Using airborne electromagnetic data for regional stratigraphic and landscape evolution studies, Murray Basin, South Australia

Ian C. Roach

Continental Geophysics, Minerals and Natural Hazards Division,
Geoscience Australia, GPO Box 378, Canberra ACT 2601

Introduction

The $2.67 m Frome airborne electromagnetic (AEM) survey was flown between May and November 2010 as a joint survey between Geoscience Australia (GA), the Geological Survey of South Australia (PIRSA, now DMITRE) and industry partners. The survey includes 2.5 km and 5 km spaced east-west flight lines across the Murray Basin, Frome Embayment and Strzelecki Desert areas of South Australia (Figure 1) using the Fugro TEMPEST™ AEM system. The survey data were inverted using the Geoscience Australia Layered Earth Inversion (GA LEI; Brodie and Sambridge 2006) and a series of data products including grids and sections were produced. The wide line spacing allows data to be gridded with 500 m cell sizes, providing a regional view of electrical conductivity of the ground, but also provides along-line detail in conductivity sections, allowing detailed interpretations of the near-surface to a depth of up to 400 m where conductivity conditions are ideal. A detailed volume of interpretations and implications from the survey will be published in 2012 (Roach, in prep.). The survey was flown with the intention of reducing risk for mineral explorers by showing areas where uranium systems could be interpreted and where detailed AEM and ground EM surveys could be performed, but the data are also capable of being interpreted for groundwater, structural and landscape evolution studies, as discussed here.

The Murray Basin

The Murray Basin on the South Australian side of the SA-NSW border contains Tertiary terrestrial and marine sediments bounded in the west by the Neoproterozoic Adelaidean sequence and the Cambrian-Ordovician Kanmantoo Group and to the north by the Paleo-Mesoproterozoic Curnamona Province. In the central part of the Basin, Tertiary sediments overlie older Cretaceous sediments of the Berri Basin (including the Canegrass Lobe), Permian to Devonian sediments of the Nadda Basin/Renmark Trough and Proterozoic to Cambrian basement rocks (Scheibner and Basden, 1998; Fabris, 2003). Deposition of the terrestrial Renmark Formation of the Murray Basin commenced in the Middle Paleocene and continued more-or-less continuously to the Middle Eocene, at which point a hiatus occurred. This Middle Tertiary hiatus is mirrored in the Frome Embayment as the hiatus between the Paleogene Eyre Formation and the Neogene Namba Formation. Sedimentation continued after the hiatus with the marine transgression and deposition of the Murray Group to the seaward side, and continued sedimentation of the Renmark Group to the landward side, until a marine regression and a second major hiatus in the Late

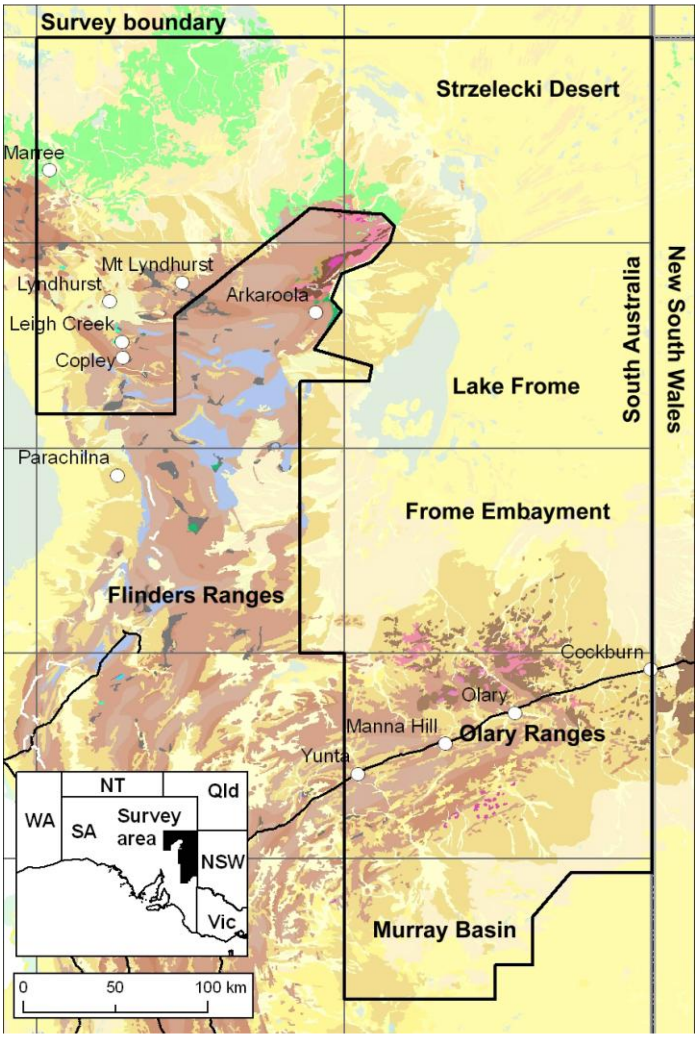

Figure 1: Location of the Frome AEM survey.

