DEVELOPING ENHANCED HEAVY MINERAL EXPLORATION STRATEGIES – LESSONS LEARNT FROM THE MURRAY BASIN IN WESTERN VICTORIA

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Introduction

Recently, due to the discovery of several heavy mineral deposits such as Wemen, Murrayville and the WIM 150 deposits (Figure 1), the Murray Basin has been identified as a new and important heavy mineral province where mid-continental beach placers associated with the Loxton-Parilla sands contain economic concentrations of ilmenite, rutile, and zircon (Roy et al., 2000). One such deposit, the Bondi Main heavy mineral beach placer deposit (currently operated by Iluka Resources), was the subject of a number of detailed studies. As a result of these studies, a number of findings were generated, many having some obvious benefits in the development of future exploration activities. These include the development of a palaeogeographic model, establishing a stratigraphic framework, rapid heavy mineral identification and provenance studies.

Regional setting

The intracontinental Murray Basin occupies over 300 000 km^2 of inland southeastern Australia (Figure 1) and contains an extensive preserved strandplain that provides a remarkable record of sea level change throughout the Late Miocene and Pliocene (Figure 1). This variably buried strandplain is characterised by a series of dominantly northerly to northwesterly trending ridges and swales that extend over a strike length of some several hundred kilometers. Although previously noted by earlier workers, these linear features were first interpreted by Blackburn (1962) as representing successive coastlines. These and associated sediments are now referred to the Loxton-Parilla sands, which were deposited in association with the regressive phase of a short-lived marine incursion into the western Murray Basin by a shallow epicontinental sea during the Late Miocene to Pliocene.

