The Frome airborne electromagnetic survey, South Australia

**Ian C. Roach**
*Onshore Energy and Minerals Division*
*Geoscience Australia*
*GPO Box 378*
*Canberra ACT 2601*
*Australia*
*Ian.Roach@ga.gov.au*

## SUMMARY

The Frome airborne electromagnetic (AEM) survey is the largest of three regional AEM surveys flown under the 5-year Onshore Energy Security Program (OESP) by Geoscience Australia (GA). The aim of the survey is to reduce risk and stimulate exploration investment for uranium by providing reliable pre-competitive data. The Frome AEM survey was flown between 22 May and 2 November 2010, is approximately 95 450 km$^2$ in area and collected 32 317 line km of new data at an average flying height of 100 m. The Frome AEM survey covers the Marree (pt), Callabonna (pt), Copley (pt), Frome (pt), Parachilna (pt), Curnamona, Olary and Chowilla (pt) 1:250 000 standard map sheets in South Australia and was flown largely at 2.5 km line spacing, with the northern portion flown at 5 km line spacing. GA partnered with, the Department of Primary Industries and Resources South Australia and an industry consortium.

The survey results indicate a depth of investigation (DOI - depth of reliable signal penetration) of up to 400 m in areas of thin cover and resistive basement (e.g., Adelaidean rocks in the Olary Ranges). In Cenozoic – Mesozoic sediments in the Frome Embayment and the Murray Basin the DOI is up to 100-150 m. A range of under-cover features are revealed, including (but not limited to): extensions to known palaeovalley networks in the Frome Embayment; the under-cover extent of the Benagerie Ridge; regional faults in the Frome Embayment and Murray Basin; folded and faulted Neoproterozoic rocks in the Adelaide Fold Belt; Cenozoic – Mesozoic stratigraphy in the Frome Embayment; neotectonic offsets in the Lake Eyre Basin; conductive Neoproterozoic rocks associated with copper-gold mineralisation; and, coal-bearing structures in the Leigh Creek area, as well as groundwater features.

**Key words:** airborne electromagnetics, Frome Embayment, Murray Basin, uranium, groundwater

## INTRODUCTION

The Frome airborne electromagnetic (AEM) survey (Figure 1) is the largest survey by area flown in Australia and is the last of three regional AEM surveys flown under the 5-year Onshore Energy Security Program (OESP) by Geoscience Australia (GA). The previous OESP surveys were the 47 600 km$^2$ Paterson survey (Roach, 2010) and the 73 700 km$^2$ Pine Creek survey (Craig, 2011). The aim of the survey is to reduce risk and stimulate exploration investment for uranium and other minerals by providing reliable pre-competitive data to the minerals industry, state and federal governments, as well as to stimulate exploration for groundwater resources.

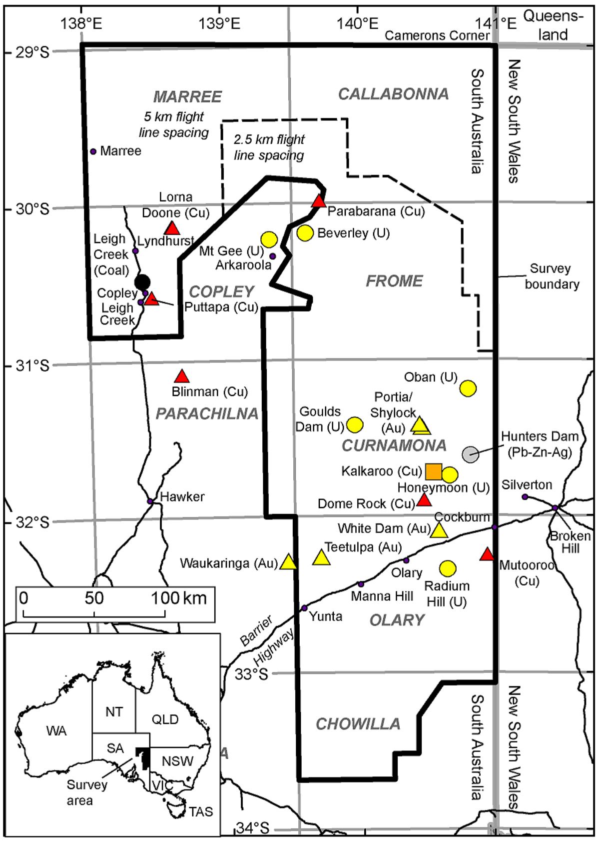


**Figure 1. Location map of the Frome AEM survey showing the principal settlements, 1:250 000 map sheet names, flight line spacing and principal mineral deposits.**

