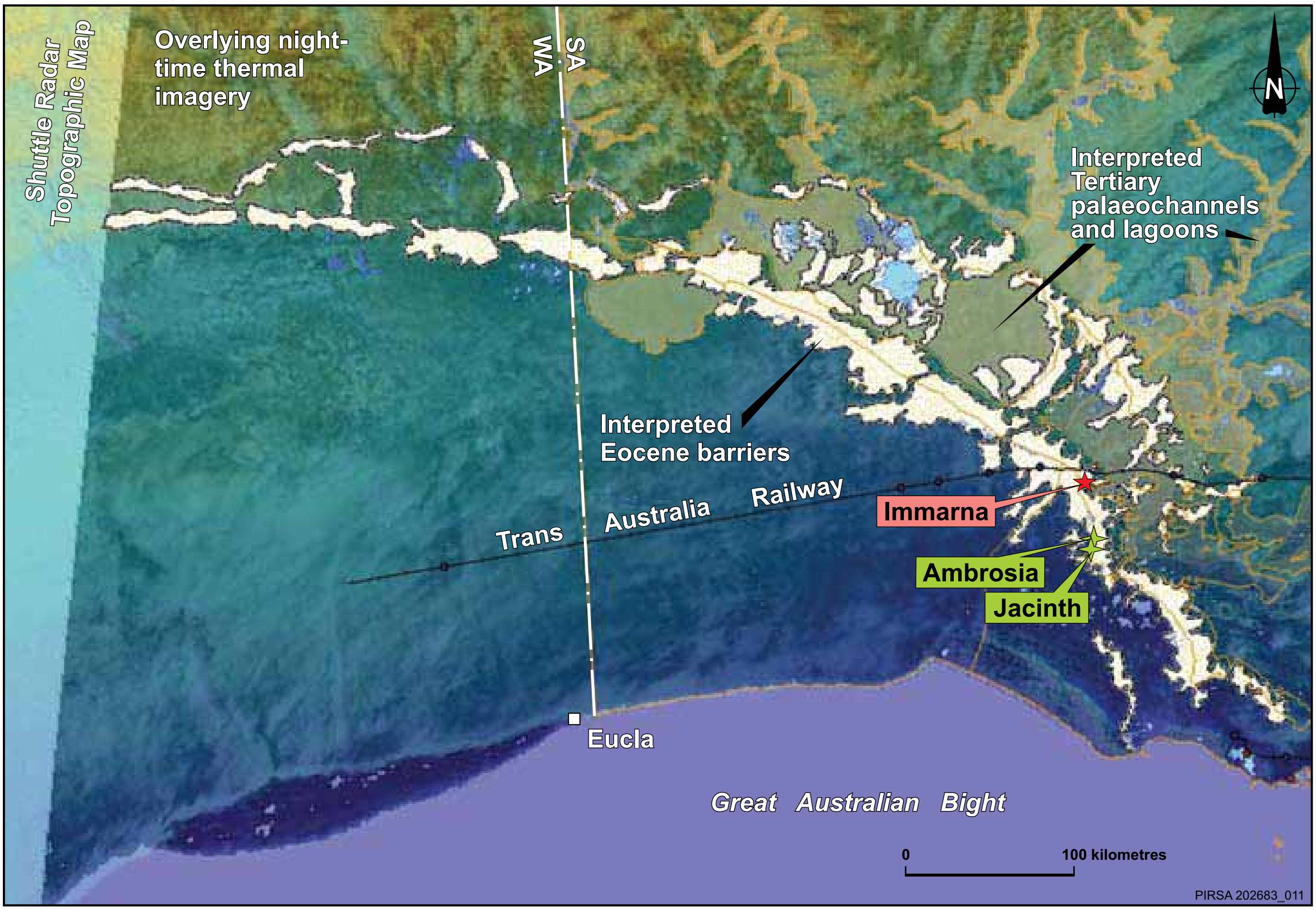


Fig. 3 Comparison of the coastal barriers delineated from previous (brown solid lines, SA_GEODATA) and this (blue dash line) study in GIS. Note that there is up to 25 km difference. The light brown tone outlined by the blue dash lines is the distribution of barrier deposits interpreted subsurface. Superimposed light brown tone (50% transparency) is the distribution of Tertiary palaeochannel and lagoonal deposits interpreted previously (brown solid lines). The old (Immarna) and new (Jacinth and Ambrosia) HMS discoveries are also shown (after Hou et al., 2004).

