AusAEM_1: One step towards a national conductivity map of Australia

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Introduction

Airborne geophysical surveys were initially conducted by Geoscience Australia (GA) and its predecessor agencies (Bureau of Mineral Resources and Australian Geological Survey Organisation) as part of regional mapping programs to build an inventory of Australia's potential resource endowment. Aerial surveys are one of the most cost effective tools for mapping and managing the Earth's resources. In conjunction with State and Territory geological surveys, for the past 50–60 years, we have systematically acquired and merged surveys to cover most of the Australian continent for the benefit of Australia's exploration investment activities.

Data collected are quality-controlled, enhanced and maintained by GA in national databases. Improvements in technology over time have led to the geophysical coverage of Australia being world-class, with over 35 million line-km of data stored. These are precompetitive datasets to be used to provide insights onto Australia's geological framework and to promote Australia's attractiveness globally to exploration companies. Knowledge gained through these surveys improves resource management and contributes to community safety.

Nowhere in Australia does exploration take place without a tremendous amount of contextual information provided by these national coverage data sets. An individual dataset might trigger some discoveries, but there would be, in all cases, several other datasets that contributed supporting information. These geophysical datasets are some of the drivers that underpin the mineral and energy industry's exploration strategies. They have been used successfully for geological mapping in remote areas that have a paucity of ground truth and outcrop.

A common problem with past national airborne geophysical coverages is that surveys were flown in a patchwork manner over many years and were registered to different datum. In the case of airborne gamma-ray spectrometric acquisition equipment, system calibration changed significantly over time. Older surveys in Australia were reported in units of counts per second, whereas modern surveys are reported in units of radioelement concentration. This meant that gamma-ray spectrometric surveys would seldom match their common borders, making it difficult to merge surveys into a continental-scale compilation thus limiting the utility of these data. Regional compilations facilitate the interpretation of large-scale features in the data, as well as the comparison of features significant distances apart. A similar problem occurred with magnetic surveys, with poor reference field removal introducing base-level shifts. In addition, the crossover tie levelling procedure commonly applied to airborne magnetic data introduced a range of spurious wavelengths into the levelled data.

The solution was to level and merge both gamma-ray spectrometric and magnetic surveys' into continental-scale compilations by acquiring new data in areas to overlap the existing surveys. This was done in a program called the Australia Wide Airborne Geophysical Survey (AWAGS; Minty *et al* 2009, Minty 2003). Data acquired have since been used to level and merge all public-domain gamma-ray spectrometric and magnetic data into seamless geophysical maps over the entire Australian continent.

Over the past three decades, airborne electromagnetic (AEM) surveying has become a routinely acquired dataset by government geoscientific agencies. Since the late 1990s, GA has been increasingly collecting AEM data over more-extensive regional areas in collaboration with State and Territory partners.

Simple levelling of AEM data from different surveys and systems yields a high degree of incoherency such that direct comparisons of the survey data are not objectively possible. Although all airborne EM systems have different characteristics, they overall should measure the same ground response. In order to allow some level of comparison, the data need to be transformed into conductivity models. GA has developed a suite of open-source algorithms that invert AEM data (Brodie 2015) to enable this transformation from data to conductivity.

Acquisition of AEM

The extent of government funded AEM survey coverage of Australia from the late 1990s to date is shown in **Figure 1**. Historically, some surveys have been particular milestones in GA's understanding, development and setting of standards of AEM data. Over this period, GA has optimised survey acquisition and contributed to the development of AEM systems to operate under Australian conditions.

In 2001, AEM was viewed as one of the emerging new mineral exploration discovery enablers for Australia. The Lower Balonne survey was a step improvement in accurate quantitative AEM surveying for land management. In 2003, GA started developing proposals to survey Australia at wide line-spacing rather than small, postage stamp areas with close line-separations. In 2007–08, GA first acquired broad line-spacing AEM surveys as part of the *Onshore Energy Security Program* (GA 2011) in the Paterson, Pine Creek and Frome regions (Roach 2012). These large-scale mapping programs have grown in size and are now an important component of projects like the *Exploring for the Future* (Ley-Cooper and Richardson 2018) AusAEM programme, a broad semi-continental scale survey aimed at enhancing exploration for new mineral, energy and groundwater resources.