The Frome AEM survey was flown between 22 May and 2 November 2010 using the Fugro Airborne Surveys Pty. Ltd. TEMPEST$^{TM}$ time-domain electromagnetic (TEM) and magnetic data acquisition system. The survey is approximately 95 450 km$^2$ in area and 32 317 line km of new data were collected at an average flying height of 100 m. Geoscience Australia partnered with the Department of Primary Industries and Resources South Australia (PIRSA) and an industry consortium to infill areas of high strategic importance for uranium exploration. The survey was flown in conjunction with the Cariewerloo Basin AEM survey using the same aircraft and survey parameters.(Wilson, *et al.*, 2011)

## DATA PROCESSING AND VALIDATION

Aircraft data were validated at Geoscience Australia in a series of tests for drift, noise, sferics and powerline interference as well as system geometry to ensure the data met standards defined in GA's deed of standing offer for airborne geophysical data acquisition. Once data passed validation, they were released in two phases: Phase 1 being the contractor-delivered data including an EM Flow™ fast approximate inversion; and, Phase 2 being the GA value-added products. Phase 2 data were inverted using the Geoscience Australia layered earth inversion (GA-LEI) algorithm (Brodie, 2010; Brodie and Sambridge, 2006). Two inversions were run on the data set: a sample-by-sample (SBS) inversion of the whole data set; and, a line-by-line (LBL) inversion of the data set excluding the southern portion comprising the Olary Ranges and the Murray Basin, because the LBL inversion could not fit a horizontal conductivity model to the complex geology in these areas. The SBS inversion enhances vertical conductivity contrasts within the data, whereas the LBL inversion enhances horizontal features and is particularly useful in the Cenozoic stratigraphy of the Frome Embayment area. Together, they represent a powerful way to present and interpret AEM data as an adjunct to commercially-available software packages. Once inverted, a series of value-added products were created from the data including:

- ASCII point-located data;
- PDF format multiplots of each survey line;
- Geolocated JPEG images of each survey line for both inversions (for easy display in a GIS);
- GOCAD™ triangulated surfaces of each survey line for both inversions;
- ER Mapper™ format gridded data (depth slices, elevation slices, conductance and depth of investigation);
- Geolocated JPEG images of gridded data (depth slices, elevation slices, conductance and depth of investigation); and,
- Ancillary data including ArcGIS shape files, metadata and explanatory notes.

Phase 2 data were validated to test whether the inversions were geologically realistic. Geological validation of the AEM data is complex and requires the use of many additional data sets including: detailed down hole geological logs of stratigraphic and mineral exploration drill holes; reliable down hole induction conductivity logs throughout the survey area; other reliable company-derived down hole geophysical logs (conductivity, resistivity, gamma, prompt fission neutron – PFN); detailed surface geological and regolith-landform mapping; airborne magnetics and radiometrics; and, high-resolution company AEM data sets (public domain and commercial in confidence). Geoscience Australia conducted a campaign of induction conductivity logging during August-September 2010 in order to obtain the highest quality, calibrated data to assess company data from the same areas in order to test the inversion process and determine the reliability of the company data.

## RESULTS

The wide flight line spacing and long flight lines give a regional overview of the geology of the survey area, together with along-line detail. What is immediately apparent is the overall moderate to high conductivity of the low-relief, saline, parts of the survey area, especially around Lake Frome, Lake Blanche and Lake Callabonna and their connecting channels (Figure 2). Here signal penetration is estimated to be as low as about 50 m, as shown in the gridded depth of investigation (DOI) image (Figure 3). Surprisingly, good penetration is achieved in the Strzelecki Desert towards Camerons Corner and Marree, between 150 and 200 m in places, highlighting a number of Cenozoic drainage channels that emptied into the Lake Eyre Basin from the incipient Flinders Ranges. Good conductivity contrasts are noted where weakly to moderately conductive Cenozoic sediments (the Namba and Eyre formations) are incised into moderately to highly conductive Mesozoic sediments of the Marree Subgroup, which includes the Bulldog Shale, and underlying Mesozoic formations.

