Magnetotellurics: Imaging basement through deep and conductive cover

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SUMMARY

The audio magnetotelluric (AMT) technique has been applied by Geoscience Australia to determine the nature and thickness of cover, plus the basement architecture in regions around Australia. The depth of cover derived from AMT data agrees with results obtained by other geophysical techniques and known information.

Key words: magnetotelluric, cover thickness, basement mapping, conductivity

INTRODUCTION

Magnetotelluric (MT) surveys have been undertaken to image crustal conductivity structures in Australia since the first MT profile data in Western Australia reported in 1967. An increasing trend is emerging where MT is being used to image both the basement architecture and characterisation and thickness of the cover sequences. As resource explorers have turned their focus to areas of deeper or more conductive cover, MT has benefits of greater penetration depth when compared to traditional techniques, such as airborne electromagnetics (AEM) and inducted potential (IP), that have limited penetration depths in some geological settings that reduce the ability of the data to fully imaging basement structures and thickness of cover. Here we show results from recent MT campaigns with a focus on AMT surveys undertaken by Geoscience Australia in partnership with State Geological Surveys. The results demonstrate that MT is a useful tool for explorers to determine thickness and nature of cover, as well as imaging the basement architecture. The MT surveys have been undertaken within a broader magnetotellurics program, whereby Geoscience Australia and partners have acquired various MT data sets including audio MT, broadband MT and long period MT to better understand the conductivity structures within the Australian continent from prospect through to continental scale.

METHOD AND RESULTS

The MT method is a passive electromagnetic (EM) technique that utilises variations of the Earth's natural magnetic and electric (telluric) fields. The transfer functions of these fields, the electrical impedance tensors, are proportional to the electrical resistivity distribution of the subsurface. MT can target a wide range of depths, where the depth of penetration depends upon the source field frequencies and local resistivity distribution. Different MT equipment and techniques were developed to utilize these source fields in different frequency ranges (Table 1). All classes of MT involve recording components of the electrical and magnetic fields with the source varying from a transmitter through to natural sources such as lightning strikes (a high frequency source) and interactions with the solar wind and the magnetosphere of the earth (lower frequency sources).

The data collected were acquired using Phoenix MTU-5a recorders with both AMTC-30 and MTC-80H or MTC-150L coils. Electrodes with 50m dipoles were deployed to the 4 cardinal axes aligned with magnetic north. Data were processed using Phoenix SSMT 2000 data processing software and modelled by Geoscience Australia using commercial WinGLink software and the Occam algorithm (deGroot-Hedlin and Constable, 1990) on in-house computers and the *rajin* supercomputer at the National Computational Infrastructure (NCI) at ANU.

AMT for cover thickness and characterisation

AMT data were recorded at sites to estimate cover thickness in the Southern Thomson region of New South Wales and Queensland. Data were acquired for 2 hours at each site and processed utilising a 1D inversion routine. Basement conductors were imaged at depths ranging from 150m through to 500m using the same acquisition and processing parameters (Figure 1). Although basement depth is not known for all sites, results concur with similar estimated depths of the cover resolved using refraction and passive seismic at the same sites. Drilling to confirm all thickness of cover estimates will occur in late 2016.

In another example, data obtained over the Georgina Basin, south of Mt Isa, highlighted the variable thickness of the basin (Figure 2). The base of the basin is interpreted by the change from green (~300 Ωm) to blue (~10 000 Ωm) at depths of 400m to 600m. In addition to imaging the depth of the basin, a conductive overburden layer plus some elements of basin stratigraphy are imaged by the AMT data.

Class	aka	Frequency Range	Source	Record Time	Depth of Investigation (subject to skin depth)
Radio-Magnetotellurics	RMT	~100 -10 KHz 10^{-6}*s to* 10^{-4}*s*	Active	~minutes	0 - 50m
Controlled Source Audio Magnetotelluric	CSAMT	~100 000–1 Hz 10^{-5}*s-1 s*	Active	~hours	0 to 1000m
Audio Magnetotelluric	AMT	~10 000 – 1 Hz 10^{-4}*s-1 s*	Passive	~hours	10m to 1000m
Broadband Magnetotellurics	BBMT	~1000 – 0.001 Hz 10^{-3}-10^{3}*s*	Passive	~days	200m to 50,000m
Long Period Magnetotellurics	LPMT	~0.1 – 0.0001 Hz 10-10^{4}*s*	Passive	~weeks (years)	10km to 200km

Table 1: Comparison of different classes of magnetotelluric data (Simpson and Bahr, 2005).

