Some regolith and landscape evolution highlights from the Murray Basin's Loxton-Parilla Sands

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The Loxton-Parilla Sands formation provides a well-constrained geological record of the Late Miocene – Early Pliocene marine regression from the western Murray Basin (Miranda *et al.* 2009). It presents the opportunity to develop a post-depositional regolith and landscape evolution framework of this unit, which will allow us to better understand weathering and induration processes in southeastern Australia and how they are influenced by parent material, eustacy, tectonics, climate change, and other environmental attributes. Further, it contributes to the environmental management and ongoing detection and monitoring of salinity and acid sulphate soils in the region, as well as holding implications for mineral exploration through sedimentary basins.

The well-constrained landscape context of this geological unit has facilitated the development of a landscape geochemical approach to this study, in particular being able to consider components of the sedimentary basin-hinterland geochemistry, such as geochemical source, transport, accumulation and preservation. Some of the key influencing processes on the evolution of the Loxton-Parilla Sands are outlined here, as well as the significance of the geochemical landscape evolution model for environmental management and mineral exploration through cover.

The undifferentiated Loxton-Parilla Sands of Brown and Stephenson (1991) is a single strandplain sequence, formed from reworking of sediments discharged from the Murray Basin and from the ancient Murravian Gulf, during a marine regression from the Late Miocene to Mid Pliocene (Roy *et al.* 2000, Miranda *et al.* 2009). As the sea level dropped the subsequent subaerial exposure of the strandplain formed a weathering profile known as the Karoonda Surface (Kotsonis 1995, Miranda *et al.* 2009). The Karoonda Surface is a variably ferruginous and siliceous profile, up to 15m thick in parts, ranging from massive silica lenses to cemented ferruginous pisoliths and jointed sandstones (Brown & Stephenson 1991, Kotsonis 1995). Compared with palaeoweathering profiles in the Victorian highlands, the low-lying Karoonda Surface is comparably less developed, owing to potentially lower rainfall than the higher elevations (Miranda *et al.* 2009). The regolith landscape evolution model of the Loxton-Parilla Sands and Karoonda Surface will investigate the relationship between variations in the nature of the Loxton-Parilla Sand and the development of the Karoonda Surface and how this varies across substrate changes and diachronous geological boundaries.

Strontium isotope stratigraphy suggests a narrow time frame for deposition of the Loxton-Parilla Sands strandplain sequence, beginning at 7.2Ma and stopping around 5.0Ma (Miranda *et al.* 2009). Miranda *et al.* (2009) go on to suggest, however, that falling sea levels alone were not sufficient for such rapid coastal ridge deposition and contemporaneous tectonic uplift was the dominant mechanism for formation of the Loxton-Parilla Sands, contrary to Brown & Stephenson (1991) and Kotsonis (1995) who suggest eustacy was a more significant mechanism for strandplain formation . Tectonism was also an important mechanism in the formation of heavy mineral placer deposits in the Loxton-Parilla Sands where up-faulted basement blocks formed headlands that trapped and concentrated mineral sands (Roy 2003). Since the Miocene some of these faults have been reactivated with NE-trending basement ridges forming regions of uplift and subsidence (Whitehouse 2009). These faults can also act as conduits for fluid flow, enabling groundwater to come into contact with basement mineralisation and move into the overlying Murray Basin sediments.

Following deposition of the Loxton-Parilla strandplain, tectonic damming of Murray Basin drainage by the Padthaway Block was largely responsible for the formation of Lake Bungunnia, an ancient Pleistocene megalake in the central Murray Basin (Kotsonis 1995). It is thought that up to 70m of uplift has occurred on the Padthaway Block in the western Murray Basin since the last marine regression, given movement of units underlying the Loxton-Parilla Sands (Kotsonis 1995).

Stephenson (1986) calculates that in order to sustain such a large lake system like Lake Bungunnia, rainfall during that time must have exceeded 500mm/year. Further, drying of the lake was from either breaching of the tectonic dam or increasing aridity, most likely a combination of the two (Kotsonis 1995). This suggests a shift from very wet to a much drier climate occurred sometime after 0.7Ma (Stephenson 1986). Such a change in climate would affect the salinity and acidity of groundwater in the Murray Basin, affecting weathering processes and groundwater chemistry in the Loxton-Parilla Sands. The Pleistocene onset of aridity in Australia, following the drying up of Lake Bungunnia, is evidenced in the shift from predominantly acid sulphate weathering to carbonate deposition, for example the Bungunnia Limestone and other calcretes in the Murray Basin (Brown & Stephenson 1991, McLaren & Wallace 2010). It is difficult to quantify the degree of erosion that has taken place since the strandplain deposit, however Miranda *et al.* (2009) suggest there is a lateral unconformity spanning up to 3.0Ma in the SW of the basin thereby interrupting the record of marine regression preserved in the Loxton-Parilla Sands.