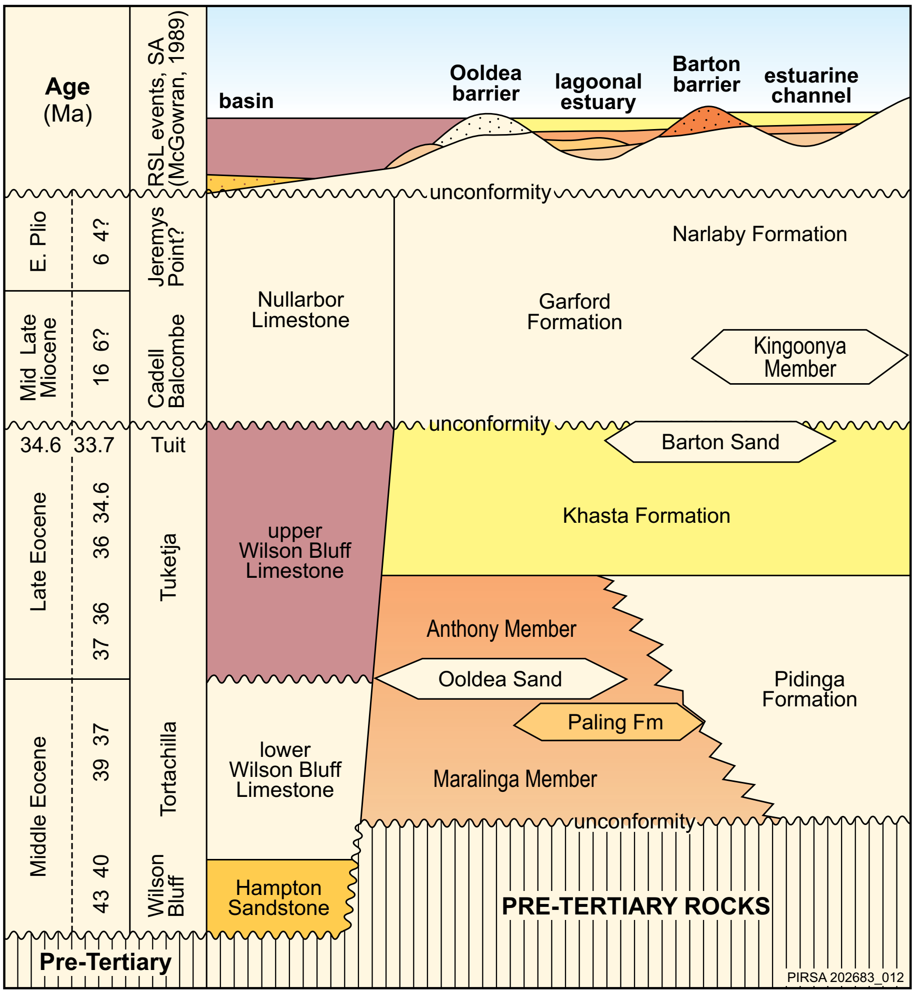


Fig. 4 *Stratigraphic framework for the eastern Eucla Basin and adjacent palaeovalleys (after Hou et al., 2004, in prep.).*

associated highstands of relative sea level (Fig. 5). The Tertiary shorelines, defined as bodies of coastal sand, here comprise beach, shoreface, barrier, dune, tidal inlet, washover and lagoonal facies (Hou et al., 2001b), probably representing multiple higher order highstands (Hou et al., 2003a). Shorelines are associated with numerous palaeodrainage systems that drained areas of cratonic basement and supplied vast quantities of sediment to the basin (Ferris, 1994).