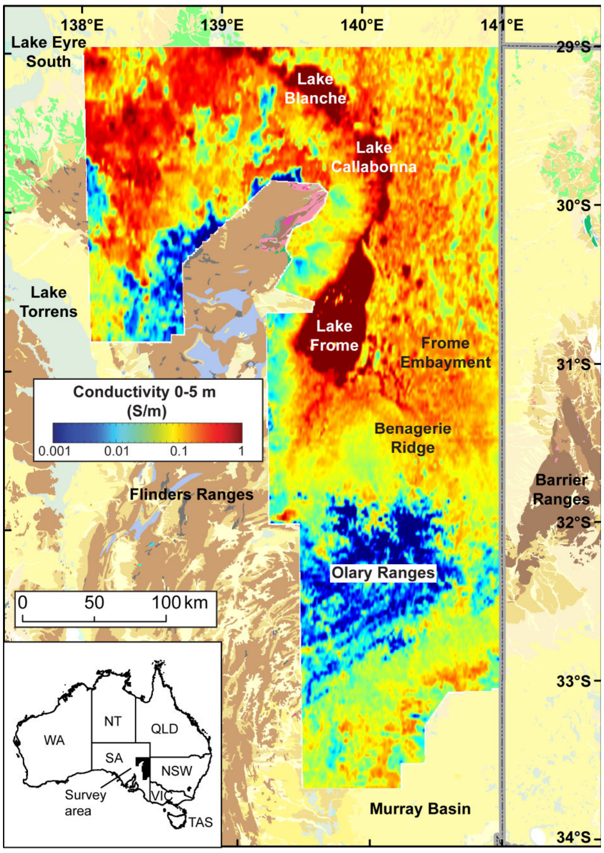


**Figure 2. 0-5 m conductivity depth slice of the Frome AEM survey overlain on the GA 1:1 million scale Surface Geology of Australia Map (Raymond and Retter, 2010).**

Signal penetration of up to 400 m is achieved in areas where resistive bedrocks of the Paleo- to Mesoproterozoic Curnamona Province and the Neoproterozoic Adelaide Geosyncline outcrop or lie under thin cover. These areas occur around the flanks of the Flinders Ranges in the north west of the survey area, and most particularly in the Olary Ranges separating the Frome Embayment from the Murray Basin in the south of the survey area. A number of conductive bedrock units occur, most particularly the Neoproterozoic Tapley Hill Formation, as well as discrete conductors within the Paleo- to Mesoproterozoic Curnamona Province rocks.

In Cenozoic sediments in the Frome Embayment the DOI is up to 200 m, allowing the upper part of the highly prospective Benagerie Ridge to be imaged. The data reveal a range of resistive and conductive rocks in this part of the Curnamona Province and broad conductivity anomalies correspond to features mapped within gravity and magnetic imagery. In the Murray Basin the DOI is between 100 and 150 m, revealing new data on the palaeotopography and neotectonics of the Basin. The data are also revealing: extensions to known palaeovalley networks in the Frome Embayment; palaeovalley systems in the Murray Basin; regional faults in the Frome Embayment and Murray Basin; folded and faulted Neoproterozoic rocks in the Adelaide Fold Belt; Cenozoic – Mesozoic stratigraphy in the Frome Embayment; neotectonic offsets in the Lake Eyre Basin; conductive Neoproterozoic rocks associated with copper-gold mineralisation; and, coal-bearing structures in the Leigh Creek area, as well as groundwater features around the Flinders Ranges and within the Murray Basin.

