

DEPOSITIONAL STRUCTURE REFLECTED IN GEOPHYSICAL SIGNATURES IN THE SOUTHWEST OF WESTERN AUSTRALIA

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INTRODUCTION

The southwest of Western Australia has a long geological history with an Archaean basement of granite and gneiss intruded by Proterozoic dolerite dykes. The basement is covered by a thick regolith that has been evolving since the Permian glaciation. The upland parts of the area have been subjected to sub-aerial weathering since the glaciation, while the lowland areas were probably inundated by a series of marine incursions during the Eocene (Worrall & Clarke, 2004). Clarke (2006) reported the area is characterised by a complex depositional environment and that salinity management must include mapping of palaeovalleys systems and characterisation of their materials to encompass the dynamic of salt and water movement in the landscape.

Palaeovalleys ranging in age from Eocene to Holocene eroded deep channels into the basement (Morgan, 1993; Van de Graff *et al.* 1977). These have filled with both marine and non-marine sediments (Clarke, 2006). Drainage in the area was originally to the west and south coasts, however uplift along both coastlines has resulted in blocked drainages and filling of the deep valleys to form playa lake systems (Salama, 1997) into which sediment is still being deposited.

The combination of a poor drainage, deep rooted sclerophyllous vegetation and high evaporation rates have resulted in the aerosol salts becoming concentrated within parts of the regolith. Surface indicators show high concentrations of the salts in the present valley floors and drainage lines. These salt concentrations can easily be mapped using frequency domain shallow penetrating electromagnetic equipment. Deep in the regolith the palaeodrainage or inset valleys (de Broekert & Sandiford, 2005) contain large amounts of saline water and their position can be interpreted from conductivity images created by inversion of data from time domain EM surveys. Also imprinted in the regolith is a complex pattern of sediments associated with the tributaries off these inset valleys. These thinner layers of sediments, often in braided streams, have been partially or completely eroded and in places only the imprints of previous dendritic drainage systems can be seen in geophysical data. Gamma radiometric data and frequency domain EM data have proved useful in mapping soil textures and particularly at differentiating clays and sands in braided stream depositional environments (Street, Abbott & Beckett, in press). The combination of deep penetrating airborne EM systems and shallow penetrating radiometrics can therefore assist the interpreter in building an architecture of sediment deposition in the valley floors.

MORBINNING

The southern end of the Morbinning Catchment, 30 kilometres east of Beverley, forms a delta as it flows southeast to meet the system of palaeo-lakes now represented by playas at the outlet of the Salt River system (Salama, 1997). An airborne magnetic and radiometric survey was flown across the catchment. In the ternary radiometric image (Figure 1A) a braided stream pattern can be seen with sandier sections showing up as darker in the image. In addition, the radiometric signature shows a distinct change where the braided stream environment meets the finer clay rich sediments deposited in the much larger Yenyening Lake system to the south. EM31 data across part of the delta area (Figure 1B) shows the sandy sections to be lower in conductivity due to both lower porosity and lower salt content than the surrounding clays. The sands, which have a higher permeability typically allow for transport of the salt out of the catchment towards the southeast. In the clays, the salts become bound-up and less mobile. At the boundary between the clay lake sediments and the braided streams the sands inter-finger with clays laterally and presumably at depth.