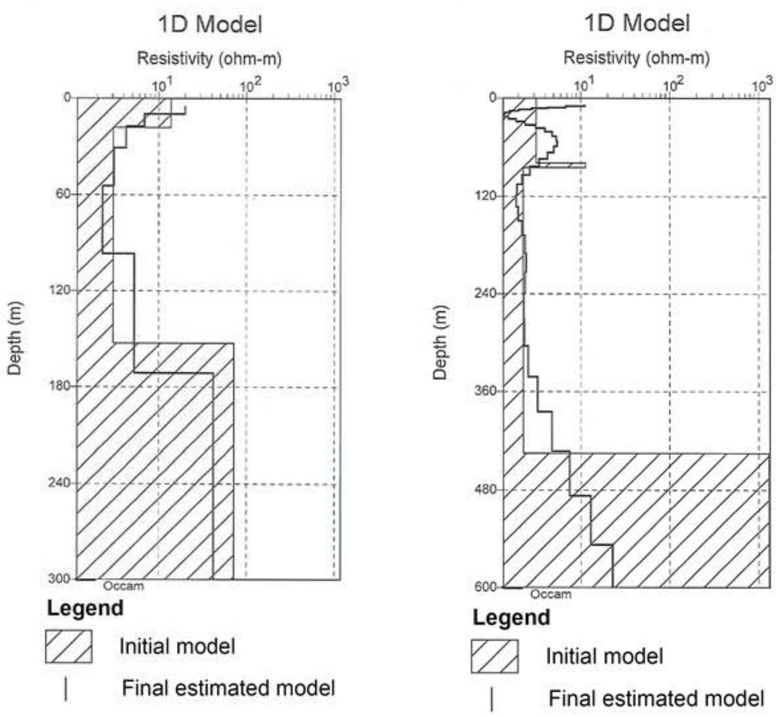

Figure 1: Model of left shows basement at ~170m, model on right shows basement conductor at ~ 490m.

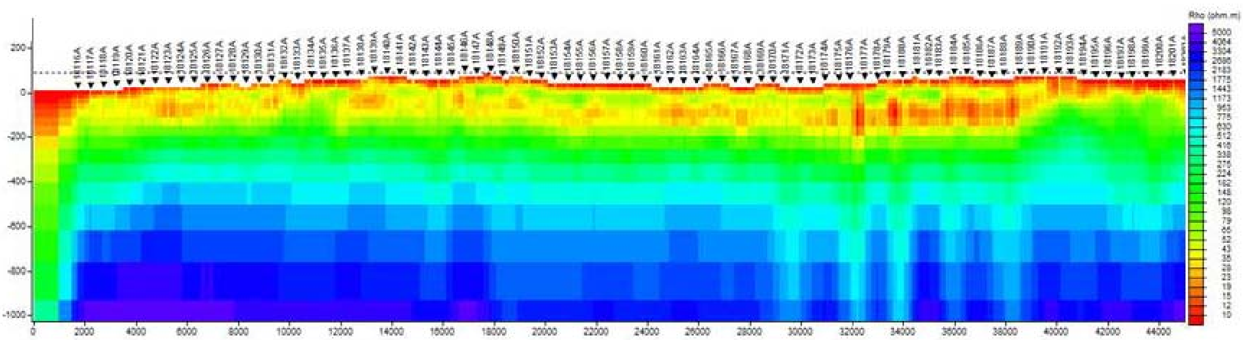

Figure 2: AMT profile through the Georgina Basin under cover.

