The role of airborne geophysics in facilitating long-term outback water solutions to support mining in South Australia

Tim Munday
CSIRO
Earth Science and Resource Engineering
Perth, Australia
Tim.Munday@csiro.au

SUMMARY

Mining and energy development in South Australia's far north is set to have significant consequences for the water resources of the region. These sectors generate significant economic value to the State and their support remains a priority for the government. The scale of the planned developments and the potential from current exploration programs facilitated by the South Australian Government's PACE Program will result in an increase in infrastructure requirements, including access to water resources and Aboriginal lands for potential mine development. Increased demand for water and in particular groundwater is compromised by the limited information we have about these resources. There is a recognised need to develop this knowledge so that water availability is not a limiting factor to development. The Goyder Institute's Long-Term Outback Water Solutions (G-FLOWS) Project was established to help address this. Particular reference is made to work completed in the Musgrave Province. It illustrates the role of local scale AEM, acquired for exploration, and regional scale airborne magnetics and terrain data in helping develop a hydrogeological conceptual model for the Province. The AEM data reveal a complex and extensive inset palaeovalley system which contains groundwater of variable quality (2000 - 4500 mg/L TDS). Examination of their location against the regional magnetics indicates a strong litho-structural control on their orientation. If mineral resources were to be developed in the area, these groundwater systems would represent the best option for water supply. A regional scale water resource map, based on information gleaned from the geophysics, existing hydrogeological and digital elevation data, is presented that provides a framework for groundwater resource determination when/if mineral deposits were to be mined in the region.

Key words: Groundwater, airborne EM, magnetics, hydrogeology

INTRODUCTION

Mining and energy development in South Australia's arid far north is set to have significant consequences for the water resources of the region. As these sectors are of significant economic value to the State, their support is a priority for the government. The scale of the planned developments and the potential from current exploration programs, facilitated in part by the South Australian Government's PACE Program, will increase the demand for access to water, and in particular groundwater, which is the primary resource of this arid region. Its appropriate allocation, to meet such demands, could be problematic given the paucity of data on the groundwater systems present. This includes information about the character and variability of aquifers, recharge rates and their sustainability, the quality of water they contain, and their relationship to groundwater dependent ecosystems and other environmental and cultural assets. The Goyder Institute's (www.goyderinstitute.org) Facilitating Long-Term Outback Water Solutions (G-FLOWS) Project was established to help address this. One component of that Projects activity is described here, specifically that concerning the use of regional (State) and local-scale (exploration company) geophysical data sets to develop a hydrogeological framework for the Musgrave Province in the north-west of South Australia.

Local scale AEM data sets have been employed to develop hydrogeological conceptual models in support of a regional scale water resources assessment. The work has required the re-processing of historical AEM data sets, including those acquired by TEMPEST, HOISTEM and VTEM AEM systems. Co-incident data from several new AEM systems, including the new SkyTEM508 (a helicopter TDEM system) and the SPECTREM2000 (a fixed wing TDEM system) have also been acquired to inform options for further pre-competitive AEM data collection, supporting both mineral exploration and groundwater resource assessment in the region. In this paper, the contribution of airborne EM and regional magnetics in refining the conceptual hydrogeology for the Musgrave province is discussed.

HYDROGEOLOGY OF STUDY AREA

The Musgrave Province is a region of crystalline basement consisting mainly of the amphibolite and granulite facies gneisses intruded by mafic – ultramafic dykes and granitoids, and swarms of dolerite dykes. While basement outcrops as isolated hills and ranges much of it is covered by regolith. Surface flow across the area is limited to intense rainfall events and primarily confined to outcropping rock and to a limited number of channels that drain across adjacent flat country (Tewkesbury and Dodds 1997). Surface flow tends occur for a short period and over small stream sections based on the location and intensity of the rainfall event. Groundwater is present in the weathered and fractured

sections of the basement, in buried palaeovalleys filled with sands, silts and clays, and in calcretes and surficial sediments consisting of alluvial, fluvial and aeolian deposits (Watts and Berens 2011). Groundwater recharge is variable, and linked to episodic rainfall events. Work by Cresswell et al. (2002) indicated that immediately adjacent to the ranges it is relatively high (~30mm/yr), and lower elsewhere (1-10mm/yr). Groundwater salinity throughout the region is highly variable, ranging from 100 mg/L to >20 000 mg/L with higher salinities observed in sediments of the palaeovalleys.

