New government geophysics from the Onshore Energy Security Program

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SUMMARY

As part of the recently completed Onshore Energy Security Program, Geoscience Australia has delivered new types of pre-competitive data to as well as the more familiar government pre-competitive data types such as aeromagnetics. These new data provide industry with additional information for assessing the geological prospectivity of a region and making targeting decisions.

The visionary AWAGS continental airborne magnetic and radiometric survey enabled the first ever national merging of all radiometric surveys to produce the Radiometric Map of Australia. The rigorously calibrated data supports quantitative normalisation of uranium anomalies against rock-type, and hence identification of zones of uranium enrichment, at either a prospect or regional scale.

Geoscience Australia also undertook three large AEM surveys (>50,000km2) to map regional scale geological structures important for uranium deposition. These surveys were effective in imaging depth of regolith, geological unconformities, shale units and fault zones. Often these features are not apparent in regional magnetic or gravity data.

MT data are now acquired along all deep crustal seismic transects to image the deep conductivity structure. These data are highly complementary to the structural information interpreted from the seismic sections. MT can also detect conductivity features in the non-reflective crust below the Moho.

Key words: pre-competitive, radiometrics, magnetotellurics, airborne electromagnetics, geological mapping

INTRODUCTION

Precompetitive geophysics collected by State and Commonwealth Governments is a bread-and-butter input for the minerals exploration industry in Australia (Stolz, 2009). The value of magnetic and gravity data are well accepted, and deep crustal seismic surveys have driven new regional geology interpretations. Australia has achieved world's best practise with coverage, quality and delivery of these important datasets.

The recently completed Onshore Energy Security Program was the latest major data acquisition initiative delivered by Geoscience Australia. The five year program aimed to encourage exploration for hydrocarbon, uranium and geothermal energy systems. A variety of data, derived products, conceptual models and interpretation reports were produced at both the continental and regional scale.

In addition to major expenditure on magnetic, gravity and deep crustal seismic surveys, the program also acquired new types of precompetitive geophysical data not previously collected by Australian governments. These included a continental-scale airborne radiometric survey, airborne electromagnetic (AEM) surveys and acquisition of magneto-telluric (MT) data. These data types provide new information for industry geologists, allowing them to:

- Map geology through surface cover which other geophysical methods cannot penetrate
- Map contrasts that are not detected with other data
- Produce quantitative rather than just qualitative interpretations
- Integrate a range of data to create more robust and better quality geological interpretations
- Make more informed exploration decisions

The resource exploration industry has enthusiastically engaged with all the new outputs generated by the Onshore Energy Security Program. This paper will introduce some of the new types of data, demonstrate how they can be applied to geological mapping and exploration targeting, and show how they complement other government datasets.

Radiometric Map of Australia

Geoscience Australia and State Government Geological Surveys have been collecting airborne radiometric data for the past 40 years. These data are normally acquired simultaneously with aeromagnetics, and the surveys have employed a wide variety of flying heights, sensor types and calibration datum. The variations between surveys present major difficulties to geophysicists attempting to merge data into consistent regional scale images. National and regional scale aeromagnetic images have been available to industry for many years and are an essential tool for regional geological assessments.

The AWAGS (Australia Wide Geophysical Survey) was flown in 2007 and acquired airborne radiometric and magnetic data on 75km spaced north-south lines and 400km spaced tie lines spanning the entire Australian Continent and Tasmania. This is the first time an entire continent has been covered by a single geophysical survey.

The AWAGS data provide a set of tie lines for levelling of all existing and future airborne radiometric surveys. This facilitated merging hundreds of individual surveys into single nation-wide grids of potassium, uranium, and thorium concentrations. A full description of AWAGS and the creation of the Radiometric Map of Australia are presented in Minty et al (2009).

Figure 1 shows an example of quantitative analysis of regional scale radiometric data applied to uranium targeting in the Mt Isa region (Wilford et al, 2009). The uranium concentration grid was overlain with the digital geology map (Raymond, 2009) in a GIS platform to calculate the average uranium concentrations within the mapped geological units. An image was created showing grid cells where the uranium value is greater than the average value for the geological unit at that location. This image maps zones of uranium enrichment relative to the expected concentrations for that rock type.

In particular, there is a section of undulating topography in the centre of the image with elevated uranium values. A regolith unit in the drainage channel shedding off this section towards the west is also clearly enriched in uranium and may warrant ground follow-up. Similar regolith units in drainage channels shedding from other rocks are not anomalous. The quantitative analysis made possible by the levelling and calibration of regional radiometrics supports the more sophisticated and scientifically rigorous selection of uranium exploration targets.