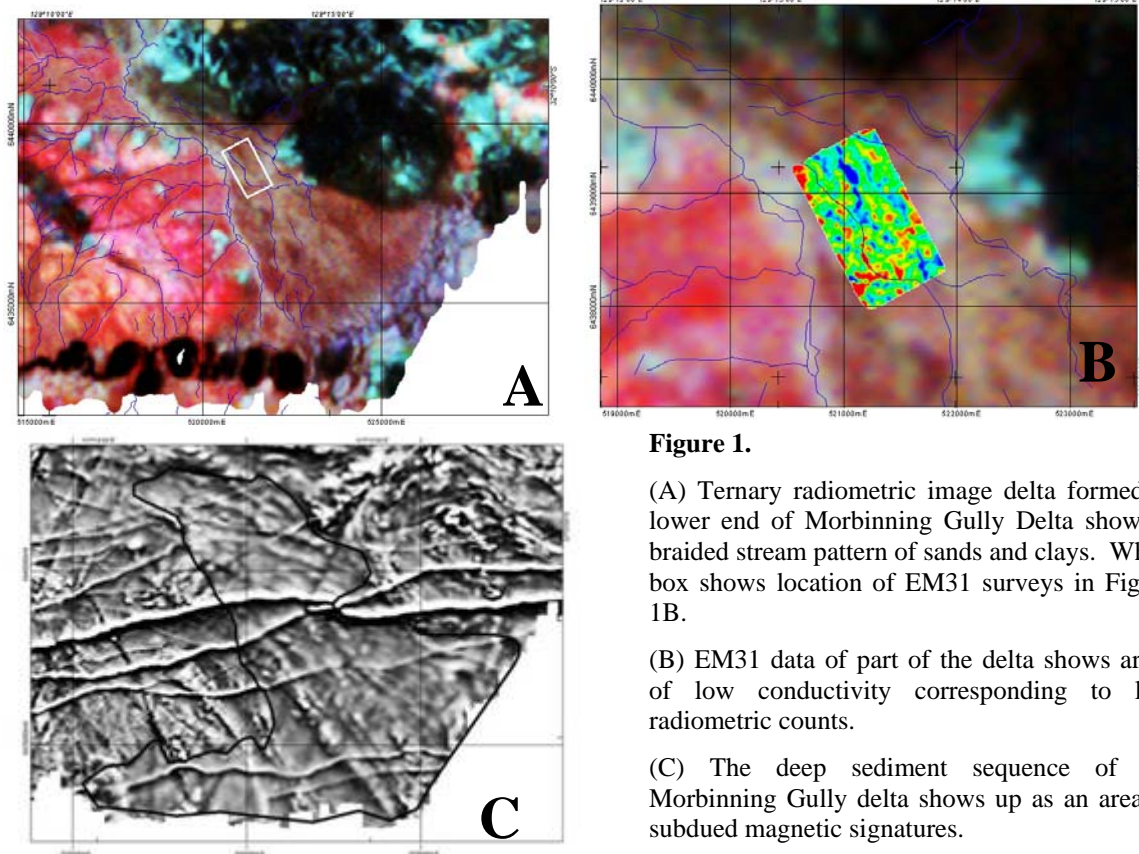


Figure 1.

(A) Ternary radiometric image delta formed at lower end of Morbinning Gully Delta shows a braided stream pattern of sands and clays. White box shows location of EM31 surveys in Figure 1B.

(B) EM31 data of part of the delta shows areas of low conductivity corresponding to low radiometric counts.

(C) The deep sediment sequence of the Morbinning Gully delta shows up as an area of subdued magnetic signatures.

While the radiometric data and EM31 show contemporary drainages, the subdued magnetic signatures indicate a thick sedimentary sequence across the area of the delta (1C). Salama (1997) suggested that magnetic surveys were an unreliable method of mapping palaeochannels, and similar responses to Morbinning are unusual over the sediment filled palaeochannel valleys of the Yilgarn.

The Morbinning Gully catchment shows a thick sediment sequence of braided sands and clays that inter-finger with a clay valley floor. At depth, hydraulic connectivity is likely between the sands of the delta and the deep palaeochannel sand aquifer. This provides a conduit for both recharge and discharge.

ELASHGIN

A low level airborne magnetic survey at Elashgin (Figure 2) also shows areas of subdued magnetics over a braided stream pattern similar to Morbinning. In some environments, high resolution low level airborne magnetic and radiometric surveys may be a technique for mapping sedimentary fill in palaeovalleys.