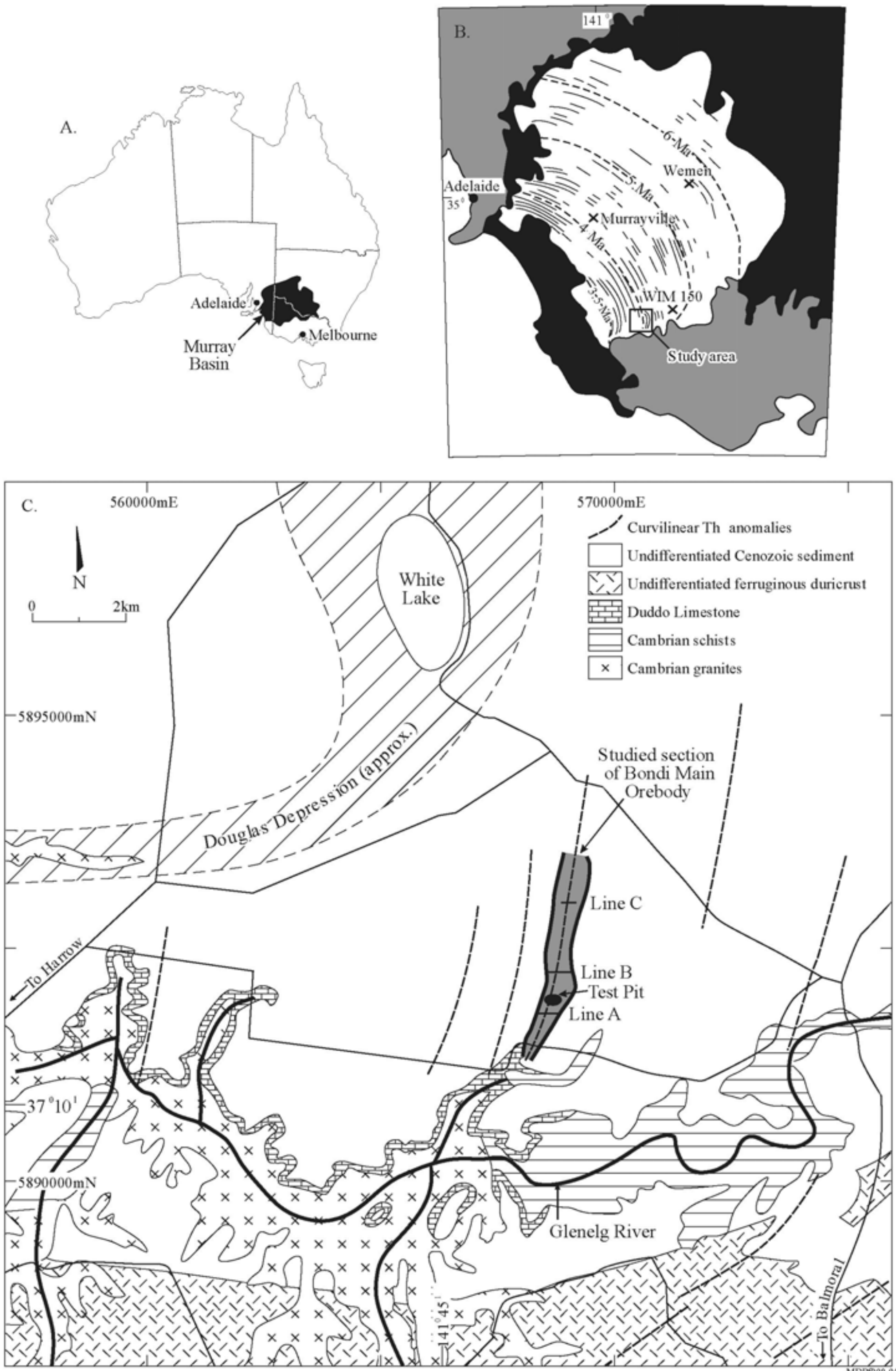

Figure 1. (A) Location of the Murray Basin within southeastern Australia. (B) Distribution of the Loxton-Parilla-sands within the Murray Basin (shaded black). Orientation of the strandlines and their assumed ages modified after Kotsonis (1995) and the location of some of the many heavy mineral placer deposits within the basin. (C) Location of the studied portion of the Bondi Main heavy mineral deposit, the three drill traverses used in this study and the location of the test pit. Curvilinear Th/U anomalies traced from radiometric imagery for the area provided by the Department of Primary Industries, Geological Survey of Victoria. After Paine (2005).

Palaeogeographical modeling

Most heavy mineral deposits form in conjunction with some form of heavy mineral trap that concentrates heavy minerals in favorable settings along the coast. Accordingly, the recognition of these traps forms an important component of a heavy mineral exploration campaign. For example, heavy mineral deposits such as the Yoganup, Capel, Minninup and Eneabba in Western Australia have all formed in “J” shaped bays with headlands at their southern ends. These headlands presumably acted like a riffle to trap heavy minerals on the updrift side but allowed less dense quartz-rich sand to bypass to the south (Lissiman and Oxenford, 1975; Shepherd, 1990). Similar geographical settings have also been noted at other heavy mineral deposits e.g. Geelwal Karoo deposit in South Africa (Macdonald and Rozendaal, 1995). Similarly the coastline hosting the Bondi Main deposit was truncated by a rocky headland in the form of the elevated Dundas Tableland (Figure 2) at its southern end. In the absence of such a prominent trap, which is often the case for the remaining Murray Basin deposits, other physical barriers are required. Consequently Whithouse et al. (1999) proposed (a) the growth faulting model or (b) the substrate erosion model as likely heavy mineral concentration mechanisms.