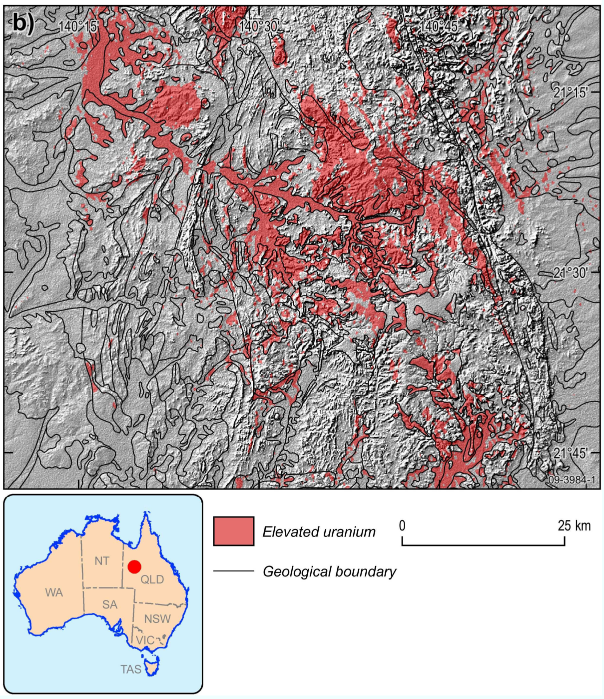

Figure 1. Elevated uranium values in the southern Mt Isa region relative to average background values calculated for mapped geological units. Uranium values are displayed over the greyscale image of topography. Black lines show the boundaries of geological units. (After Wilford et al, 2009)

Airborne Electromagnetic Surveys

Airborne electromagnetic (AEM) surveys have previously been flown in Australia over small (<1000km^2) areas for direct detection of massive sulphide deposits. Under the Onshore Energy Security Program, Geoscience Australia demonstrated the use of AEM as a regional geological mapping tool by completing three large scale (>50,000km^2) AEM surveys over regions considered prospective for uranium.

The AEM method images the conductivity structure of the subsurface to depths about 400m, making it very suitable for mapping geology down to explorable depths over wide areas. AEM is also effective at mapping horizontal contrasts in the earth and is thus useful for mapping sedimentary basins, whereas other methods such as magnetics are more suited to detecting vertical contrasts.

The AEM survey data were converted to conductivity-depth sections, depth slices and conductance images. These were calibrated against borehole conductivity logging and then analysed in combination with other geological and geophysical information to produce integrated geological interpretations and assessments of uranium prospectivity. Results showed that AEM data were effective at mapping regolith (cover), saline groundwater (including seawater intrusion) paleo-channels, geological unconformities, shales and fault zones (Craig, 2011).

Results from the Rum Jungle and Woolner Granite AEM surveys flown in 2008 over the Pine Creek region in the Northern Territory are presented in Figure 2. The two surveys were acquired using the Fugro TEMPEST^{TM} AEM system with line spacings of between 500m and 5000m. Note the vast area of the surveys which cover nearly 250km by 250km. This allows regional scale geological structures to be mapped over long distances.

The lower panel of Figure 2 shows the 0-400m conductance image derived AEM surveys while the upper panel shows a reduced to the pole magnetic image for the same area. The magnetic and conductance images define curvilinear features in the central and eastern parts of the survey area. These are attributed to steeply dipping Proterozoic meta-sedimentary rocks surrounding granite plutons (Craig, 2011). However, there are very few anomalies in the southern section of the magnetic image. This is attributed to a lack of magnetic contrast in this area and flat-lying geology. The conductance image in this area shows several well defined features. The extent of the Paleozoic Daly Basin is defined by a zone of moderate conductance, and south-east trending anomalies may indicate structures within the basin. The ability of AEM to map geological features with no expression in magnetic or gravity makes it a complementary addition to the explorer's pre-competitive data toolkit.

Magnetotelluric Surveys

Deep-crustal seismic reflection transects undertaken by Geoscience Australia over four decades have greatly added to the knowledge of the deep structure of the Australian continent and its contained mineral and energy resources. Seismic surveys were a major component of the Onshore Energy Security Program. These surveys spanned hundreds of kilometres and detected structures at depths of up to 60km, allowing regional scale interpretation of the full crustal lithosphere (Figure 3).

Geoscience Australia also collected magnetotelluric (MT) data along these seismic transects. MT uses variations in the Earth's natural magnetic and electric fields due to lightning strikes and solar activity to make a sounding of the conductivity structure of the crust (Vozoff, 1991). Broadband MT measurements (100Hz to 0.001Hz) were acquired at 5 or 10 km intervals along the seismic transects while long period MT measurements (1Hz to 0.0001Hz) were collected at 20km or 50km station spacing. A detailed description of MT data acquisition, processing and modelling at Geoscience Australia is presented in Korsch and Kositcin (2010) and Milligan and Lilley (2010).