Extensive salinisation of groundwater and soils in the Murray Basin is a major environmental problem, common in arid to semi-arid climates but propagated by human activities. Particularly in the Murray Basin, clearing of native vegetation in favour of shallow-rooted crops and regulation of river flow for irrigation and human consumption has contributed to increased catchment run-off and erosion, and raised water tables (Macumber 1991). The subsequent rise in groundwater has drawn salts up from aquifers to the surface leading to widespread salinisation of landscapes (Macumber 1991, Jolly *et al.* 1993). To date, techniques to monitor rising salinity levels in the landscape have relied on access to bores or undertaking expensive geophysical surveys. Plant biogeochemistry, however, shows promise as a novel method for detecting salinised landscapes as well as a mineral exploration technique (McLennan *et al.* in prep.).

The naturally high salt levels in the Loxton-Parilla Sands aquifer that are contributing to the salinity problem may be an advantage when it comes to mineral exploration. The mineralised bedrock underlying some areas of the Murray Basin is a source of metal ions that complex with chloride in the saline groundwater it comes into contact with (Whitehouse 2009). These chemical signatures are transported in the acidic, saline water creating dispersion haloes in the overlying Loxton-Parilla Sands that could be used to vector towards underlying mineralisation in regions like the Nackara Arc and Stawell Zone. Further, structural and stratigraphic fluid flow paths allow for groundwater to reach mineralised bedrock and carry the hydrogeochemical signature of the near-surface in the Loxton-Parilla Sands or to the surface as groundwater discharge features (Macumber 1991, Whitehouse 2009). Further to an understanding of how hydrogeochemical processes can be used in mineral exploration, understanding tectonism in the basin is important in the formation and discovery for heavy mineral sand deposits in the Loxton-Parilla Sands sequence (Whitehouse 2009).

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References

BROWN C. M. & STEPHENSON A. E. 1991. *Geology of the Murray Basin, Southeastern Australia*. Australian Government Publication Service, Canberra.

JOLLY I. D., WALKER G. R. & THORBURN P. J. 1993. Salt accumulation in semi-arid floodplain soils with implications for forest health. *Journal of Hydrology* **150**, 589-614.

KOTSONIS A. 1995. Late Cainozoic Climatic and Eustatic Record from the Loxton-Parilla Sands, Murray Basin, Southeastern Australia. Master of Science thesis, School of Earth Sciences, University of Melbourne, Melbourne (unpubl.).

MACUMBER P. G. 1991. *Interaction between groundwater and surface systems in northern Victoria*. Victorian Department of Conservation and Environment.

MCLAREN S. & WALLACE M. W. 2010. Plio-Pleistocene climate change and the onset of aridity in southeastern Australia. *Global and Planetary Change* **71**, 55-72.

MCLENNAN S. M., HILL S. M., HATCH M., BAROVICH K. & BERENS V. in prep. *Riparian eucalypt biogeochemical expression of groundwater salinity, Murray River, South Australia*.

MIRANDA J. A., WALLACE M. W. & MCLAREN S. 2009. Tectonism and eustacy across a Late Miocene strandplain: The Loxton-Parilla Sands, Murray Basin, southeastern Australia. *Sedimentary Geology* **219**, 24-43.

ROY P. S. 2003. Changing Pliocene Sea Levels and the Formation of Heavy Minerals Beach Placers in the Murray Basin, Southeastern Australia. *Economic Geology* **98**, 975-983.

ROY P. S., WHITEHOUSE J., COWELL P. J. & OAKES G. 2000. Mineral Sands Occurrences in the Murray Basin, Southeastern Australia. *Economic Geology* **95**, 1107-1128.

STEPHENSON A. E. 1986. Lake Bungunnia - A Plio-Pleistocene megalake in southeastern Australia. *Palaeogeography, Palaeoclimatology, Palaeoecology* **57**, 137-156.

WHITEHOUSE J. 2009. Mineral Systems of the Murray Basin, New South Wales. *Geological Survey of New South Wales Department of Primary Industries*.

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