The pre-Pliocene palaeovalley system, incised into Musgrave Province, is known to be present from limited exploratory drilling, and has been postulated to contain a significant groundwater resource (Dodds and Sampson, 2000). However, their geometry and extent remains largely hidden from view by a valley fill of Pliocene to Pleistocene sediments and overlying Quaternary sand dunes of the Great Victoria Desert (Lewis et al. 2010). Their evolution is postulated to be similar to that described for the palaeodrainage systems located on the margins of the Gawler Craton (see Hou et al. 2003).

GEOPHYSICAL DATA INTERPRETATION

A range of historical (5-12 years) and more contemporary (<5yrs) AEM data sets exist across the Musgrave Province, data that has been acquired as part of exploration activities. These data include time domain EM from TEMPEST, HOISTEM and VTEM systems. However, their distribution is varied, and of limited geographical extent. These data were inverted using a 1D layered earth inversion, specifically the the GA-LEI and AarhusInv (formerly EM1DINV) algorithms described in detail by Brodie (2012) and Auken et al. (2005) respectively.

Where present, the LEI inversions define a conductive palaeovalley fill, and detail a complex palaeo-drainage system. The palaeovalleys identified in the local scale AEM datasets, are coincident with broad lows that characterise the contemporary landscape (Figure 1). In this case we have used the terrain index – MrVBF (Gallant and Dowling 2003) on the 1sec SRTM elevation data to delimit contemporary valleys or low points in the landscape. MrVBF is a topographic index designed to identify areas of deposited material at a range of scales based on the observations that valley bottoms are low and flat relative to their surroundings and that large valley bottoms are flatter than smaller ones. The conductivity depth sections from the various AEM data sets show a complex, well defined and relatively narrow set of valleys which contrast with those depicted in the contemporary landscape. Nonetheless, the results suggest that the position of the broad low valley systems is a good starting point for locating the position of the deeper portions of the older valley system.

Examination of the palaeovalley system, as determined by the AEM data, against the regional magnetics (1ST Vertical Derivative) indicates that both lithology and structure exerted a significant influence the development of the palaeo-drainage system. The orientation of some of the defined valley systems follow major structures observed in the magnetics (Figure 2).

Calculation of the thickness of the conductive layer in the TEMPEST data set from the GA-LEI inversion, provides a good surrogate for regolith or valley fill thickness (Figure 3). This is aided by the palaeovalley sediments containing brackish-saline, and therefore conductive, groundwater. Subtracting the derived "regolith thickness" data from the contemporary elevation data provides aa good indication of how the landscape would have looked prior to it filling with sediment in the Pliocene to Pleistocene period (Figure 4). The derived surface for this part of the Musgrave Province indicates that the trunk drainage line has its headwaters in the Northern Territory. The surface also indicates a strong structural control on the development of the drainage system (see arrows for the Mann Fault).

The combined interpretation of the AEM and regional magnetics has contributed to the development of an updated hydorogeological conceptual model (Figure 5) and a framework for groundwater resource assessment.

CONCLUSIONS

An examination of historical AEM data sets over the Musgrave Province reveals a complex, extensive inset palaeovalley system which contains groundwater of variable quality (2000 - 20,000 mg/L TDS). If mineral resources were to be developed in the area, these systems would represent the best option for water supply, particularly in the absence of surface water resources. A review of available and more recently acquired AEM data sets indicates that most commercially available TDEM systems would effectively map the distribution of these palaeovalleys, although some may be better at defining variability associated with the sedimentary fill than others. In the absence of a greater regional AEM coverage, the results of this study indicate that a combination of the magnetics and the MrVBF product could be used to guide where to look for groundwater resources in the palaeovalley systems that dissect the region.

