Interpreting the Eromanga and Georgina Basins from magnetotelluric data

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SUMMARY

This study uses broadband magnetotelluric (BBMT) and audio magnetotelluric (AMT) data to model the Eromanga and Georgina Basins in the Boulia region of western Queensland. Extensive data analysis to establish dimensionality, strike and the presence of galvanic distortion was conducted before inversion. The OCCAM 2D MT inversion code was used to produce conductivity sections for interpretation. The results of OCCAM inversions were compared the results of other inversion codes to ascertain the presence of any inconsistencies in the results. Several inversions were run for each profile to optimise inversion parameters with detailed inspection of data fit at each site to establish any systematic data misfits. Inversions were run on the full frequency of AMT data first as the resolution of the data was better. The broadband data was subset to frequencies above 0.4 Hz to focus the inversion on resolving the shallow features. A priori knowledge from the AMT inversions was very useful in interpreting the lower resolution BBMT data. Independent constraint in the form of drillhole and seismic data was used to aid interpretation of the inversions profiles. The BBMT inversions allowed the two-layer Georgina Basin signature evident in the south of the project area to be traced further north. They also delineated more complicated basin morphology in the west of the project area.

Key words: Magnetotelluric, Georgina Basin, Eromanga Basin, OCCAM, Conductivity.

INTRODUCTION

In 2014-2015 the Geological Survey of Queensland, together with Geoscience Australia, undertook the collection of a large magnetotelluric (MT) survey in the Boulia region, called the Isa Extension survey. The survey was proposed by industry under the Industry Priorities Initiative, part of the $30 million Future Resources Program from the Queensland Government. The MT survey crosses the location of the interpreted contact between the Mount Isa and Davenport Provinces *(Withnall et al., 2013*).

This MT survey forms the core of a project aiming to advance the geological understanding of the undercover southern extension of the Mount Isa Province, its overlying basins and adjacent terranes. The project also aims to provide a methodology for incorporating geological constraint into MT inversions with the goal of improving the reliability of MT inversion products. The first phase of this project, discussed in this abstract, involves modelling the Eromanga and Georgina Basins which comprise the cover sequences obscuring the Proterozoic basement. The depth of these basins is currently poorly constrained, with past studies by the Geological Survey of Queensland (2011) and Teasdale and Pryer (2002) using magnetic depth to basement estimates and sparse drillholes to ascertain thickness. While the depth of this cover remains poorly constrained, it is a vital consideration in mineral exploration programs.

The outcropping Eromanga Basin (Figure 1) in the project area is dominated by the Wilgunya Subgroup which encapsulates the Allaru Mudstone, Tooelbuc Formation and Wallumbilla Formation *(Cook et al., 2013)*. It is expected that these mud-rich units will have low electrical resistivity. In contrast, the outcropping Georgina Basin is dominated by the limestone and sandstone rich units of the Toko and Cockroach Groups *(Kruse et al., 2013; Withnall et al., 2013)* which are expected to have higher electrical resistivity.