Miocene. A further marine transgression occurred after this hiatus, depositing the shelf muds of the Bookpurnong Formation and the coastal barrier beach sand units of the Loxton-Parilla Sands (Whitehouse *et al.*, 1999) and their contained heavy mineral sand deposits (Roy *et al.*, 2000). In the western Murray Basin, tectonic damming led to the formation of Lake Bungunnia (Firman, 1965; Stephenson, 1986; Bowler *et al.*, 2006) and the deposition of lacustrine sediments of the Blanchetown Clay and Bungunnia Limestone after the final marine regression.

Validating AEM data

Conductivity anomalies, their textures and patterns in AEM data are used to help map subsurface geology and groundwater. The typical electrical conductivities of geological units within a survey area are determined using independent induction conductivity logging and by collating quality data from other sources including minerals and groundwater investigations. For the Frome AEM survey, a literature review and an induction conductivity logging program were conducted within the Frome Embayment and Triassic coal measures at Leigh Creek to verify that results from the aircraft were accurate and repeatable and that the data inversion accurately reflected the true conductivity conditions within the ground. Once the aircraft data and inversion results were verified, conductivity values for geological units extracted from the inverted AEM data (Figure 2a) were used to aid geological interpretation of conductivity anomalies within the wider data set. A number of interpretation products were generated from the inversion data, including conductivity grids and conductivity sections. Conductivity sections were produced in two different colour stretches - logarithmic and linear – for comparison to highlight subtle differences in conductivity between horizontally layered sedimentary units (Figure 2b).