Figure 3 presents data from the Gawler – Officer – Musgrave – Amadeus seismic traverse in northern South Australia. These data were acquired in 2008 in a collaborative project between Geoscience Australia, AuScope Earth Imaging, Primary Industry and Resources South Australia, and the Northern Territory Geological Survey. Reflection seismic and broadband and long period MT were recorded over a 634km south-north traverse from the northern Gawler Craton, across the eastern Officer Basin and eastern Musgrave Province and finishing in the Amadeus Basin in the Northern Territory (Korsch and Kositcin, 2010).

The seismic section defines four major fault zones in the southern half of the transect: the Cedric Bore Fault (CBF), the Karari Shear Zone (KSZ), the Horse Camp Fault (HCF) and the Box Hole Creek Fault (BHCF). All of these faults are also associated with discontinuities in the 2D conductivity model derived from the MT data, suggesting they constitute significant lithological boundaries. In particular, the Karari Shear Zone has a coincident north-dipping conductivity high which extends to the deep crust (40-60km). The elevated conductivity may be attributed to rocks in the vicinity of the fault being altered by fluids percolating from the deep crust or upper mantle. The MT may be imaging a deep fluid alteration system at a major crustal boundary, suggesting the area could be prospective for iron-oxide-copper-gold deposits. Large conductivity anomalies have also been detected at depth beneath the giant Olympic Dam copper-gold-uranium mine (Heinson et al, 2006).

The Moho layer is evident on the southern end of the seismic sections as the boundary between an upper reflective zone and a lower non-reflective zone at about 16s TWT (~50km). The lithospheric mantle beneath the Moho is typically non-reflective because rocks at these pressures and temperatures are seismically homogenous, limiting the usefulness of seismic at these depths. By analysing the long-period MT data, however, it is possible to model the conductivity structure to depths of several hundred kilometres.

The conductivity model in Figure 3 shows the deep crust and mantle becoming progressively more conductive from north to south, with a large conductivity high at the southern end at a depth of 120km. Variations in the lithospheric mantle may hold clues to metal enrichment in overlying geological provinces (Spratt et al 2009) and also provide information for geodynamic interpretations of the overlying crust. MT data is likely to become increasingly important as more geologists and explorers become interested in the deep earth.