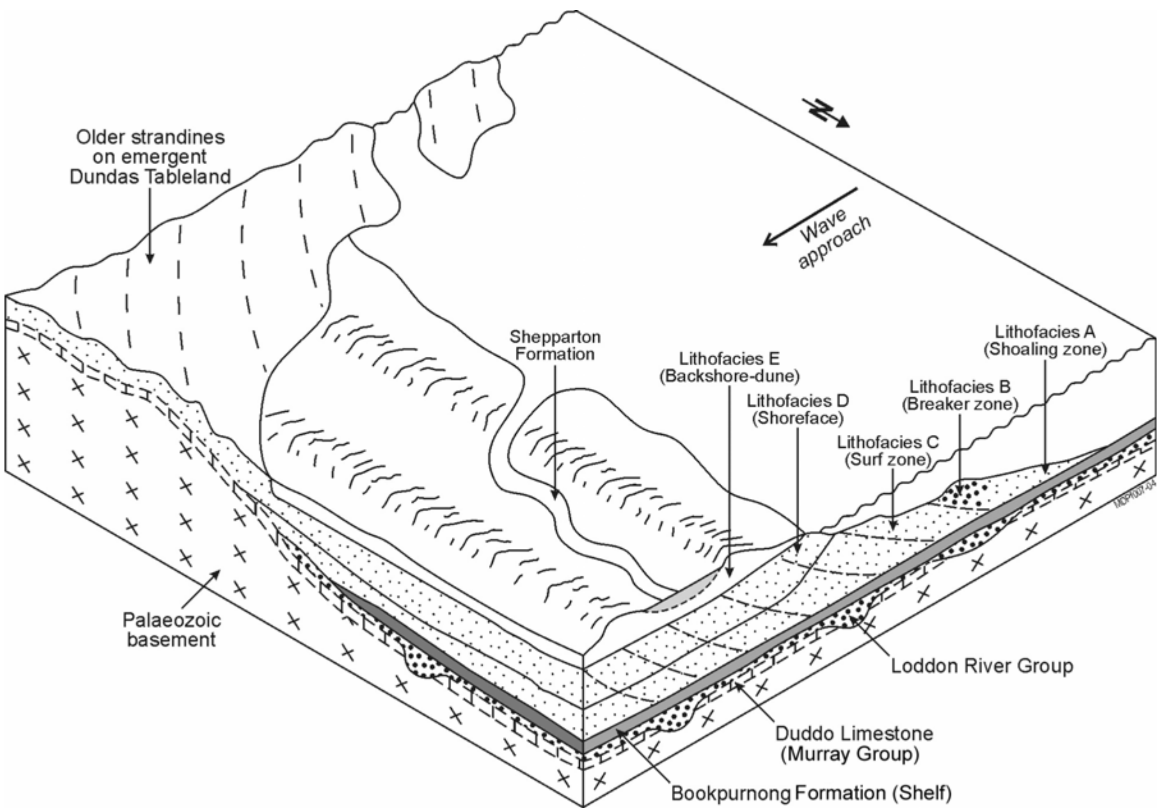

Figure 2. Palaeogeographical model for the Bondi Main deposit showing depositional environments for the units and established lithofacies studied. After Paine (2005).

Stratigraphic framework

The majority of the worlds heavy mineral resources occur as placer deposits hosted by coastal sediments. More specifically, heavy mineral deposits commonly occur within facies deposited in the more energetic environments such as the swash zone. Site-specific stratigraphic models however often reveal a more complex story, demonstrating their necessity at individual sites.

Complications such as stacked heavy mineral lenses, re-mobilisation of heavy minerals into the adjacent aeolian dunes and storm wash overs are some of the features encountered. Indeed this is the case at the Bondi Main deposit, where a detailed lithofacies analysis demonstrated (a) both individual and stacked heavy mineral rich swash zone facies (Lithofacies D, Figure 3), (b) remobilization of heavy minerals into aeolian sediments and (c) the establishment of a basal unit (the Bookpurnong Formation) that effectively represents the base of the heavy mineral-bearing sequence.

Rapid heavy mineral identification

Commonly, heavy mineral analysis of both modern and ancient placer deposits has relied upon either magnetic separation (Franz Isodynamic Separator, Rapid Magnetic Separator), point counting techniques or a combination of the two. These techniques have been used to provide both weight % and/or frequency % data where typically 300 grains are counted per sample. The Automatic Geological Scanning Electron Microscope (AutoGeoSEM) offers an alternative to these techniques and has some advantages in that (a) it is fully automated, (b) it produces objective compositional data and (c) it is capable of analysing large numbers of grains (Robinson et al. 2000). By utilizing the AutoGeoSEM, down hole heavy mineral concentrations were plotted for studied sections through the Bondi Main deposit (Figure 3). Following this, a number of implications relevant to exploration were deduced. Firstly, it was found that the weathering overprints at the Bondi Main deposit, such as ferruginous pisoliths, nodules and hardened mottles, have contributed significantly to the heavy mineral suite. It is prudent therefor not to rely solely on heavy mineral grade; varietal studies are also required when assessing the economic potential of a deposit. Secondly, it was found that the swash zone sediments not only contain the greatest quantity of heavy minerals, they also contain greater proportions of the valuable heavy minerals such as ilmenite, the intermediate titanates, rutile/anatase and zircon. This renders them as the most favourable lithofacies to target for sourcing economic concentrations of heavy minerals. Thirdly, it appears that there are no significant differences in the relative proportions of heavy minerals between the transgressional and regressional swash zone Lithofacies (Lithofacies D, Figure 3). Finally, the fact that at least locally the interpreted dune sediments contain a heavy mineral suite that is representative of the heavy minerals in the underlying swash zone deposits, presents an interesting implication for at least local scale heavy mineral exploration. Backshore-dune deposits generally occur at the top of regressive coastal deposits (as they do here) and consequently, present an accessible sample medium, which in this case would provide a representative sample of the various heavy minerals in the underlying swash zone.