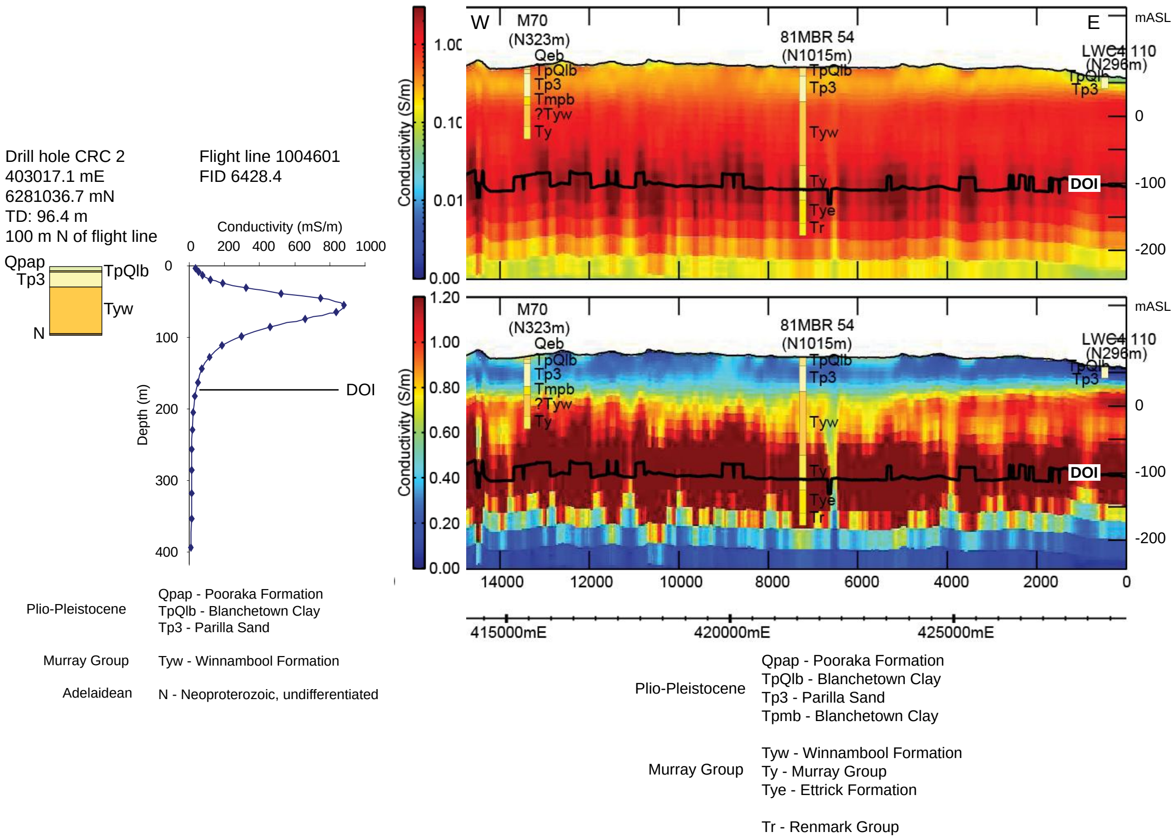

Figure 2a (left): An example inversion conductivity profile and corresponding drill hole stratigraphic profile showing resistive Blanchetown Clay and Parilla Formation over conductive Murray Group sediments and resistive Neoproterozoic basement; **b (right):** An example of drill hole stratigraphy plotted on logarithmic (top) and linear (bottom) colour-stretched conductivity sections, Line 1004501. Murray Group sediments are variably conductive, with the moderately conductive Winnambool Formation thickening to the east over highly conductive undifferentiated Murray Group and Ettrick Formation. The distance between the drill hole and the flight line is shown for each, e.g., N1015m, meaning the drill hole occurs 1015 metres north of the flight line. DOI – Depth Of Investigation - defines calculated reliable depth of conductivity results.

Groundwater salinity within the AEM survey area is variable, from fresh to high (≤ 12 000 mg/L TDS; Fabris, 2003), but is not uniformly distributed, altering the depth of reliable AEM signal penetration (Depth Of Investigation – DOI) and adding further complexity to the interpretation.

Mapping geology with geophysics

The surface geology of the northwestern Murray Basin may seem relatively bland, but it is actually a dynamic system dominated by aeolian, colluvial and fluvial regolith processes, neotectonic activity and weathering. The most obvious features in the landscape are large alluvial fans draining the Nackara Arc, visible in the radiometric imagery (particularly the Manunda Creek and Olary Creek fans), and well-developed fault scarps produced by surface-rupturing faults visible in digital elevation models (DEMs), particularly those close to the range front including the Anabama-Redan Fault Zone and the Morgan Fault. These large-scale features are visible in the gridded AEM data as abrupt conductivity contrasts, particularly the large range-bounding faults separating the Nackara Arc from the Murray Basin (Figure 3). Other detail is visible in the conductance image including conductive units in the Neoproterozoic rocks of the Nackara Arc (the Saddleworth Formation in the Burra Group), a palaeovalley associated with the Olary Creek and bedrock features underneath the Murray Basin including a bedrock high in the south of the image.