The *Exploring for the Future* Australia-wide AEM (EFTF AusAEM) program is acquiring data over extents never previously attempted, some 22% of the total area of Australia. It continues a long-lasting tradition at GA of delivering precompetitive data to stimulate exploration,

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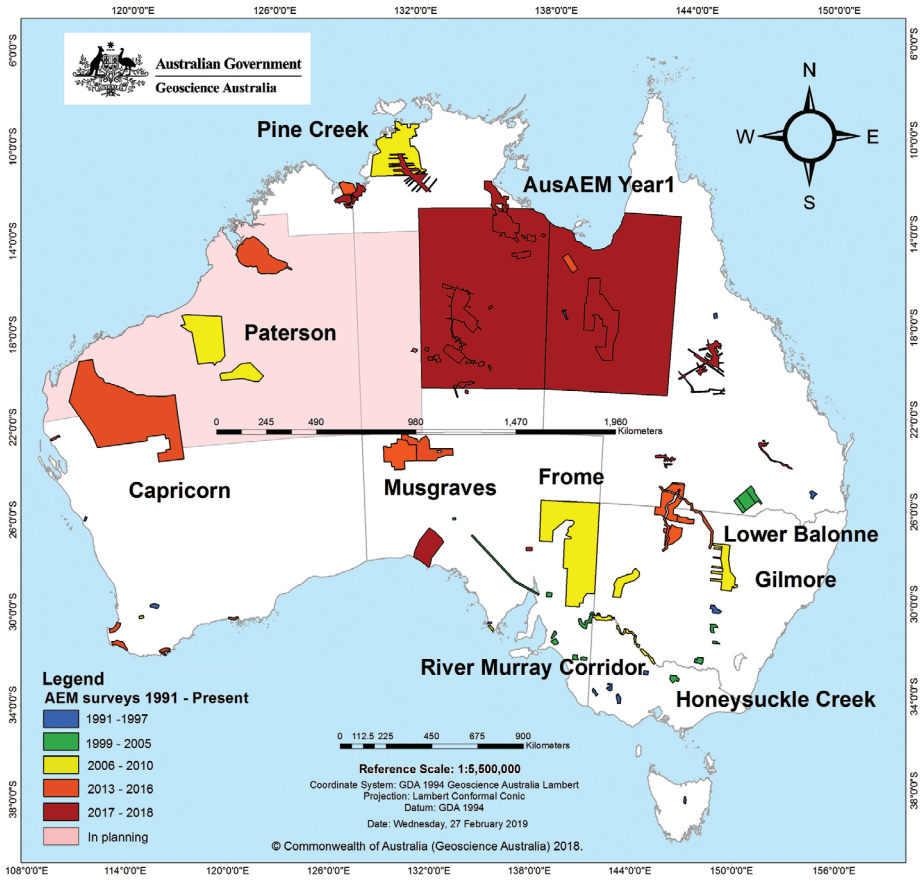

Figure 1. Historical acquisition of airborne electromagnetic data coverage. Survey funded by GA in partnership with States and Territory geological surveys and other government agencies.

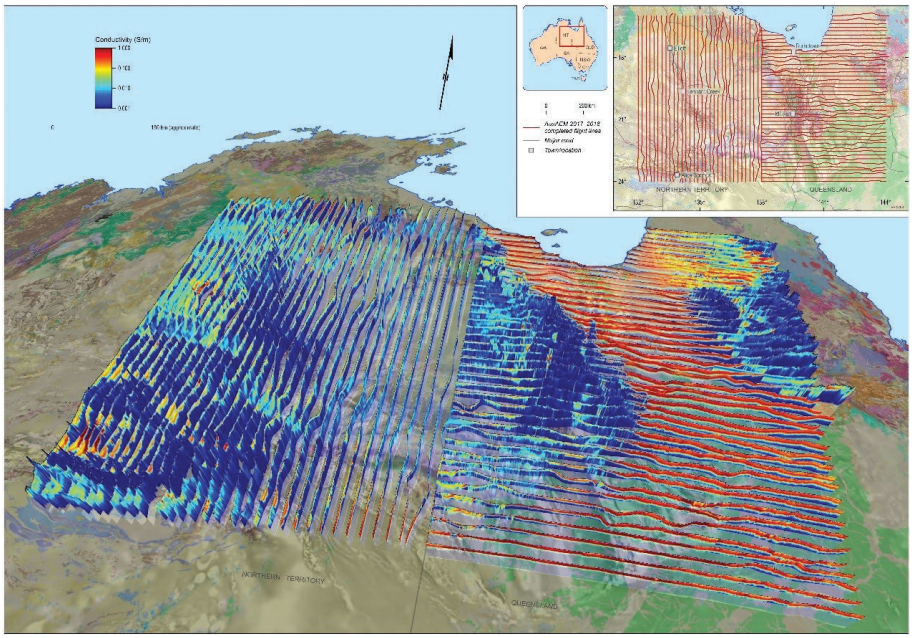

Figure 2. 3D composition of 900 km long conductivity depth-sections draped over a map of surface geology.

particularly by acquiring AEM data in areas with a paucity of data as a way of promoting exploration in new frontiers. Results from the first year of data acquisition (areas covered shown in **Figure 2)** have already proven useful in mapping the cover and basement interface. The data show new under-cover geological features that could host mineral deposits and groundwater resources. These data will provide explorers with insights in areas of thick cover with potential to generate targets for further investigation.

The image in **Figure 2** illustrates the distribution of 900 km long conductivity-depth sections from GA's 1D laterally constrained algorithm. Sections derived from the 20 km-spaced flight lines are analysed and displayed as 3D images; the sections are integrated with other datasets like gravity (**Figure 3**), magnetics, and radiometrics. The results have provided enough detail to map cover thickness and basement topography.