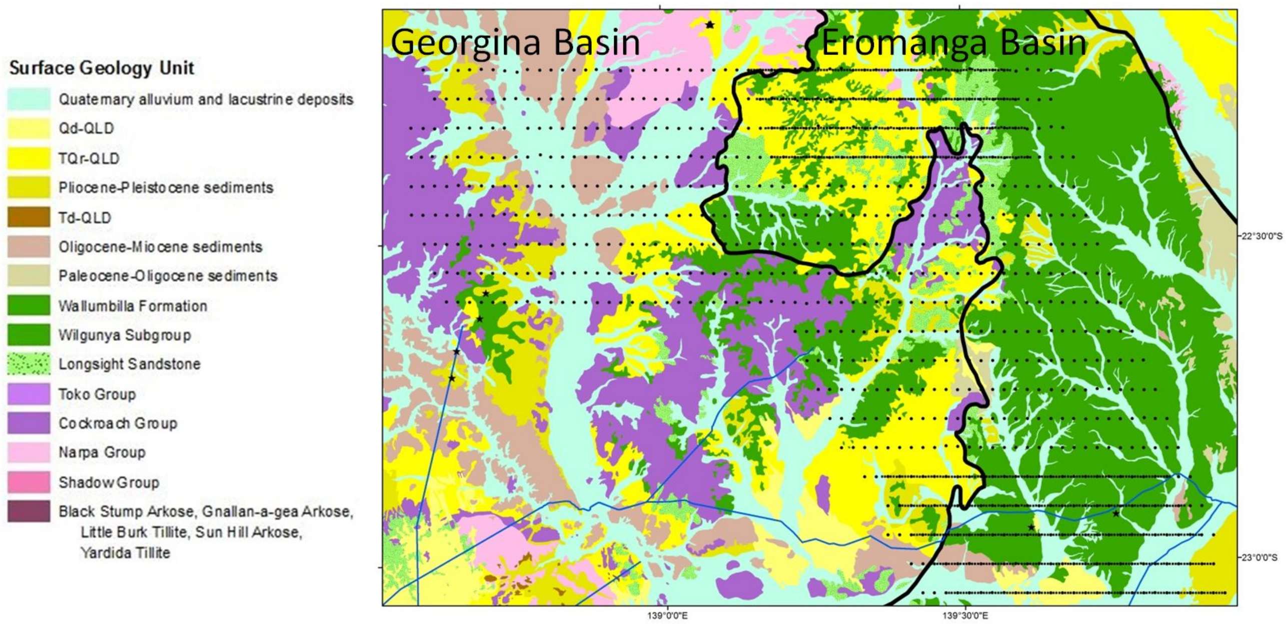

Figure 1: Mapped distribution of Georgina and Eromanga basin sediments in the project area. The black circles represent BBTM stations, black squares are the AMT stations and black stars represent drillhole locations. The blue lines are available seismic data.

Magnetotellurics is a passive geophysical technique which records natural variations in the Earth's magnetic and electric fields. This information is then processed to the following relationship:

$$\begin{pmatrix} Ex \\ Ey \end{pmatrix} = \begin{pmatrix} Zxx & Zxy \\ Zyx & Zyy \end{pmatrix} \begin{pmatrix} Hx \\ Hy \end{pmatrix}$$

Where Ex and Ey are the measured variation in the electrical field in the x and y direction, and Hx and Hy are the measured variation in the magnetic field in the x and y direction. Zxx, Zxy, Zyx and Zyy are components of the electrical impedance tensor which describe the conductivity distribution in the crust. Broadband magnetotelluric (BBMT) stations were collected at 809 sites at 2km station spacing along east-west oriented lines. Due to the predominantly north-south strike of the regional geology, the spacing between lines was increased to 5km in an effort to maximise coverage while maintaining lateral continuity. These stations were complemented by 855 audio magnetotelluric (AMT) stations collected at 500 m intervals along 9 lines co-located with the BBMT data where possible (Figure 1).

DATA ANALYSIS

Data analysis with MT-py codes (Krieger and Peacock, 2014) was conducted before inversion of the project dataset. This analysis is necessary to determine critical factors such as dimensionality, geoelectric strike and the presence of galvanic distortion. Phase tensor (Caldwell et al., 2004) pseudosections (Figure 2) and maps were produced to assess the character of the data and noise distribution. Dimensionality was assessed through both phase tensor method (Caldwell, et al., 2004; Bibby et al. 2005) and WALDIM analysis (Martí et al., 2009). Results from two methods are broadly similar however the phase tensor method showed a more coherent dimensionality pattern (Figure 3) and was therefore the preferred method of analysis. As expected, the data was determined to be predominantly 1D and 2D in the basin terrains.

Where the data was determined to be 2D, MT-Py was used to calculate the geoelectric strike. This code calculates strike based on the phase tensor (Caldwell et al., 2004) and impedance tensor invariant (Weaver et al., 2000; Weaver and Lilley, 2004) methods and produces the mean, mode and median for consideration. The strike analysis used has a 90° ambiguity (Thiel, 2008), so the geological strike was used in concert with the strike analysis results to determine the strike of N160°E used for inversion.

Finally data was assessed for the presence of galvanic distortion – primarily static shift. Static shift is a frequency independent shift of apparent resistivity which results from localised near-surface conductivity inhomogeneity (Simpson and Bahr, 2005). There are three main ways to reduce static shift effects - spatial filtering (e.g. Tournerie et al., 2007), independent constraint (e.g. Spitzer, 2001) and inversion (Ogawa, 2002). For this study static shift was accounted for during inversion.