Heavy mineral beach placers

Features and types

Concentrations of detrital rutile, zircon, ilmenite, and minor leucoxene and monazite occur as beach placers in highstand strandlines along the Tertiary shorelines (e.g. Hou et al., 2003c). Highstand geomorphic features are excellent for the formation and localisation of beach placers, mainly by longshore drift (Fig. 2). Selected drillhole and cross-sectional distributions of HMS anomalies (1–27% heavy minerals) from the Ooldea Range (Fig. 6) show that the placers occur either in the upper part of thick barrier–dune sand bodies, often 20 m or more below the surface, or close to an erosional bedrock contact. Analogous to the beach placer deposits of the eastern Australian coast classified by Roy (1999), several types of HMfl deposits can be identified by sedimentological study (Hou et al., 2003c):

- lag deposits along erosional disconformities and/or unconformities
- transgressive deposits at the rear of highstand (swash-aligned) barriers, including those trapped near the palaeovalley passes
- regressive deposits at the front of prograded barriers
- aeolian deposits, as low-grade disseminated concentrations in transgressive dunes.

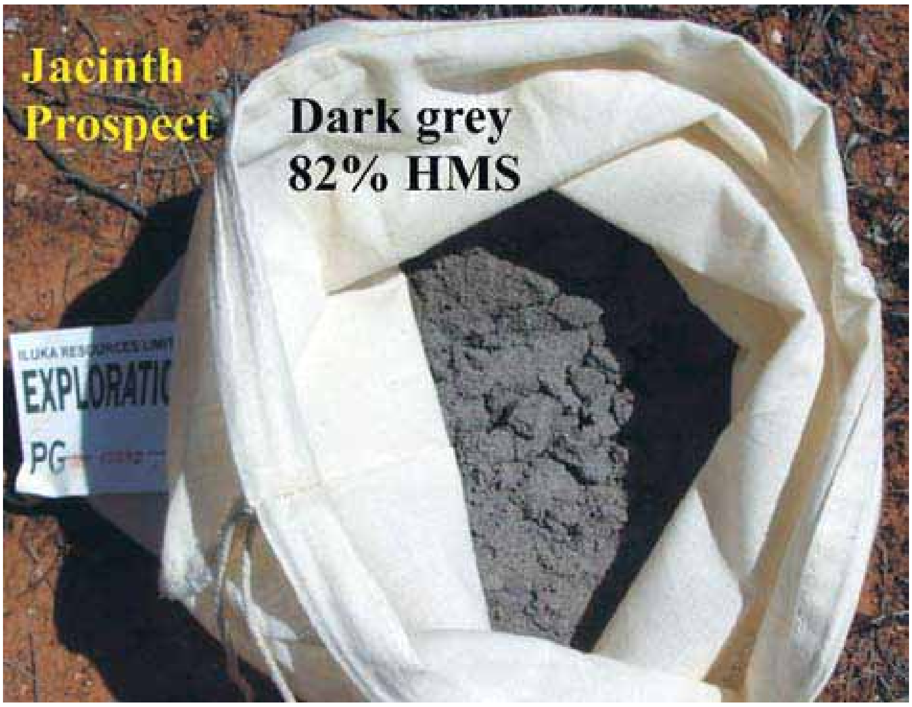
Based on interpretation of the depositional environments, the HMS accumulated in Tertiary shorelines as bodies of coastal sand, probably representing multiple higher order highstands (Hou et al., 2003b). Recognition of these coastal depositional environments within several generations of shorelines gives meaning to anomalous intersections of beach placers and aids targeting of future drilling.