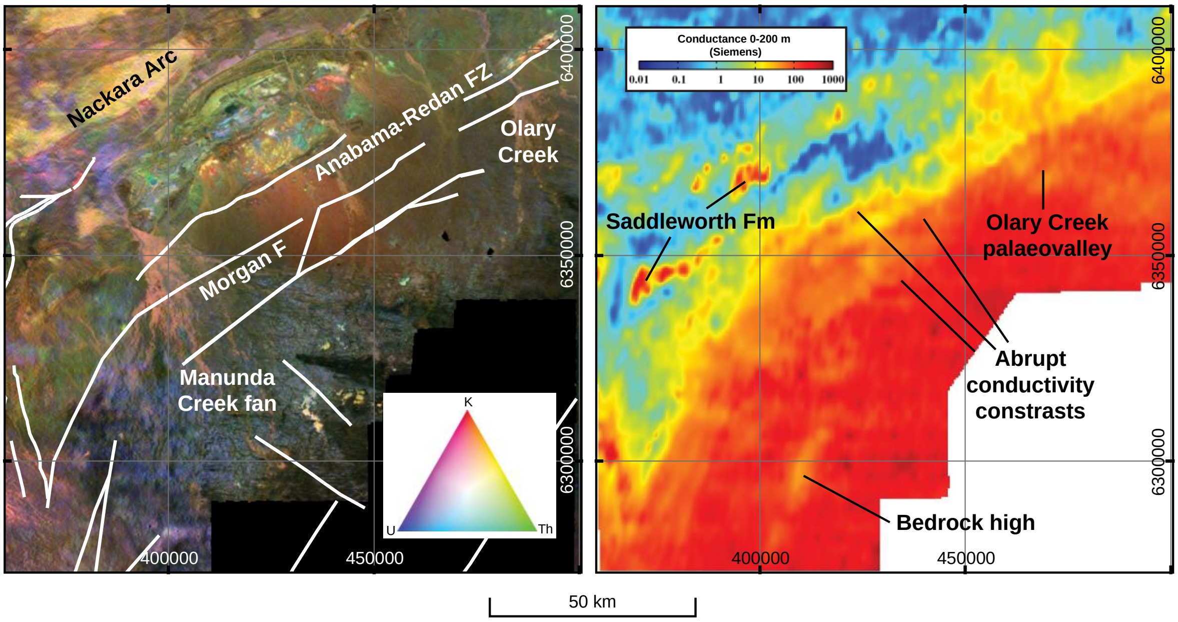

Figure 3: Ternary radiometric (left) and 0-200 m conductance image (right) of the Nackara Arc and Murray Basin. The radiometric image includes mapped faults (from SARIG, 2011) and geographical features. The conductance image depicts the summed conductivity of the Frome AEM data set for the top 200 m of the inversion.

While the conductance image (Figure 3) and depth slices give a regional overview of the correlation between conductivity and geology, conductivity sections such as that shown in Figure 2b offer far more along-line detail allowing 2D and 3D detailed interpretations of local stratigraphy to be made from the AEM data set. Figure 4 illustrates a 3D model constructed using conductivity sections and grids to demonstrate the relationship between Murray Basin sediments and the underlying resistive basement rocks, in this case a mixture of Proterozoic Nackara Arc rocks and Phanerozoic Kanmantoo Group rocks. The model highlights a number of modern valley and palaeovalley systems as well as sharp offsets in the conductivity anomalies associated with sedimentary packages on conductivity sections, indicating the presence of range-bounding faults. These offsets indicate that some fault movement has occurred after the deposition of the Murray Group, and with more detailed investigation, may show further Pleistocene movement.

Conclusions

The Frome AEM data set is an immensely useful tool for mineral and groundwater search (for which it was originally intended), but also for developing more detailed 3D landscape evolution models of regions. The data are capable of interpretation for far more than just palaeovalley mapping, but can be used to map surfaces defining sediment packages and unconformities, provided adequate drill hole control is available. The data are freely available to the public (download from http://www.ga.gov.au/energy/projects/airborne-electromagnetics.html#) and are capable of revealing a great deal more information than has been shown in this short article.

