2.5D inversion of airborne EM data – a case study from new regional AEM data from the Mammoth Mines region, Queensland.

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SUMMARY

2.5D (2D geology, 3D source) inversion of airborne electromagnetic (AEM) data has evolved into a routine and established practice on datasets from an array of applications. Large datasets may be inverted in days using conventional PC's, or cloud computing for faster results.

The 2.5D inversions in this study were carried out using a highly modified adaptation of the ArjunAir program originally developed by the CSIRO and subsequently by AMIRA project P223F. The new program is called Moksha.

Results are presented from a continental scale AEM regional mapping survey carried out by Geoscience Australia. 2.5D inversions performed in a study area in the Mammoth Mines mineral district of Queensland defined discrete conductivity anomalies on a line over the Mount Gordon Fault Zone, and imaged a series of steeply-dipping conductors on a nearby regional traverse.

The study demonstrated the ability of 2.5D inversions to image steeply-dipping and folded geology, and present possible exploration targets, in a mineralised deformed terrane.

Key words: inversion, electromagnetic, geology, mapping, AusAEM

INTRODUCTION

It is desirable to obtain 2.5D (2D geology, 3D source) inversions of AEM data to better image steeply-dipping or complexly folded geology and targets where 1D layered Earth assumptions are not valid. This scenario applies to most hard rock mineral provinces, metamorphic belts and deformed terranes. Furthermore, AEM surveys are frequently flown at a line spacing too large for effective 3D modelling at a resolution appropriate to the target size.

The P223 series of CSIRO/AMIRA projects formed to develop forward and inverse modelling codes began in 1980 and ran for 27 years, after which the code base was released to the public (Raiche et al., 2007). The 2.5D conductivity inversion of airborne electromagnetic data has been possible since the 1990's when algorithms were first developed and tested on desktop computers (Chen et al., 1998). P223 continued the development of 2.5D algorithms, leading to the release of the ArjunAir finite-element modelling program (Wilson et al., 2006).

After the public release of the P223 software suite, significant modifications and corrections to the ArjunAir program were carried out, along with the development of a GUI, to provide accurate inversion results and a commercially viable platform for large scale 2.5D inversions of AEM data (Silic et al., 2015, 2018). , FitzGerald et. al., 2018.,

The modernised version of ArjunAir (Moksha) has the ability to invert data from both time domain and frequency domain AEM systems, and to date data from various generations of the following historic and current systems have been successfully inverted: AEROTEM, DIGHEM/RESOLVE, GEOTEM, HeliGEOTEM, HoistEM, Hummingbird, SkyTEM, SPECTREM, TEMPEST, VTEM, XCite and XTEM.

Large AEM datasets may be processed in reasonable runtimes (hours to days) depending on survey size and resolution by use of parallel processing and multiple threaded CPU's. Currently a single quad-core workstation will process data at a rate of around 2 m/s. Further developments to improve optimization and productivity of the methodology are planned.

This paper presents Moksha 2.5D inversion results from data acquired from a continental scale airborne EM survey carried out by Geoscience Australia.

METHOD AND RESULTS

In 2017 Geoscience Australia contracted CGG Aviation to acquire approximately 60,000 line-km of TEMPEST Airborne EM data (Ley-Cooper and Brodie, 2019). The survey commenced in August 2017 and was completed in July 2018. Lines were spaced widely at 20km, covering an area of 1,117,000 km^2 of the Northern Territory and Queensland (Figure 1). The purpose of the survey was to map the character and thickness of sedimentary cover and regolith in regions surrounding crystalline basement, to conduct groundwater investigations, and to further assess mineral potential.

Specifications related to the survey are available on the Geoscience Australia AusAEM website.