New discoveries

Two discoveries of significant zircon-rich HMS were announced on 5 November and 17 December 2004 by Iluka Resources Ltd at their Jacinth and Ambrosia prospects. Assay results from the discoveries show the prospects to have an average heavy mineral content of 10% (up to 82%) containing an average of 55% zircon, 7% rutile and 22% ilmenite — comparing 'favourably' to the Eneabba province in Western Australia in its 'heyday' (Fig. 7). Ambrosia prospect may have an even higher zircon endowment compared to the nearby Jacinth deposit. Visual indications for the other reconnaissance lines suggest that anomalous mineralisation extends across an extensive area; so far all that detected occurs in unconsolidated sand above the watertable. The highly prospective nature of the region is highlighted by the fact that both Jacinth and Ambrosia are located along the same geological feature and that there is >40 km strike length of this feature still untested.

In 2001, Iluka applied for EL 2900, which includes the new Jacinth and Ambrosia discoveries. During 2003, the company applied for additional exploration rights over substantial tracts of the Ooldea and Barton Ranges. Drilling of strandlines commenced in 2004, and the Jacinth and Ambrosia prospects are early exploration successes that will drive an expanded program of exploration drilling and sample testing during 2005. Adelaide Resources Ltd is also set to benefit, with increased activity on their adjoining EL 2840, in joint venture with Iluka.

To date, identified high-grade anomalies of rutile, zircon, ilmenite and leucoxene occur in shoreline deposits. Mineralised zones are thought to represent stacked shoreline facies that accumulated during marine