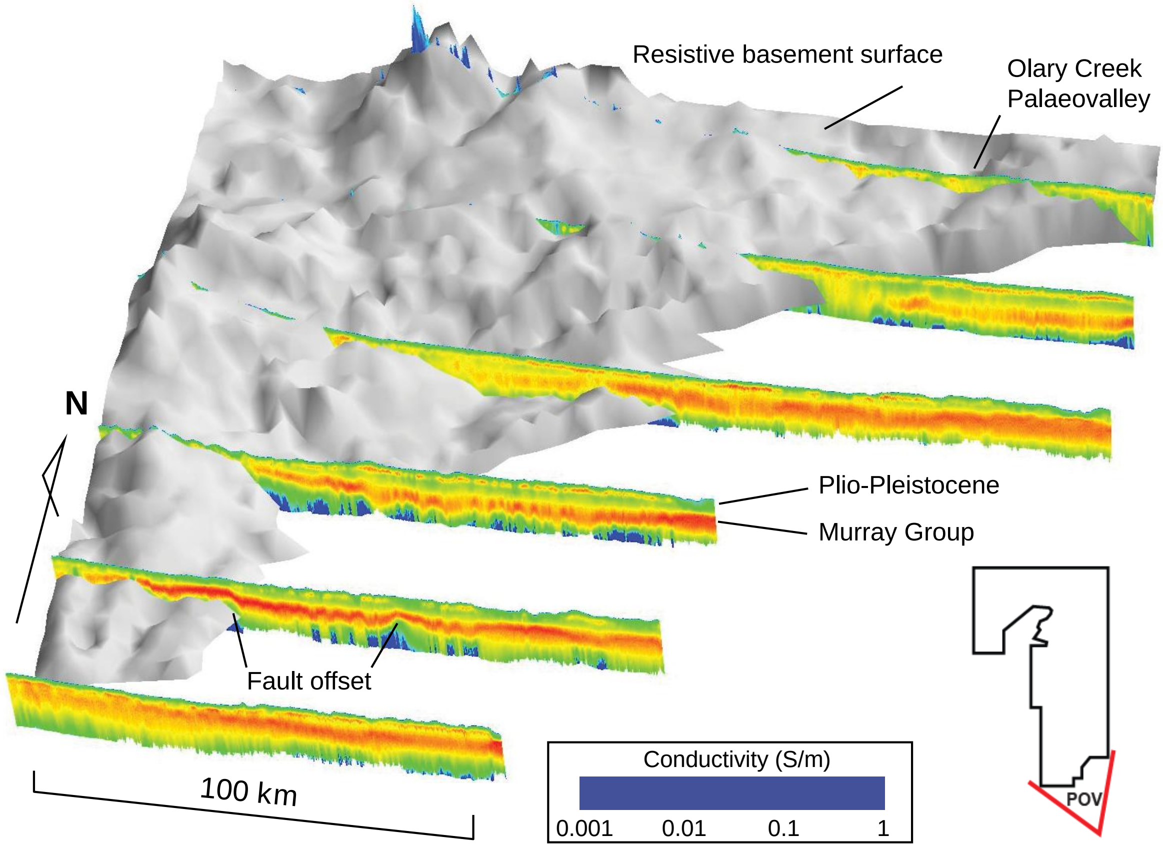

Figure 4: A 3D model of the resistive basement underneath the Murray Basin showing conductivity sections of every 10th flight line used to develop the model. The resistive basement includes Proterozoic and Phanerozoic rocks of the Nackara Arc and Kanmantoo Group. Relatively resistive Plio-Pleistocene sediments of the Blanchetown Clay and Parilla Sands overlie conductive Murray Group sediments and finally relatively resistive Renmark Group sediments. The resistive basement model extends downwards to the DOI of each individual conductivity section used to make the model, a depth of about 200 m in this case. Fault lines are not shown in this model.

Acknowledgements

Survey partners DMITRE and Callabonna Uranium Ltd.; reviewers Marina Costelloe, Murray Richardson and Matilda Thomas; the rest of the Frome AEM team at GA: Ross Brodie, David Hutchinson and Subhash Jaireth.

References

Bowler J. M., Kotsonis A. and Lawrence C. R. 2006. Environmental evolution of the Mallee region, western Murray Basin. *Proceedings of the Royal Society of Victoria* **118(2)**, 161-210.

Brodie R. and Sambridge M. 2006. A holistic approach to inversion of frequency domain airborne EM data. *Geophysics* **71**, G301-313.

Fabris A. J. 2003. North-western Murray Basin geological synthesis, South Australia. South Australia, Department of Primary Industries and Resources. 81 pp.

Firman J. B. 1965. Late Cainozoic lacustrine deposits in the Murray Basin, South Australia. Geological Survey of Australia: *Quarterly Geological Notes* **16**, 1-2.

Munday T. J., Hill, A. J., Wilson, T., Hopkins, B., Teler, A. L., White, G. J. and Green, A. A. 2004. Combining geology and geophysics to develop a hydrogeologic framework for salt interception in the Loxton Sands aquifer, central Murray Basin, Australia. **CRC LEME Open File Report 180/CSIRO Exploration and Mining Report P2004/86**, 20 pp.

Roach I.C. ed. in prep. The Frome airborne electromagnetic survey, South Australia: implications for energy, minerals and regional geology. Geoscience Australia/Geological Survey of South Australia, record.

Roy P. S., Whitehouse J., Cowell P. J. and Oakes G. 2000. Mineral Sands Occurrences in the Murray Basin, Southeastern Australia. *Economic Geology* **95(5)**, 1107-1128.

SARIG 2011. South Australia Resource Information Geoserver. Online: https://sarig.pir.sa.gov.au/Map.

Scheibner E. and Basden H. (editors) 1998. Geology of New South Wales - Synthesis. Volume 2 Geological Evolution. Geological Survey of New South Wales, *Memoir*. **Geology 13(2)**, 666 pp.

Stephenson A. E. 1986. Lake Bungunnia – A Plio-Pleistocene megalake in southern Australia. *Palaeogeography, Palaeoclimatology, Palaeoecology* **57(2-4)**, 137-156.

Whitehouse J., Roy P. S. and Oakes G. M.,Stewart, J. R. (editors) 1999. Mineral sand resource potential of the Murray Basin. Geological Survey of New South Wales Department of Mineral Resources. **Geological Survey Report GS 1999/038**, 74 pp.