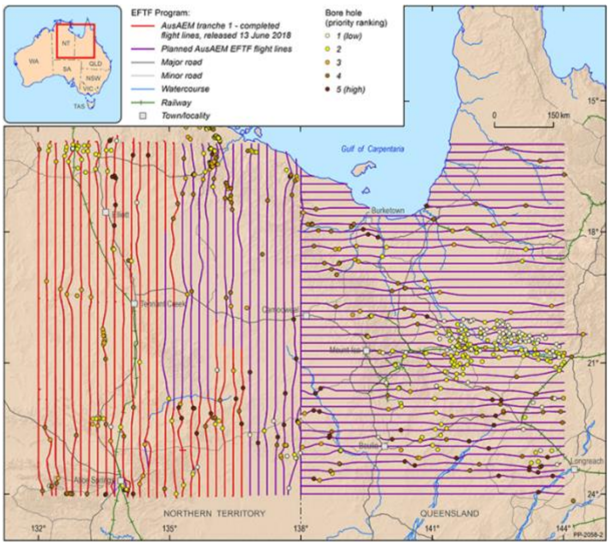

Figure 1. Coverage of the Geoscience Australia AusAEM TEMPEST Survey (source: Geoscience Australia website)

Data from the survey were downloaded from the Geoscience Australia website. A system file tailored to the TEMPEST system was created, incorporating the transmitter waveform, channel times and widths, and the data channels containing the transmitter and receiver geometry. Both Z and X components were selected for joint inversion. The late time noise in the EM data was quantified by extracting data from representative areas of low signal, and a multiplier applied to each channel for both components.

The Moksha 2.5D inversions take account of variable receiver-transmitter geometry, and make use of the recorded receiver pitch channel as well as the vertical, along line and across line transmitter-receiver separation (Figure 2).

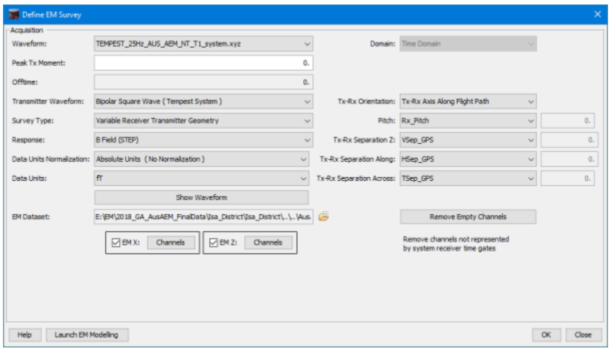

Figure 2. 2.5D Inversion set-up window showing incorporation of variable receiver-transmitter geometry

Inversions were set up in a GeoModeller project, which captured the DEM from the survey, the 2D tuning and mesh parameters, the initial ground resistivity model, the noise settings, and the EM system parameters. As survey lines from the AusAEM survey are hundreds of kilometres long, to manage computer memory lines were broken into 5km segments with 1km overlap, and then merged at completion.

An example of the inversion GUI inside GeoModeller is shown on Figure 3.

Study areas were established over important mineral districts at Tennant Creek, Mount Isa, and in the Mammoth Mines area, the latter of which will be presented here.

The Mammoth Mines district located in western Queensland is a historic and present day mining district and includes the Lady Loretta stratabound Zn Pb Ag deposit, and the Mount Oxide and Capricorn (Mount Gordon) fault-bound breccia and replacement copper deposits (Hutton and Wilson, 1985), (Figure 4).

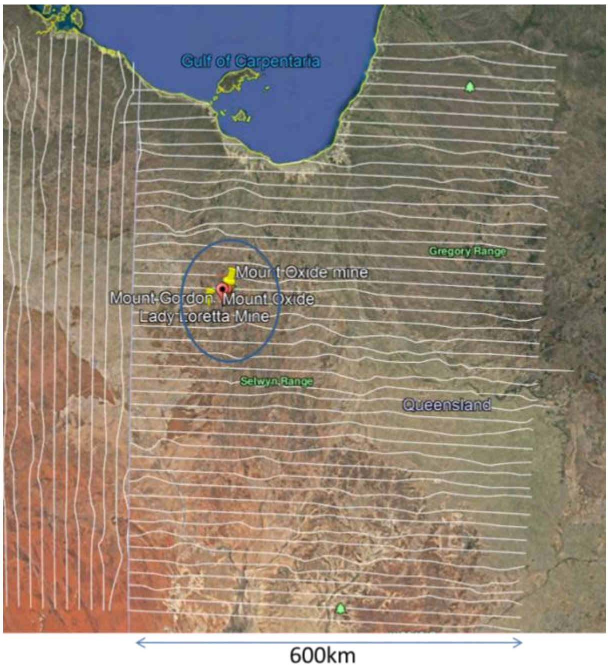

Figure 4. Location of the Mammoth Mines mineral district in western Queensland. AusAEM survey lines shown on Google Earth imagery.