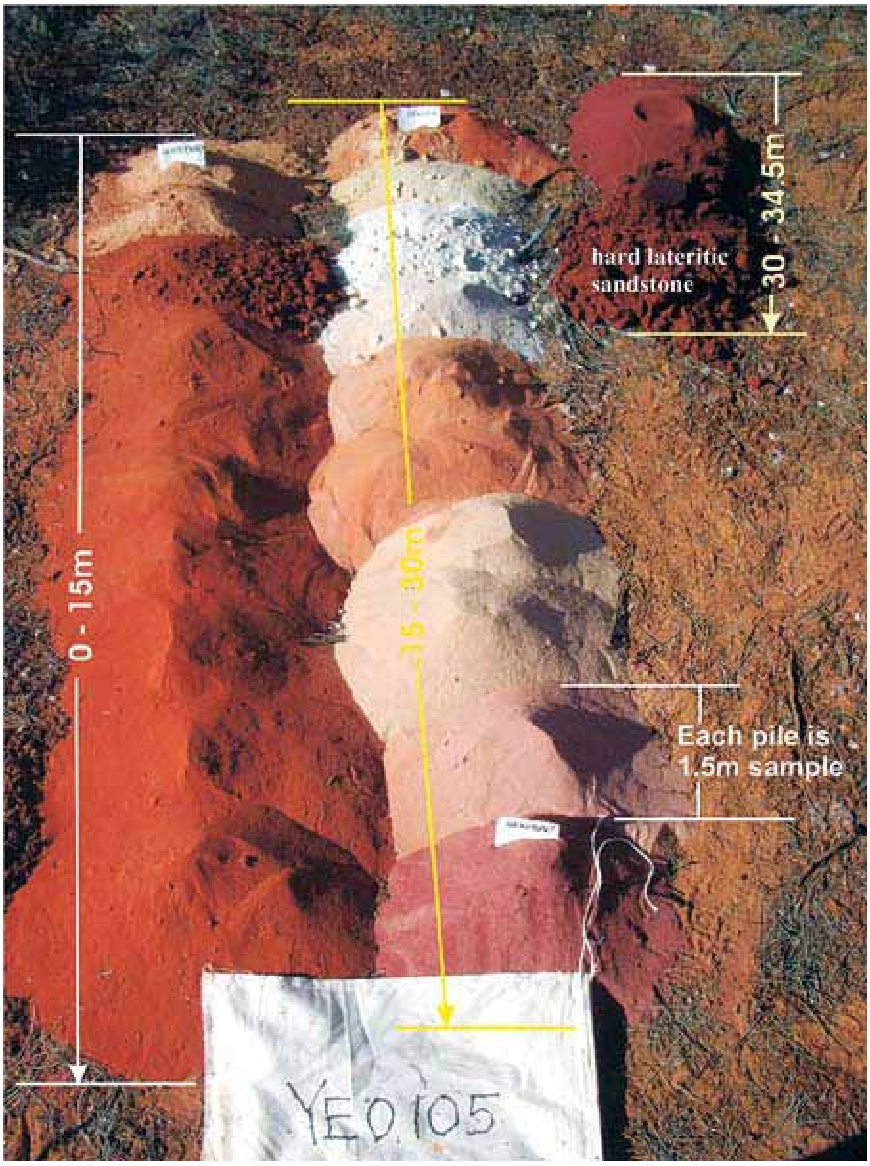


Dark grey HMS (82%) in sample bag, Jacinth prospect. (Photo 401703)

transgressions in the Tertiary. The Jacinth and Ambrosia prospects contain up to 45% detrital HMS over a thickness of 25 m, with the richest up to 82% HMS and the thickest part being ~35 m. There is a tendency for the Jacinth and Ambrosia prospects overall to become a continuous and more mineral-rich zone towards both the southeast and northwest of their enclosing portion of the Ooldea barrier (Pidinga Bay; Figs 2, 3). HMS appear to have been concentrated where the oversteepened shoreface acted as a virtual headland that focused wave-reworking processes during marine transgressions (Roy and Whitehouse, 2003). The most prospective strata are the barrier and associated sands of Tertiary shorelines that were buried by voluminous sand dunes over a period of 40 million years. The geographic and stratigraphic distributions of HMS in Tertiary sediments suggest contemporaneous transport through palaeovalleys predominantly from Precambrian cratons.

Conclusions and future work

The Eucla Basin has potential as a major new HMS province in Australia. Here, recent re-examination of the Tertiary lithostratigraphy and geography has revealed a record of stepwise evolution of marine and non-marine environments for these potentially economic sediments. The new model of shoreline evolution in the eastern Eucla Basin has provided valuable geological information for the Tertiary landscapes. flignificant anomalies in beach placers and related coastal deposits are associated with at least four third-order Tertiary shorelines, ranging in age from Middle Eocene to Early Pliocene. The region is highly prospective for beach-sand-hosted heavy mineral deposits related to wave-associated highstands and rises of relative sea level.



Sample sequence of drillhole YE 0105 (for location see Fig. 7), Jacinth prospect. Note that the whole sequence similar to this is often mineralised at Jacinth. (Photo 401704)