ACKNOWLEDGMENTS

The G-FLOWS Project is funded through the Goyder Institute. Andrew Fitzpatrick, Tania Abdat, Andrea Viezzoli and Yusen Ley-Cooper contributed to this study and their efforts are appreciated. AEM data sets were sourced from PepinNini Minerals Ltd and Colin Skidmore and Todd Williams are acknowledged for their help in this regard. Staffs of DMITRE and DEWNR are also thanked for their help in the conduct of the work.
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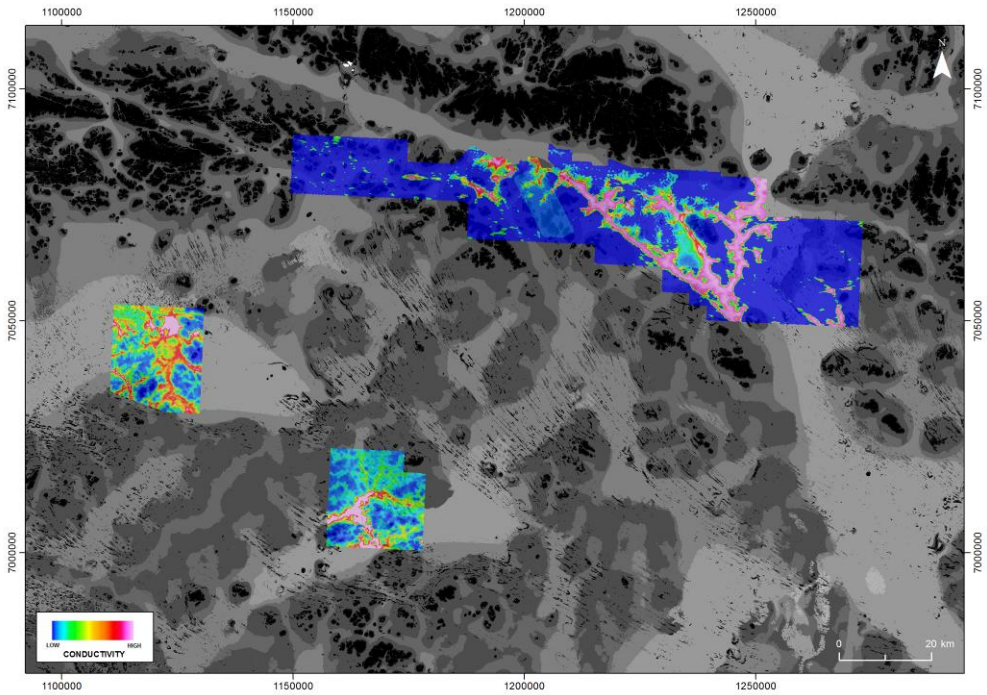

Figure 1. Conductivity-depth interval for 70m below ground level for TEMPEST (top) and HOISTEM (lower left) TDEM data sets superimposed on Terrain Flatness index (MrVBF).