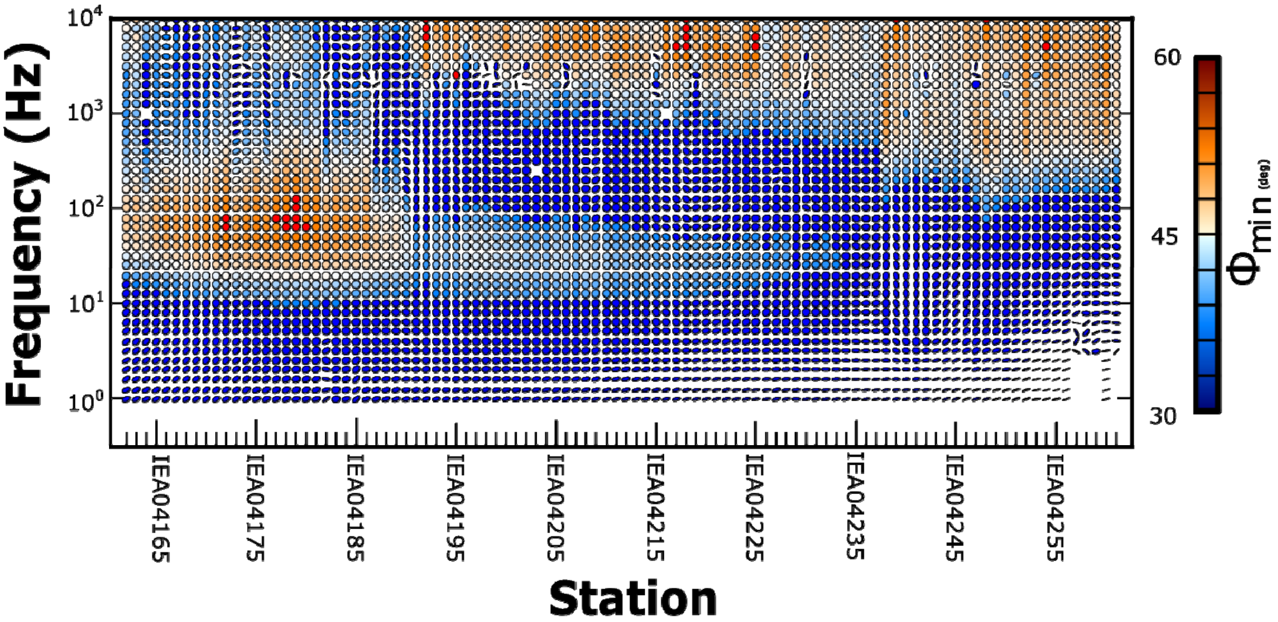

Figure 2. Pseudosection plot of the phase tensor analysis for line 4000 of the southern AMT block produced in MT-py, phase tensor ellipse are coloured by the minimum phase. The circular phase tensor ellipses indicate that the data is predominantly 1D with distorted ellipses representing 2D or 3D data. The distorted ellipses at around 3000Hz are the result of noisy data. The variation in minimum phase (Φ_{min}) provide an indication of the number of layers expected to be produced by inversion