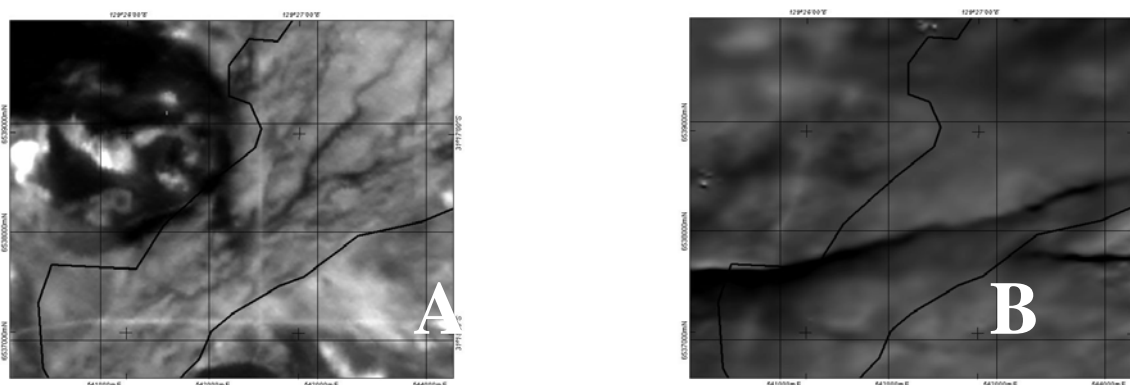


Figure 2. The total count radiometric data at Elashgin (A) shows a similar braided stream pattern to Morbinning and magnetic data also has a subdued magnetic signature (B) suggesting deep sediments underlie the braided stream.

TOOLIBIN LAKE

In the Toolibin Lake Catchment a Tempest AEM survey (Lane & Pracilio, 2000) showed high conductivity associated with near surface contemporary drainage patterns (Figure 3A). In contrast, the deeper palaeochannel sands show lower conductivity (due to lower porosity) than surrounding clays (Figure 3B). Around Toolibin Lake and extending almost 5 km upslope the surface layer is composed mostly of clays and shows a high radiometric response in all channels (Figure 4). Further up the catchment the braided stream pattern emerges with stringers of sands and clays at surface that is reflected in radiometric image (Figure 4). Macumber (1991) reported that there was groundwater movement between similar systems of surface sands and deep palaeochannel sediments in northern Victoria. It is likely that the greatest groundwater and surface interaction at Toolibin occurs where the contemporary braided stream pattern overlies the deeper palaeodrainage. Thus, these areas may be locations of higher recharge to the palaeochannel sand aquifer but also points of discharge as the deep aquifer becomes under pressure. Martin (1986) reported the floor of Toolibin acted as a recharge and discharge area depending on season.

Drilling of the deep palaeochannel aquifer at Toolibin (Dogramci, 1999) showed a 10 metre thick clay layer overlies the deeper palaeochannel sands. The piezometric pressure from the deep palaeochannel sand aquifer brought groundwater close to surface in bores. Salama (1997) showed hydraulic continuity along the Salt River palaeochannel at Yenyenning Lakes. Discharge could then occur from the sand aquifer either upslope through the braided sands as indicated in the radiometric data; laterally through more permeable zones in regolith; and/or through sand stringers in the valley floor.

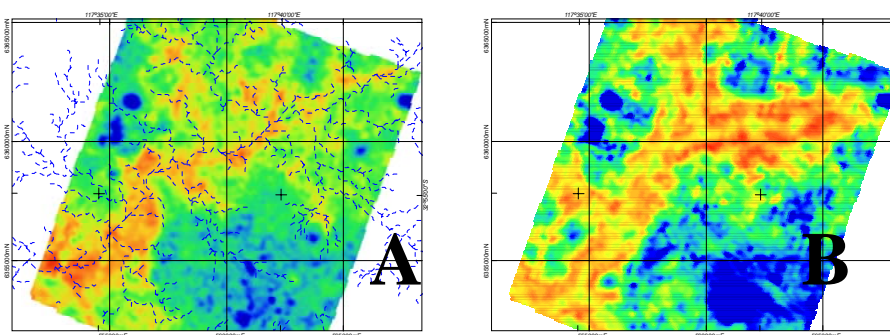


Figure 3. EM conductivity images for layers (A) 2-6 m; and (B) 20-24 m bgl at Toolibin Lake.