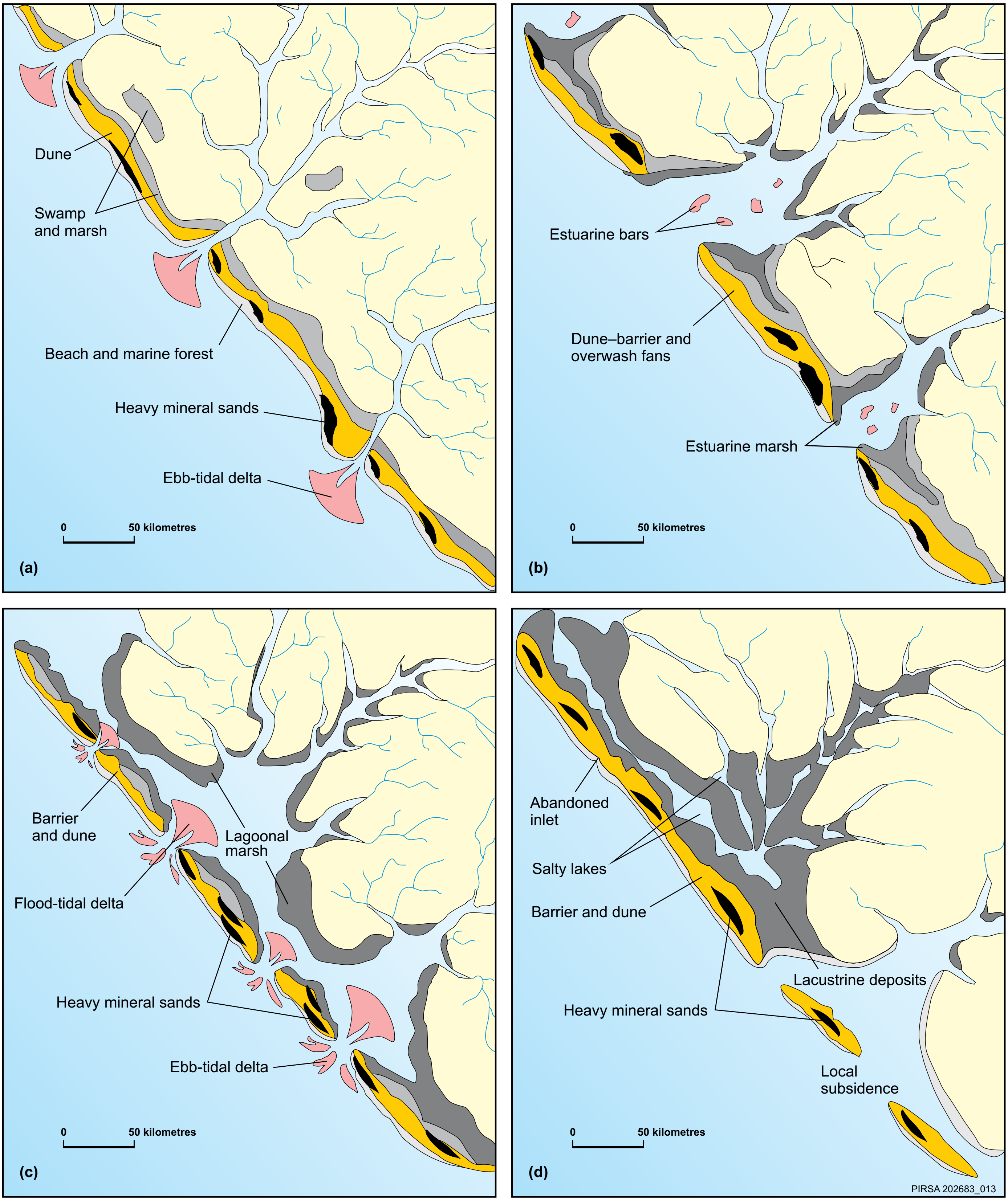


Fig. 5 *Palaeogeographic evolution model of the Eocene coastal barriers and related facies (after Hou et al., in prep.).*

The widespread development of strandlines beneath the extensive sand dunes, and their possible role as major HMS carriers, make them an important element and a challenge in further exploration. The presence of thick cover (up to 100 m) at the axes of the sand ranges will obviously deter exploration, but the impressive width of the barriers (up to 25 km) which blanket large areas of more shallow cover (0–40 m) suggests that the heavy-mineral-bearing strandlines are detectable. The challenge for future exploration lies in discovering not only dune–barrier sands beneath cover, but also beach, shoreface, dune, tidal inlet, and washover sediments beneath thin cover. The use of high-resolution DEM and