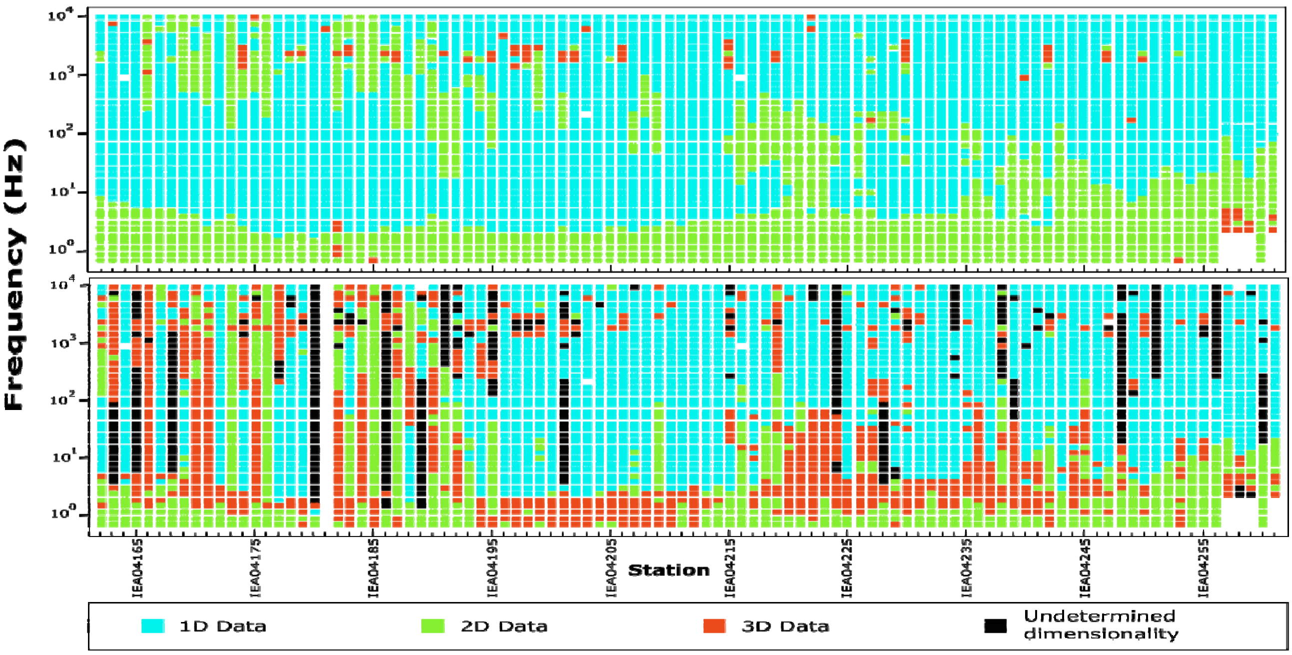

Figure 3. Comparison of dimensionality analysis conducted with the phase tensor method (top) and WALDIM (bottom) for line 4000 of the southern AMT block. Each vertical column represents the complete frequency range for a single AMT site. β_{Φ} = 5 and Φ_{max} = Φ_{min} = 0.1 were used as the cut-offs for determining the dimensionality with the phase tensor method. These cut-offs are necessary to account for noise in the measured data. Note the more coherent dimensionality pattern from the phase tensor method when compared to the WALDIM method.

INVERSION AND INTERPRETATION

Occam 2D MT inversion code (deGroot-Hedlin and Constable, 1990) was selected to produce the inversions. This code allows for inversion of 2D data and can also jointly invert for static shift alongside the impedances. The AMT data was inverted first as it has better resolution and there were no 3D data present based on the dimensionality analysis. The data for the southern AMT block is not significantly affected by noise but the northern block AMT data is noisier. This noise is generally confined to frequencies between 3000 – 5000 Hz or below 1 Hz; however, after initial inversions it was evident that this noise was affecting the inversion results. The noisy data, most likely the result of low signal due to daytime acquisition (Garcia and Jones, 2002), was masked to minimise its effect for subsequent inversions. Several inversions were run for each profile and detailed examination of the data fit was undertaken to optimise the inversion parameters.

The BBMT data was truncated to frequencies above 0.4 Hz in order remove the majority of data assessed as 3D. A small subset of the data in the western part of the project area displayed 3D characteristics above 0.4 Hz; this data was also removed before inversion. Up to one in three BBMT stations were identified as have static shift effects during data analysis. Consequently, inversions were parameterised to allow static shift inversion for affected sites. While the BBMT data is significantly lower resolution (2km station spacing compared to 500m station spacing for the AMT data) the inversions still reproduced basin features evident in the AMT inversions. Again several inversions were run to optimise inversion parameters.

The resulting profiles produced with optimised parameters were then compared to inversion results produced with other codes, primarily the Rodi and Mackie (2001) algorithm. This was to look for any inconsistencies between inversions in an effort to minimise the presence of model driven, rather than data driven, features. Where there were differences, the fit of the model to the data was further scrutinised.

The preferred inversion results were imported into 3D software for interpretation. Drillhole and seismic data (Figure 1) was also used during to the interpretation process, ensuring that the final interpretation is consistent with all available data. This independent information was of great assistance in unravelling the geological information from the resistivity sections and viewing the data in 3D proved important to producing a consistent interpretation. The high resolution AMT data was valuable in interpreting the lower resolution BBMT data (Figure 4).

As expected, The Eromanga basin has low resistivity and is easily interpreted from the inversions as a shallow, low resistivity feature thinning to the west. The Georgina Basin also has the predicted higher resistivity however, the resistivity of the sediments decreases towards the base of the basin where the inversion show rocks with moderate resistivity. This decrease is possibly due to a higher