Four AusAEM TEMPEST lines flew in the vicinity of the Capricorn/Mount Gordon and Mount Oxide deposits (Figure 5). One survey line, L2026001, flew approximately 6km along strike over the mineralised Mount Gordon Fault Zone from the Capricorn Copper Mine, and, fortuitously, adjacent to a cross section line from the Mammoth Mines 1:100,000 geological sheet (Figure 6).

Moksha 2.5D inversions were performed on the extracted survey lines following the approach described above. For comparison, a 1D inversion was also performed on the same line. The results for Line 2026001 are shown on Figure 7 along with the near-coincident geological cross section.

The Whitworth quartzite hosts mineralization at Capricorn/Mount Gordon, and elsewhere along the Mount Gordon Fault Zone (Hutton and Wilson, 1985). Note that the depth range of the conceptual geological section is considerably greater than the depth of investigation of the TEMPEST system, which was approximately 400m in this area. The 2.5D conductivity section indicates a pair of anomalies coincident with the Mount Gordon Fault zone and historic copper prospects. Similar anomalies are present over additional fault zones lying to the west. The 1D inversion result, whilst broadly identifying the same key features, poorly defines the steeply-dipping conductors and contains artefacts at lateral discontinuities and at depth. By comparison, the 2.5D inversion improves the definition of steep conductors and produces a much cleaner section geometry at greater depths through the higher sensitivity of a joint inversion using both X and Z components.

The 2.5D conductivity inversion result for another line is shown on Figure 8. This section of line shows a series of steeply-dipping and folded conductors and possible exploration targets aligning well with folded geology reflected in the topography.

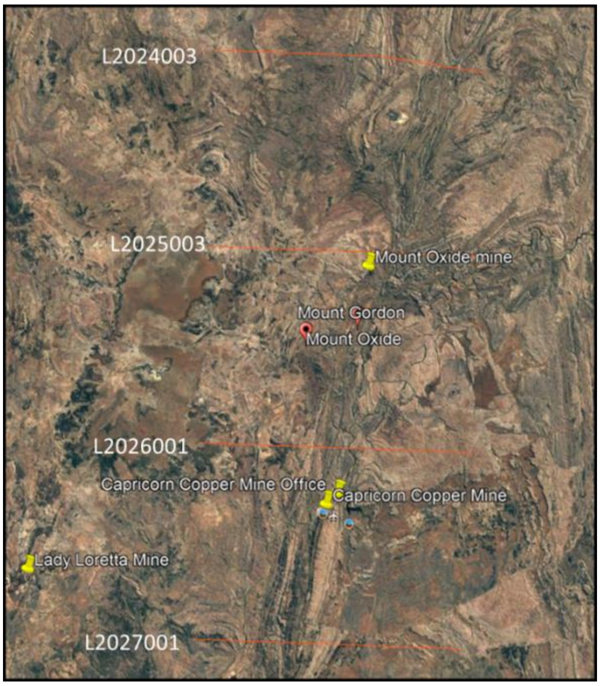

Figure 5. Extracts of AusAEM TEMPEST survey lines in the vicinity of the Capricorn Copper and Mount Oxide Mines, shown on Google Earth imagery. Survey lines spaced at 20km.

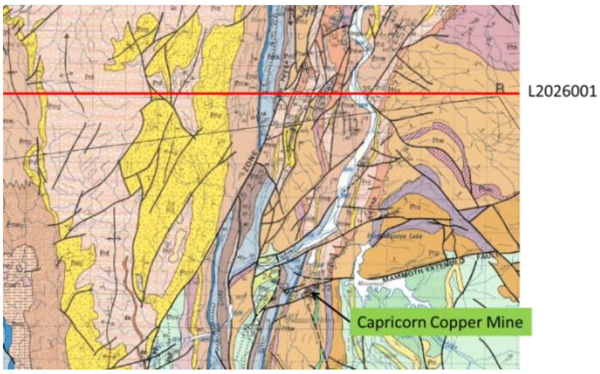

Figure 6. Line 2026001 shown on Mammoth Mines 1:100,000 geology (graticule 1km). Location of sub parallel cross section A-B shown south of TEMPEST line.