AEM vs AMT vs BBMT

AMT data were obtained coincident with broadband MT (BBMT) traverses in the Southern Thomson region (Wang et al., 2016) and provided both additional resolution of the basement architecture and also imaged the crustal architecture. Comparisons with AEM data for the region (Roach, 2015) indicate that the AMT data can resolve deep conductive cover as well as imaging basement architecture beneath conductive overburden (Figure 3).

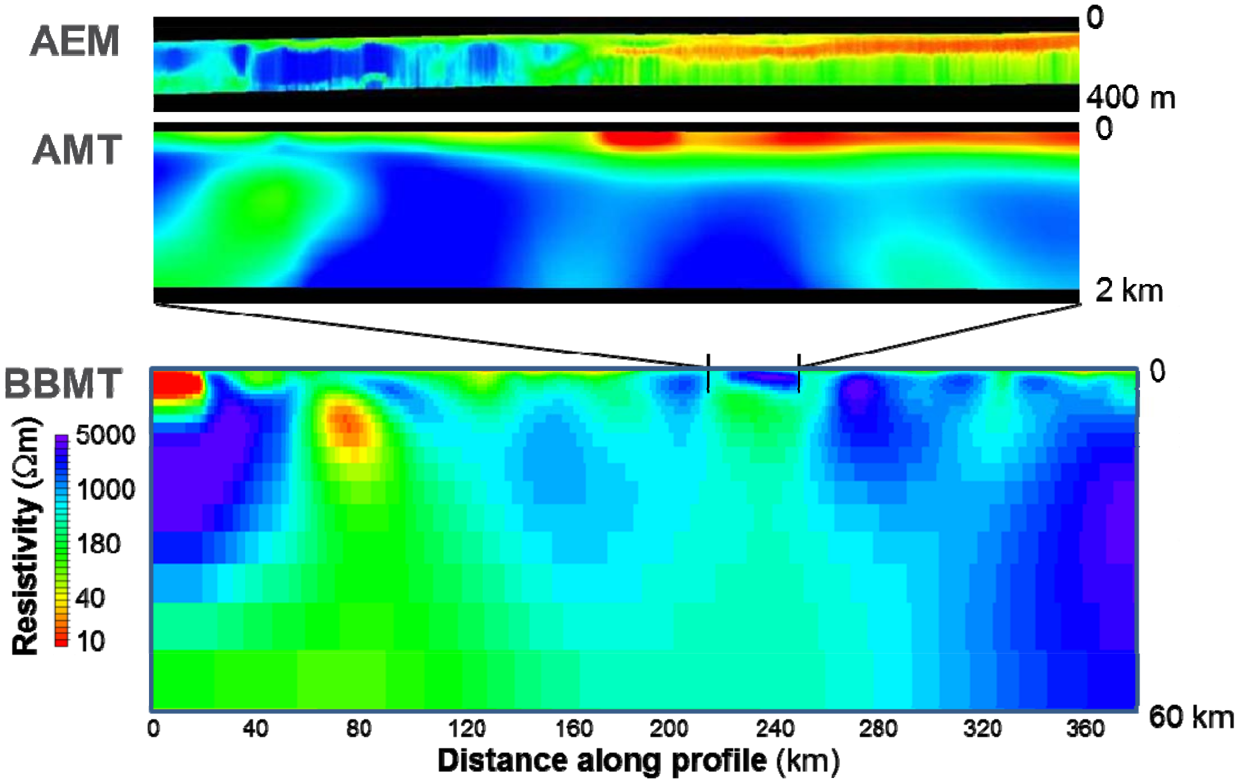

Figure 3: Comparison of AEM (upper), AMT (lower) and BBMT line (lowermost panel).

CONCLUSIONS

Magnetotellurics is a cost effective method for exploring to great depths. Geoscience Australia has applied magnetotelluric data to determine the nature and thickness of cover and to characterize the basement architecture in regions around Australia. The depth of cover assessments produced by AMT surveys agrees with depth of cover assessments made by other geophysical techniques and will be tested by an ongoing program of stratigraphic drilling. AMT data also compare favourably with other electrical datasets, such as AEM, and provide another tool to see through a variety of cover sequences.

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