Inverted conductivity-depth models are enhancing our capacity to derive depth-to-target information of regional features, to map potential alteration and structural zones that delineate architecture within the regolith, and more broadly, to increase our understanding of mineral and groundwater

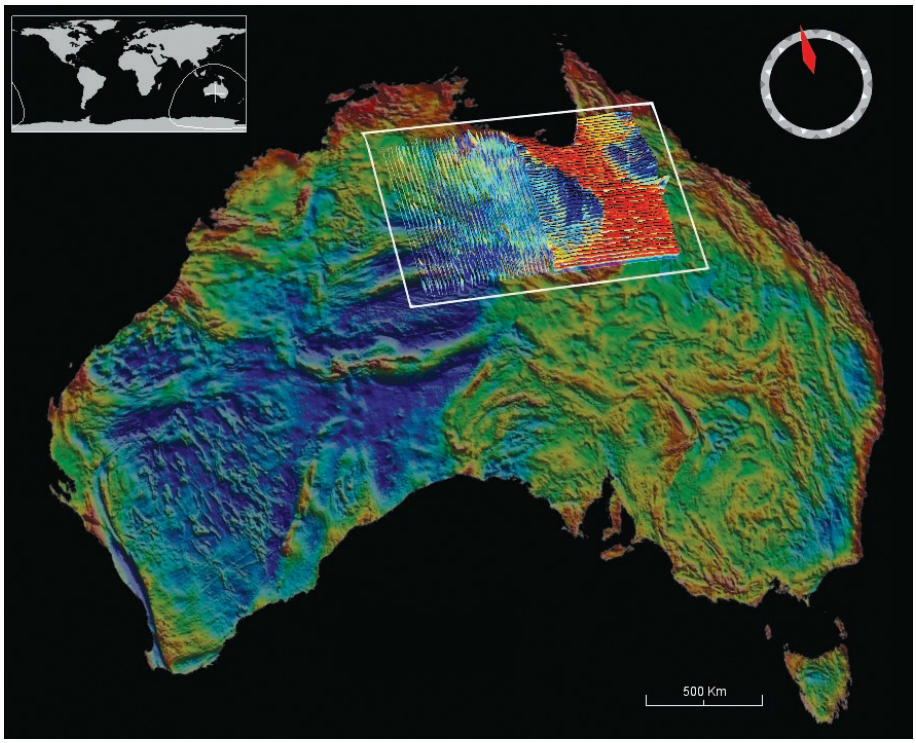

Figure 3. Extent of AusAEM's first year of acquisition draped over GA's national map of gravity. We are working towards a national AEM coverage à la radiometric and magnetics.

resource potential of the surveyed areas. Some anomalous confined conductive units in the basement and under a cover of what appears to be un-mineralized rocks, and regolith have also been unveiled by these models. In the right geological setting, these features would be of interest to mineral explorers and become the object of further examination.

AEM data also have numerous applications outside mineral exploration; in particular, the data are valuable for agricultural management and environmental monitoring. Farmers and graziers can use the data and derived products (in the form of maps and sections) to assess potential water resources to inform sustainable crop production and cattle grazing management.

Conclusion

The volume of downloads of geophysical data from the GA website is a silent testament to the usefulness of the precompetitive geophysical data for Australia. The contents of this data are conservatively valued at ~$240 million at today's cost of data acquisition per line km. However, these data have an enduring value that goes beyond a monetary figure.

Explorers can use the airborne magnetic, radiometric and electromagnetic data to reliably compare radiometric signatures observed over different parts of Australia, identify potential magnetically susceptible minerals, and identify new under-cover geological conductivity features that could host new mineral deposits and groundwater resources.

AEM is particularly useful in areas that have a significant thickness of surface cover (regolith and sedimentary basins) that can mask the underlying basement rocks. The high resolution, non-intrusive nature of the survey methods and the ability to scan the conductivity of the ground in three dimensions, have made the current AusAEM program a successful one. The program is acquiring data over extents never previously attempted. The conception of these broad-spaced large coverage surveys comes from a long-lasting tradition at GA of delivering precompetitive data to stimulate exploration, including AEM acquisition in data-poor areas as a way of promoting exploration in new frontiers.

These regional and continental data support a range of different applications, including geological mapping, mineral and petroleum exploration, geomorphological studies, and environmental and land management studies. Refinement and coverage of precompetitive geophysical data (airborne magnetics, airborne radiometric, ground gravity, and crustal reflection seismic) continues. Successful insights from less conventional methods, eg airborne EM, airborne gravity, airborne gravity gradiometry, magnetotellurics and passive seismic, have also gained traction. We are now working on the acquisition of data from these less conventional methods towards a national coverage à la gravity, radiometric and magnetics.

Aus AEM year 1 data are freely available for download from the GA website (www.ga.gov.au).

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