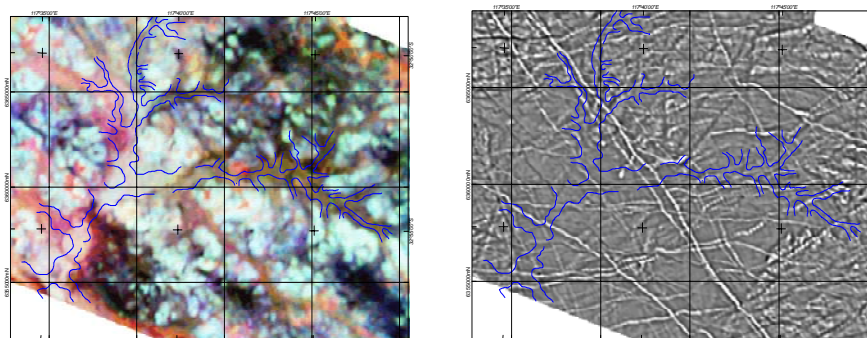


Figure 4. Radiometric ternary and magnetic first vertical derivative images for Toolibin Lake Catchment with interpreted extent of palaeochannel sands overlaid.

BROOMEHILL

The Broomehill study area lies 260km south of Perth and covers an area of 46,500 ha. The area is significant because it straddles the catchment divide between the west flowing Blackwood catchment and the south flowing Gordon/Frankland system. Along the catchment divide are some of the highest points in the catchments.

Figure 5 shows digital terrain, radiometric ternary and SALTMAP channel 5 conductivity images in the upper parts of Carlecatup Creek from the survey data. The asterisk on figure 5 is Byenup Hill which at 465m is the highest point in Kojonup Shire. The radiometric image shows a high uranium thorium count as well as patches of sand along the catchment divide associated with areas mapped as Tertiary sediments (Chin & Brakel, 1986). The area is also conductive on AEM channel 5 image. Chin & Brakel (1986) report that these

sediments are similar in age to the Plantagenet Group which occurs in the Bremer Basin due to similar fossil assemblages. If so, then the sediments are at much higher elevations than near Esperance which are close to sea level or those with similar geophysical signatures reported by Clark *et al.* (1998) for the Towerrinning area. The high conductivity and thicker regolith indicated by the AEM indicates that deep weathering and/or sediments on the catchment divide at this point contain high concentrations of salt. Perched lakes also occur on the catchment divide. The combination of the geophysical signatures and geology, suggest a landscape inversion. The data cannot date the time of the concentration of salt within the regolith/sediments but does give an explanation for saline seeps within 100 m of the highest point in the survey area.

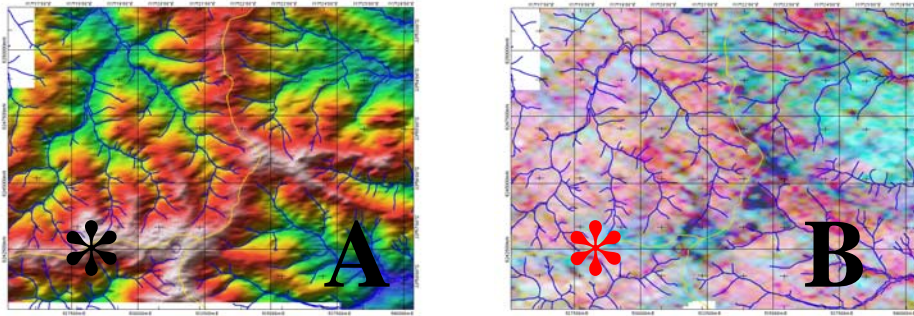


Figure 5. (A) Digital terrain model, (B) radiometric ternary and (C) Channel 5 SALTMAP AEM conductivity from Broomehill survey.

In figure 5C the drainage pattern is offset towards the northeast of the channel 5 conductivity, particularly in the southwest half of this image. The pattern suggests some migration of drainage towards the northeast. Drilling of these areas indicated deep regolith but no sediments. However, these areas are clearly filled with saline water and discharge is occurring on the downslope side along the edge of the creek. Weathering and possibly salt

accumulation appears to have occurred prior to migration of drainage.