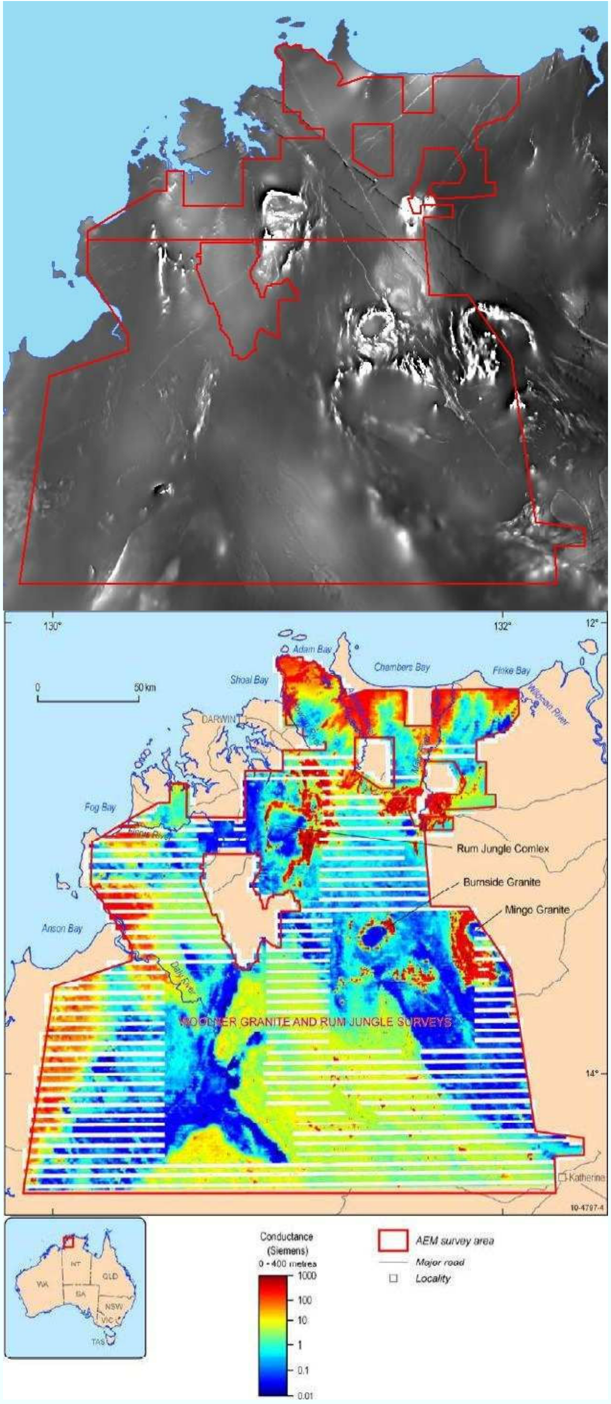

Figure 2. Reduced-to-the-pole magnetic image (upper panel) and 0-400m conductance image (lower panel) of the Woolner Granite and Rum Jungle TEMPEST™ surveys. Note the curvilinear anomalies in the centre of both images and moderate conductance (yellow) zone defining the Daly Basin (after Craig, 2011).

CONCLUSIONS

The new types of pre-competitive data delivered by GA under the Onshore Energy Security Program have proven effective at mapping regional scale geology and assisting explorers with area selection and prospectivity assessments. They are also highly complementary to existing government datasets such as magnetics, gravity and deep crustal seismic.

Industry and other stakeholders have engaged positively with the new data types with strong uptake of data and large attendances at conference presentations and industry workshops. Geophysical innovation by government agencies in Australia is essential so industry has access to with the most up-to-date pre-competitive products which will assist the discovery and development of Australia's natural resources.

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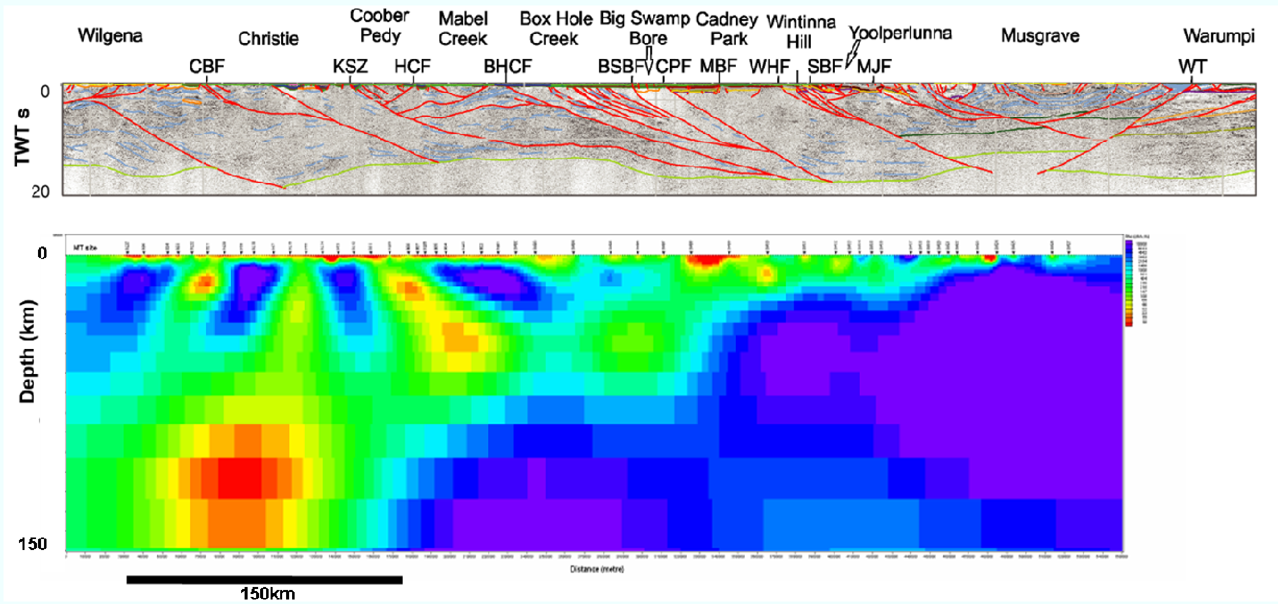

Figure 3. Interpreted seismic section (upper) and 2D conductivity model derived from MT data (lower) from the Gawler-Officer-Musgrave-Amadeus (GOMA) seismic transect in northern South Australia. The vertical scale of the seismic sections is 20s two-way-time (TWT) corresponding to about 60km depth. Hot colours on the conductivity model denote higher conductivities. Major geological regions and structures are marked on the middle panel. Geological features on the southern end of the line with seismic and conductivity signatures are the Cedric Bore Fault (CBF), the Karari Shear Zone (KSZ), the Horse Camp Fault (HCF) and the Box Hole Creek Fault (BHCF). Note the increasing conductivity of the deep crust and upper mantle (> 50km depth) from north to south, and the conductivity high at the southern end at a depth of 120km (after Korsch et al, 2010, and Selway, 2006).