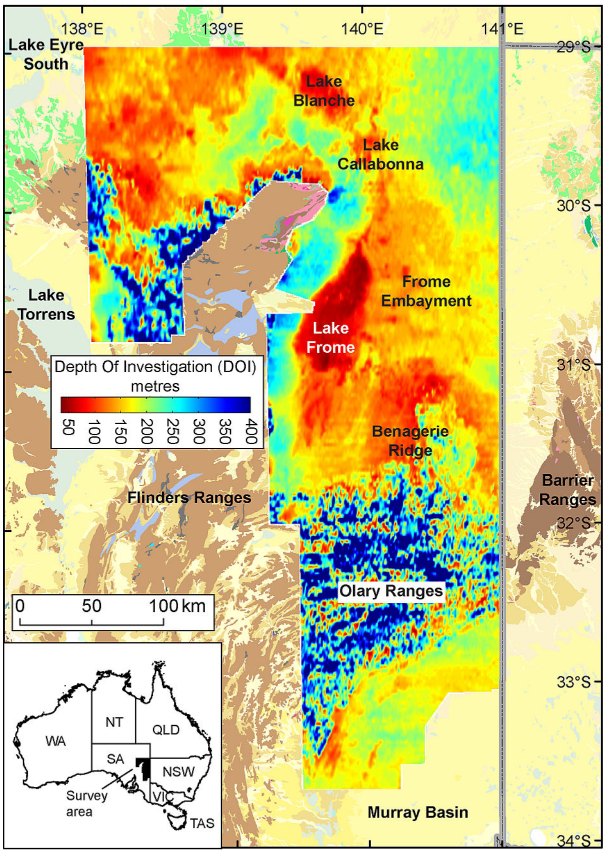


**Figure 3. Depth Of Investigation (DOI) image for the Frome AEM survey. Methodology is after Christiansen and Auken (2010) described in Hutchinson *et al.* (2011).**

## CONCLUSIONS

The Frome AEM survey reveals new information about the mineral potential, groundwater resources and geological history of the region. The survey will help reduce risk for the minerals and groundwater industries by highlighting areas of conductive cover, where future EM surveys may not be appropriate, and saline groundwater which is not suitable for exploitation. An interpretation record, due for release in 2012, will highlight the potential of the Frome AEM survey, and regional AEM surveying in general, for better depth to target information and cover thickness mapping for the development of under-cover resources at explorable depths.

## ACKNOWLEDGMENTS

The AEM team at GA, who helped make this survey a success, include Ross Brodie, Marina Costelloe, David Hutchinson, Subhash Jaireth, Richard Lane, Nick Williams and Alan Whitaker. Additional thanks for help with geological interpretations go to colleagues at PIRSA including Tania Dhu, Adrian Fabris, Claire Fricke, Steve Hore, Bernd Michaelsen and Tania Wilson, and, at the University of Adelaide, Steve Hill. Marina Costelloe and Murray Richardson are thanked for their thoughtful reviews of this document.

## REFERENCES

Brodie, R., 2010, Holistic Inversion of Airborne Electromagnetic Data: PhD thesis, Research School of Earth Sciences, Australian National University, Canberra.

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

Christiansen, A. and Auken, E., 2010, A global measure for depth of investigation in EM and DC modelling: ASEG Conference 2010, Australian Society of Exploration Geophysicists, Extended Abstracts.

Craig, M.A. (ed), 2011, Geological and energy implications of the Pine Creek region airborne electromagnetic (AEM) survey, Northern Territory, Australia: Geoscience Australia, Canberra, Geoscience Australia Record 2011/18.

Hutchinson, D.K., Brodie, R.C. and Costelloe, M.T., 2011, Frome Embayment TEMPEST™ AEM Survey: Inversion Report: Geoscience Australia, Canberra, GEOCAT #72589, 57 pp.

Raymond, O.L. and Retter, A.J., 2010, Surface geology of Australia 1:1 000 000 scale, 2010 edn: Geoscience Australia, Canberra, Online: http://www.ga.gov.au/mapconnect/.

Roach, I.C. (ed), 2010, Geological and energy implications of the Paterson Province airborne electromagnetic (AEM) survey, Western Australia: Geoscience Australia, Canberra, Geoscience Australia Record 2010/12, 318 pp, Online: http://www.ga.gov.au/image_cache/GA18513.pdf.

Wilson, T., Bosman, S., Heath, P., Gouthas, G., Cowley, W., Mauger, A., Gordon, G., Baker, A., Dhu, T., Fairclough, M., Delaney, G., Roach, I., Hutchinson, D. and Costelloe, M., 2011, What is in the data release for the Cariewerloo Basin: the potential for unconformity-related uranium mineralisation in South Australia: Unlocking SA's mineral wealth technical forum, Adelaide, Primary Industries and Resources South Australia, 21-22.