LAKE TOWERRINNING

Northwest of Lake Towerrinning a deep inset-valley is cut into bedrock. In this case the recharge area is to the west and the channel sands are filled with fresh water. Figure 6 shows how surface drainages are saline but the deeper system forms a confined palaeochannel aquifer. Similar fresh palaeochannels aquifers are indicated near Mt Kokeby near Beverley. Recharge is indicated towards the west where rainfall is higher and salt loads in shallow groundwater significantly less. Drilling of the channel showed a deep sandy aquifer that is artesian (R. George, pers comm). Discharge from this aquifer will occur through more permeable zones such as sand stringers, in overlying clays, and/or permeable zones in surrounding regolith. The radiometric data in the area over the Towerrinning palaeochannel indicates large areas of sand.

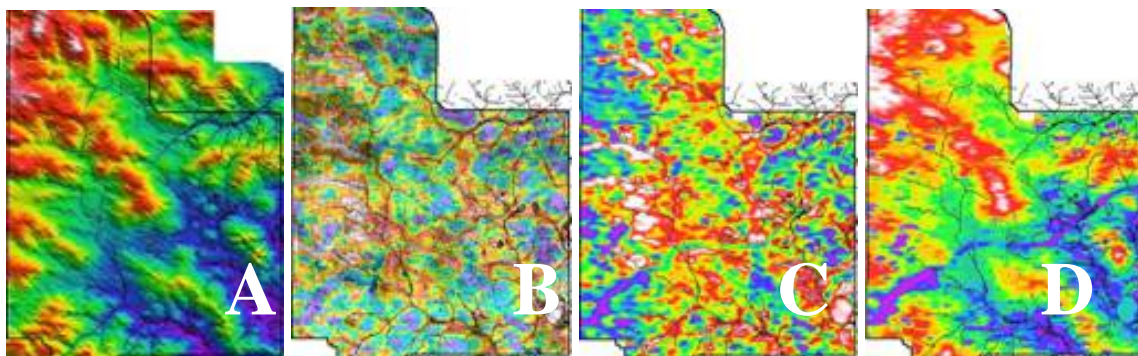


Figure 6. At Lake Towerrinning the topography (A) shows the present drainage is closely aligned with near surface conductivity (B) particularly in the east side of the area. The layer 2 conductivity shows a low conductivity channel that traverses the present topography (C). Bedrock topography (D) shows a channel cut into the bedrock.

CONCLUSION

Geophysical data collected over catchments in the wheatbelt of Western Australia reflect the deposition of sediments and regolith development since the early Cainozoic. This data provides gain insight into possible hydrogeological interaction between surface and groundwater. In broad valley floors radiometric and ground electromagnetic (EM) survey data show braided stream environments leading to clay filled valley floors which represent remnants of playa lake systems. Time domain airborne electromagnetic (AEM) surveys show that sandier sediments continue under the clays and there may be continuity between the braided streams and the deep palaeochannel aquifer in inset-valleys. Drilling of the palaeochannel sands often encounters artesian or sub-artesian saline groundwater. The recharge of this aquifer is via the sand stringers in the braided streams of the upper catchment; through more permeable zones along the sides of the palaeo-valley; and sediments in tributary valleys, which inter-finger with the sediments of the main valley floor. This groundwater also has potential to discharge outwards through these more permeable zones. The higher hydraulic head also provides a hydraulic barrier to further recharge of water to the channel aquifers. Thus, models for groundwater discharge (or salt hazard sites) can be developed from a detailed understanding of the sedimentary structure of the valleys.

In contrast, drainage in upland landscapes appears to have migrated with time leaving behind deep regolith with high salt concentrations. Understanding the development of the regolith and depositional structure in valley floors provides important information for land management decisions.

The role of airborne magnetic surveys in mapping sediments is less clear than AEM and radiometric data. Data presented here from Elashgin shows that images prepared from high resolution low level airborne magnetic surveys can be interpreted to map areas of subdued magnetic signature corresponding to deeper regolith and/or sediment. Images from surveys at higher terrain clearance do not generally reflect these signatures. Magnetic surveys are a low cost option for mapping deep regolith and/or sediments however AEM surveys are more effective at resolving the sedimentary structure.

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