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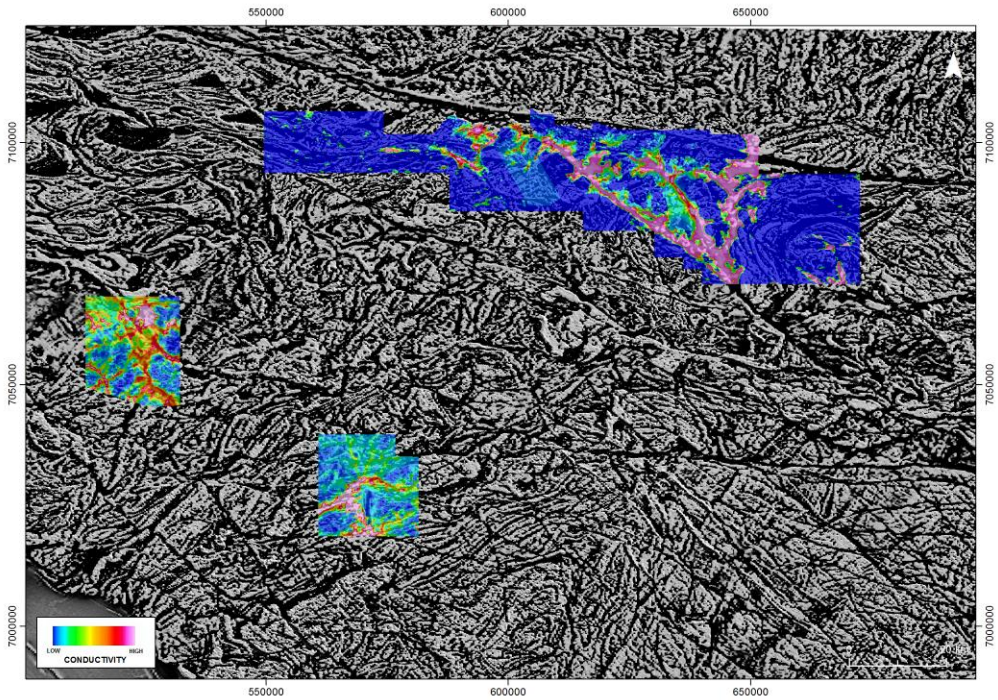

Figure 2. Conductivity-depth interval for 70m below ground level for TEMPEST (top) and HOISTEM (lower left) TDEM data sets superimposed an image of the 1st VD of the regional magnetics