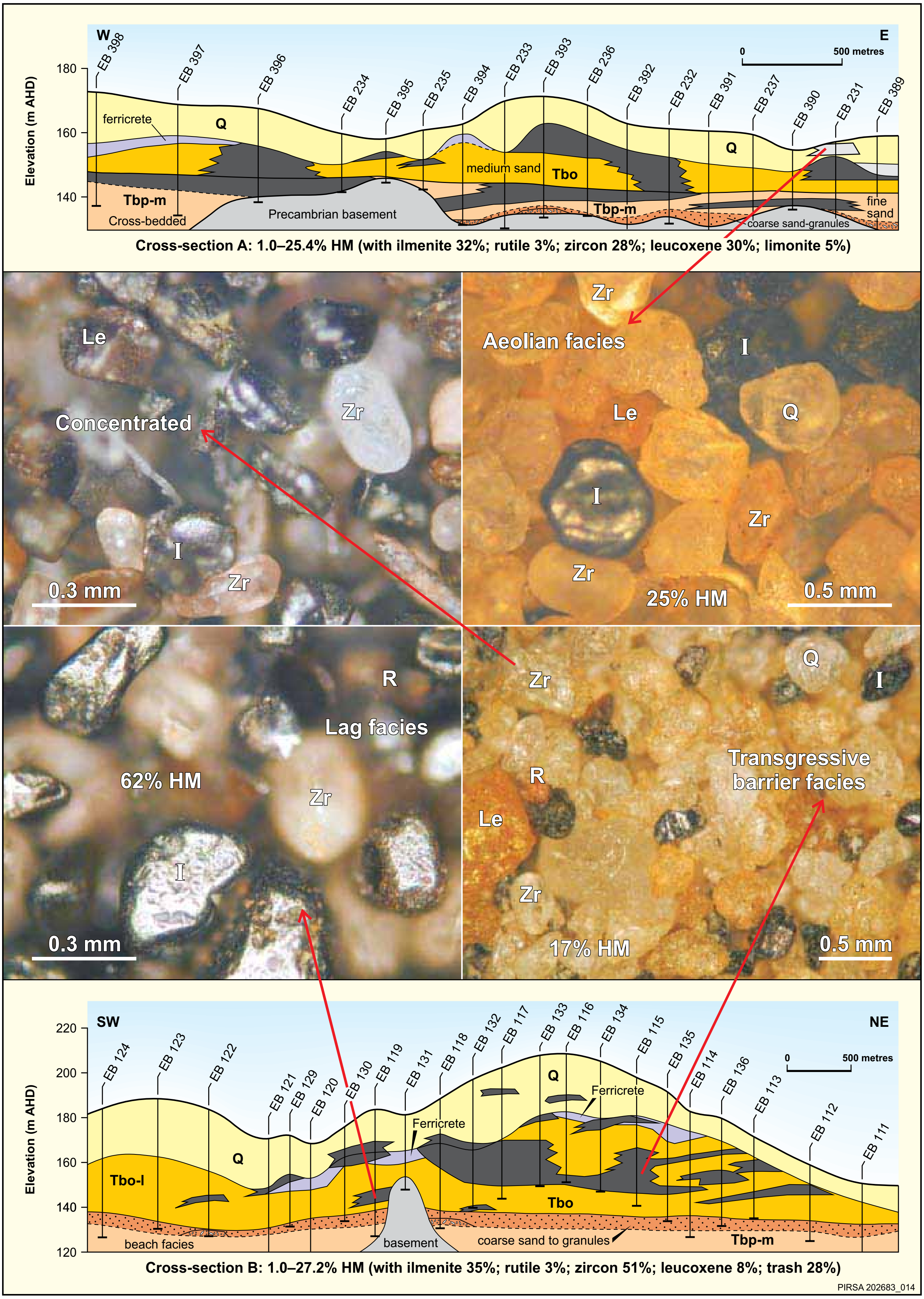


Fig. 6 *Selected geological sections and intersected HMS (Zr, zircon; I, ilmenite; R, rutile; Le, leucoxene; Q, quartz; reflected polarised light; cross-sections are located in Fig. 2).*