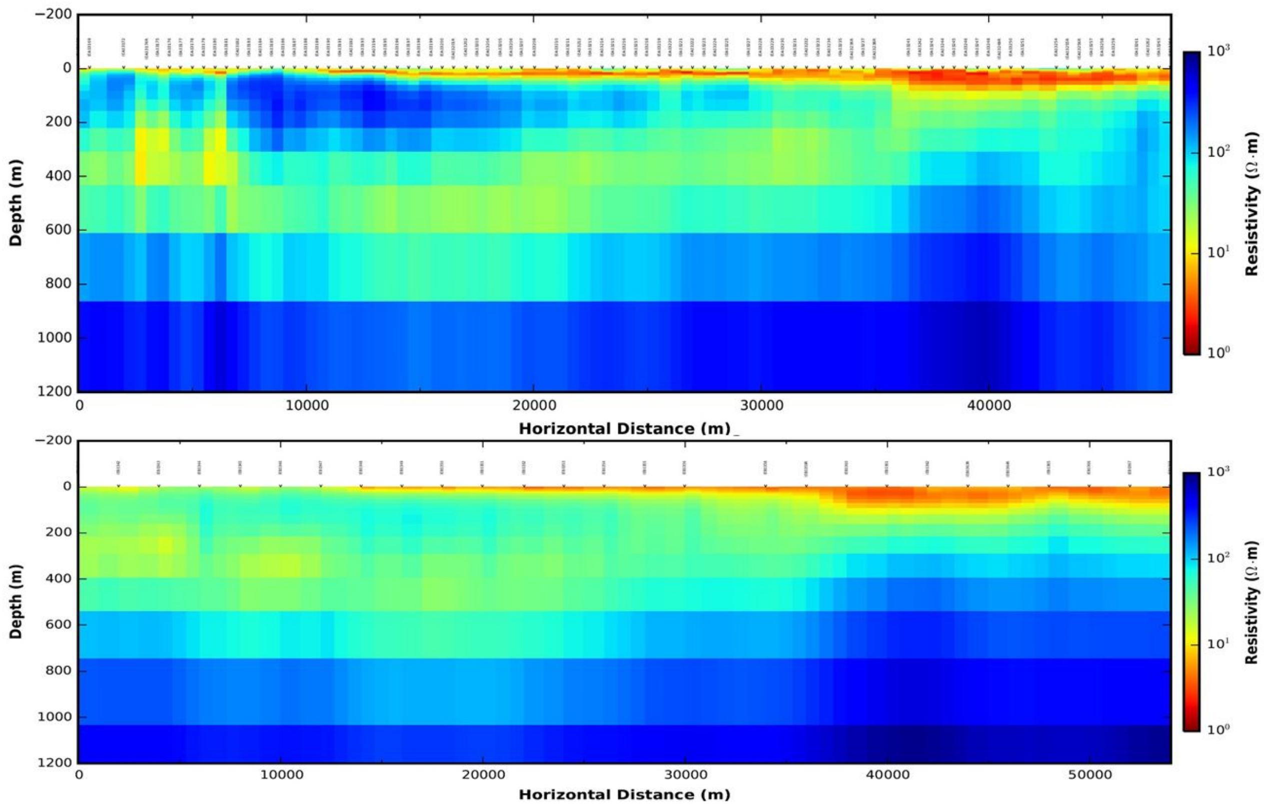

Figure 4. The top panel shows the result of inverting the AMT data for line 3000. The shallow low resistivity layer on the east of the section is interpreted as the Eromanga Basin sequence. The western end of the section shows the two-layer resistivity signature attributed to the Georgina Basin. The bottom section is the result of inverting the BBMT data on the same line. The two-layer resistivity of the Georgina Basin is subtle but present.

prevalence of more mud dominated units in the lower stratigraphy of the Georgina basin. The Georgina basin shallows to the north and deepens to the west where the basin morphology is more complex. The BBMT data allowed the two-layer Georgina Basin signature evident in the south of the project area to be traced further north where it thins as it approaches the Mount Isa Inlier.

CONCLUSIONS

Inversions produced from a spatially limited AMT survey provided the a-priori knowledge to interpret regionally extensive lower resolution BBMT data, leading to a better understanding of the Eromanga and Georgina Basins in the project area. Data analysis to establish dimensionality, strike and the presence of galvanic distortion was vital to producing reliable inversion results. Comparing inversions produced with OCCAM to the results of other inversion code further increased the confidence in inversion results. Knowledge gained from the higher resolution AMT data proved a vital aid in interpreting the lower resolution BBMT data. Interpretation of the MT data in concert with available drillhole and seismic data was important in producing robust model for the basins. The basin depths are broadly similar to the Geological Survey of Queensland (2011) and Teasdale and Pryer (2002) results, however the MT data has improved the spatial resolution of the interpretation.

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