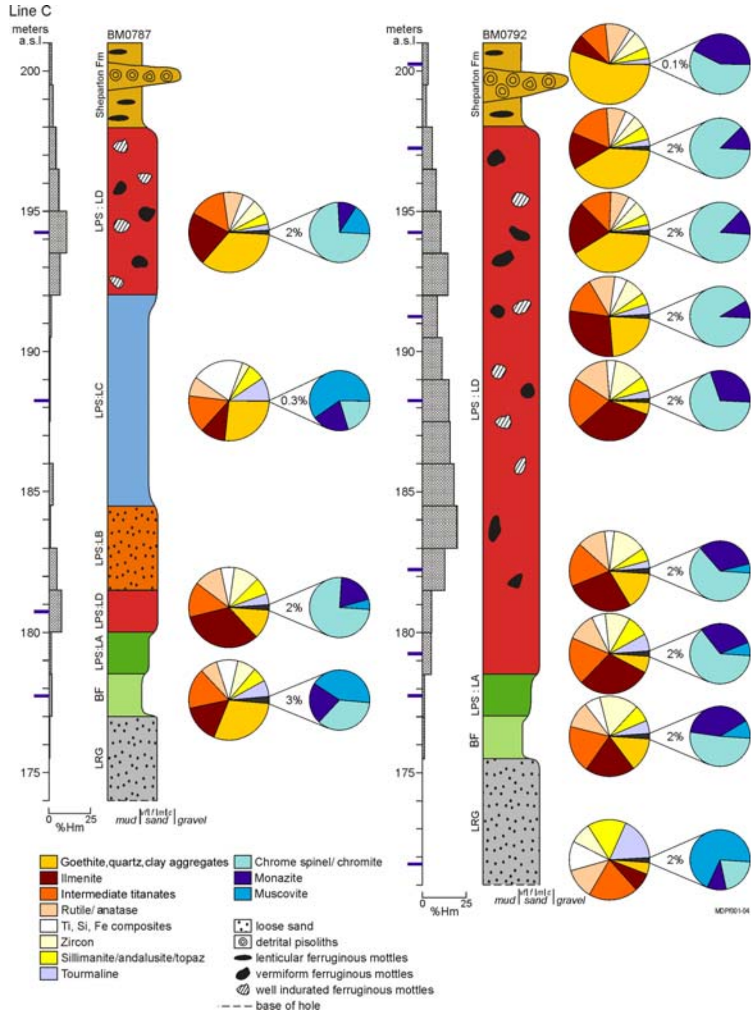

Figure 3. Vertical stratigraphic sections for drill holes along Line C across the Bondi Main deposit and associated heavy mineral type and concentration. BF = Bookpurnong Formation, LPS = Loxton-Parilla sands (Lithofacies A to E), LRG = Loddon River Group, SF = Shepparton Formation. Iluka Resources supplied hole names, collar elevations and total heavy minerals as weight % for each drill interval. After Paine et al. (2005).

Heavy mineral provenance

One of the principal factors contributing to the modern interest in provenance studies is the affect that source rocks have on the overall quality of the detrital heavy minerals they produce. For example, Basu & Molinaroli (1989) found that detrital ilmenites derived from igneous source rocks show a wide range of TiO_2 contents with a mode of about 47 % whereas those from metamorphic source rocks show a tighter cluster around 52 %. Belousova et al. (2002) demonstrated that trace elements such as Y, Ce, U, Eu, Yb, Sm, Nb, and Ta, in igneous zircons were also influenced by source rock type. They found that there is a general trend of increasing REE abundance in zircons from ultramafic through mafic to granitic rocks. Consequently the provenance and composition of both zircons and rutile from the Bondi Main deposit were investigated using Laser Ablation ICPMS analysis. These results will be presented at the conference.

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