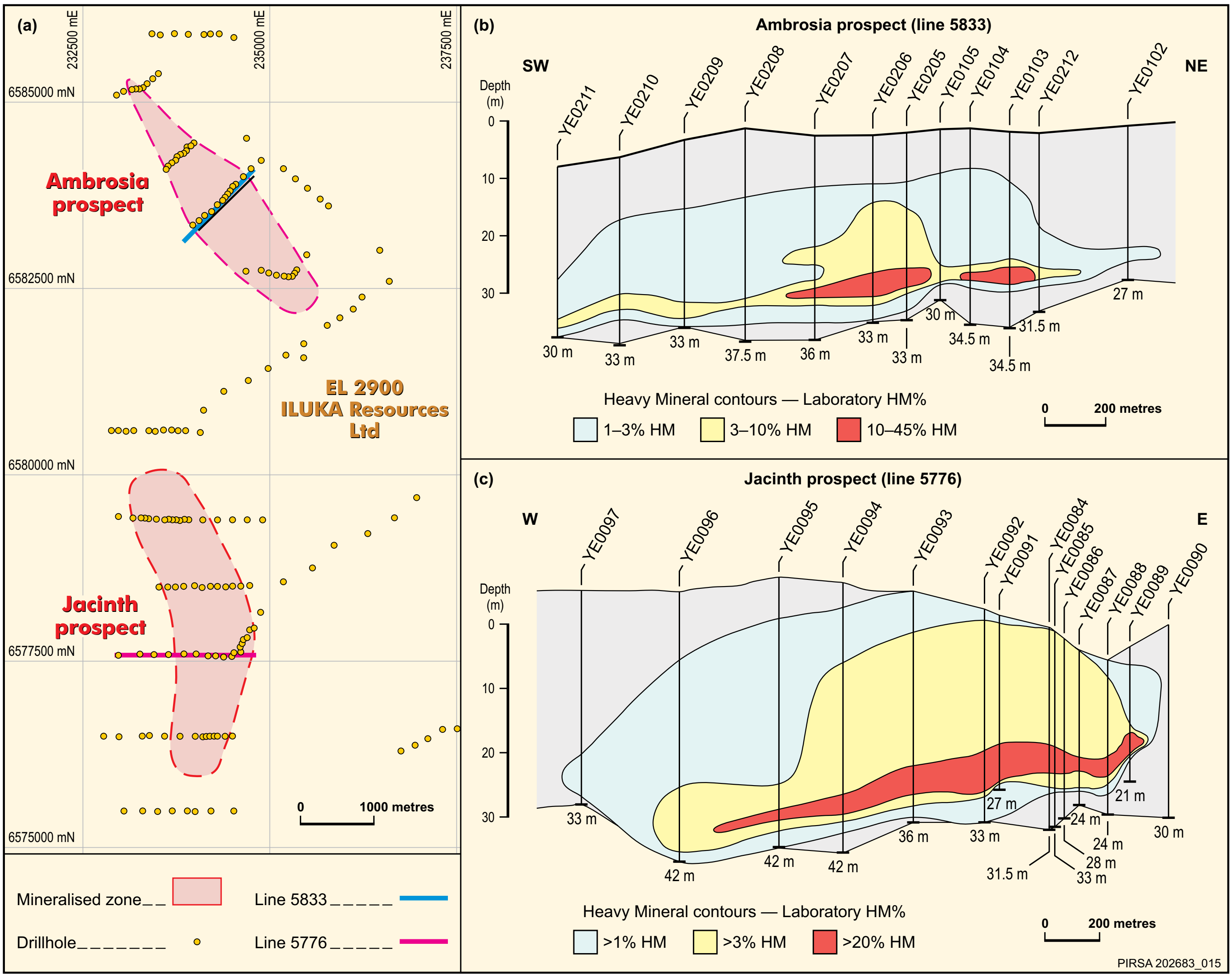


Fig. 7 *Drilling sections showing heavy mineral content of the Ambrosia and Jacinth HMS prospects.*

ground magnetics, remotely sensed (e.g. NOAA, Landsat, ASTER) night-time thermal imagery (Fabris, 2002), induced polarisation and ground penetrating radar in the areas of shallow cover may target strandlines developed in the high-energy beach facies. Future exploration should seek a greater understanding of the allostratigraphic significance of the Tertiary succession and apply a greater emphasis to palaeogeomorphic and palaeogeographic factors.

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Above *Iluka drill rig testing the Jacinth deposit.* *(Photo 401705)*
Right *Lexie Bracher and Ian Warland of Iluka Resources holding a pan of heavy mineral sands at the Jacinth prospect.* *(Photo 400958)*

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