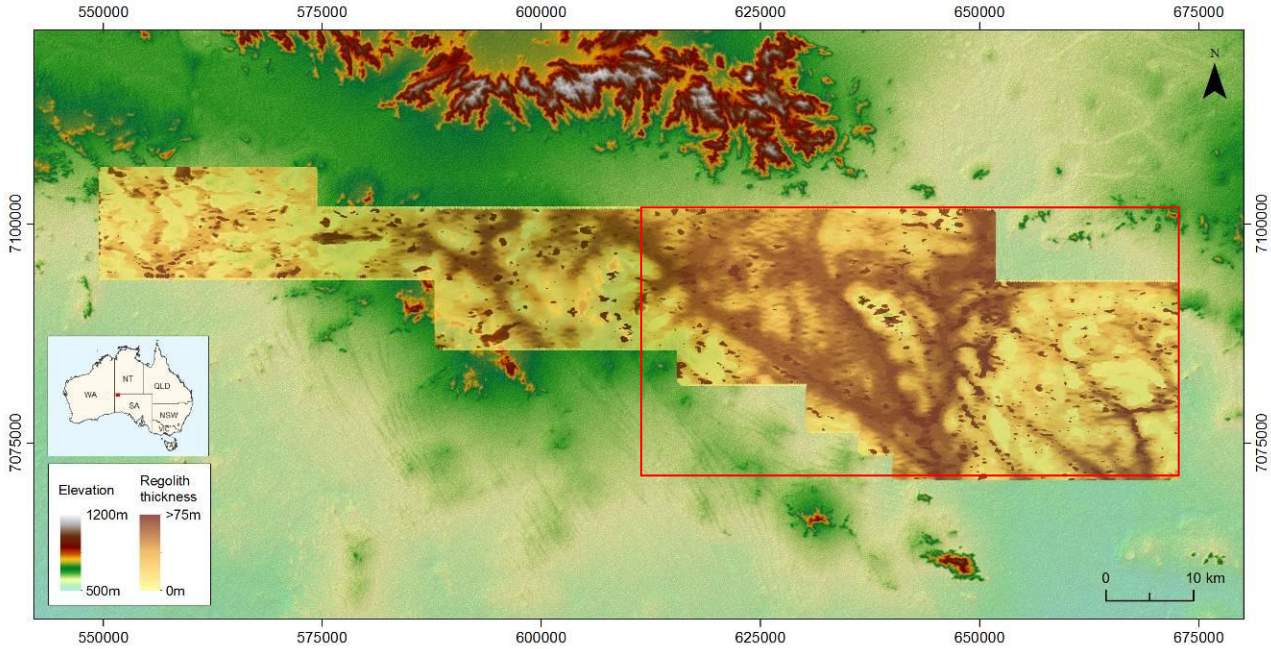

Figure 3. A map of regolith thickness superimposed on a DEM for the western part of the Musgrave Province. It reveals a complex palaeodrainage system filled with sediments beneath a sand cover. The thickness map was derived from a 1D LEI inversion of TEMPEST fixed-wing TDEM data. Area of red polygon is shown in Figure 2.

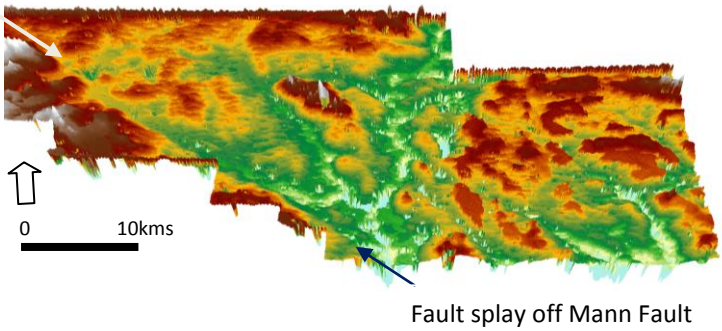

Figure 4. A perspective view (looking north) of basement topography for the area shown in the red polygon in Figure 1. The image shows a complex, deeply incised drainage system (valleys up to 120m deep) draining south from the Mann Ranges.

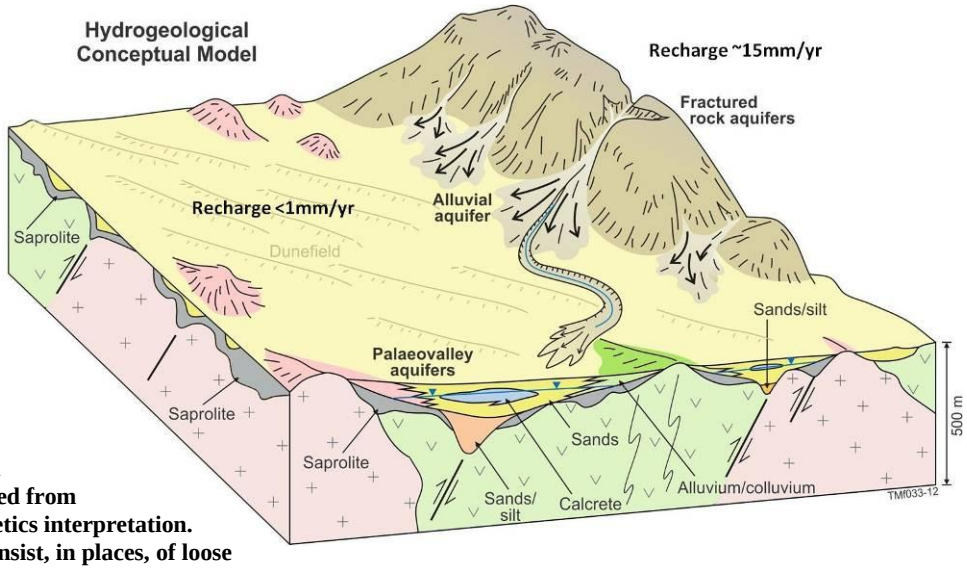

Figure 5. Hydrogeological conceptual model developed from AEM and airborne magnetics interpretation. Palaeovalley sediments consist, in places, of loose running sands, fine quartz sands to granule conglomerates (probably developed in braided stream systems similar to that seen today), fine- to medium-grained quartz sand, silt and minor clay, coarser-grained carbonaceous and lignitic sediments. Nodular calcretes are developed in many places. Some of these units have high transmissivities.