CONCLUSIONS

This case study covers a relatively small area of the large AusAEM TEMPEST survey. Whilst the survey was conducted at a wide line spacing, conductivity imaging by Moksha 2.5D inversions has demonstrated the ability to identify possible exploration targets and map steeply-dipping and folded geology in a deformed terrane.

The results from the Mammoth Mines study has provided encouragement to perform 2.5D inversions over other mineral belts covered by the AusAEM survey such as the Tennant Creek block and extensions of key fault zones such as the Mount Isa fault. However it is likely that large areas underlain by significant sedimentary and regolith cover would not have been penetrated by the TEMPEST system, though opportunities may exist for the imaging of areas with groundwater potential.

ACKNOWLEDGMENTS

The authors acknowledge Geoscience Australia for online access to the AusAEM data.

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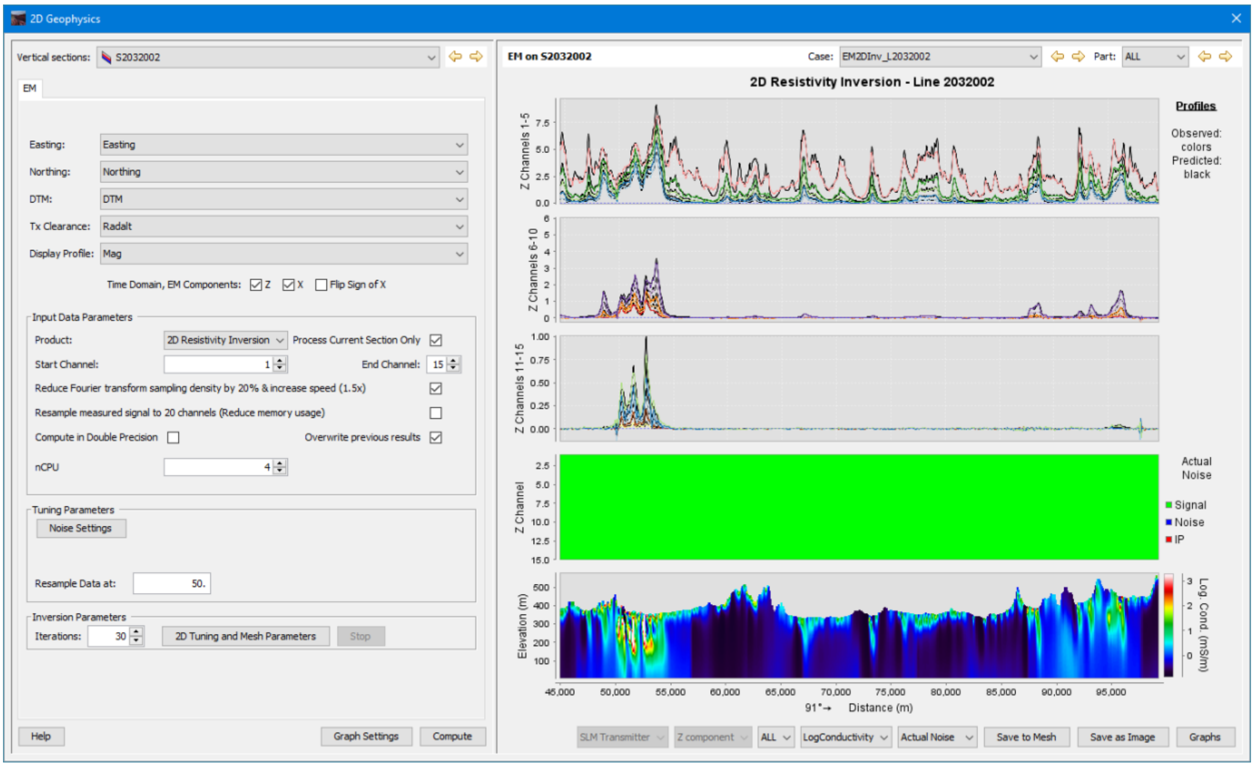

Figure 3. Example of the Moksha 2.5D inversion GUI inside GeoModeller. Conductive stratigraphy associated with the Mount Isa orebody is evident near the western (left) end of the line.

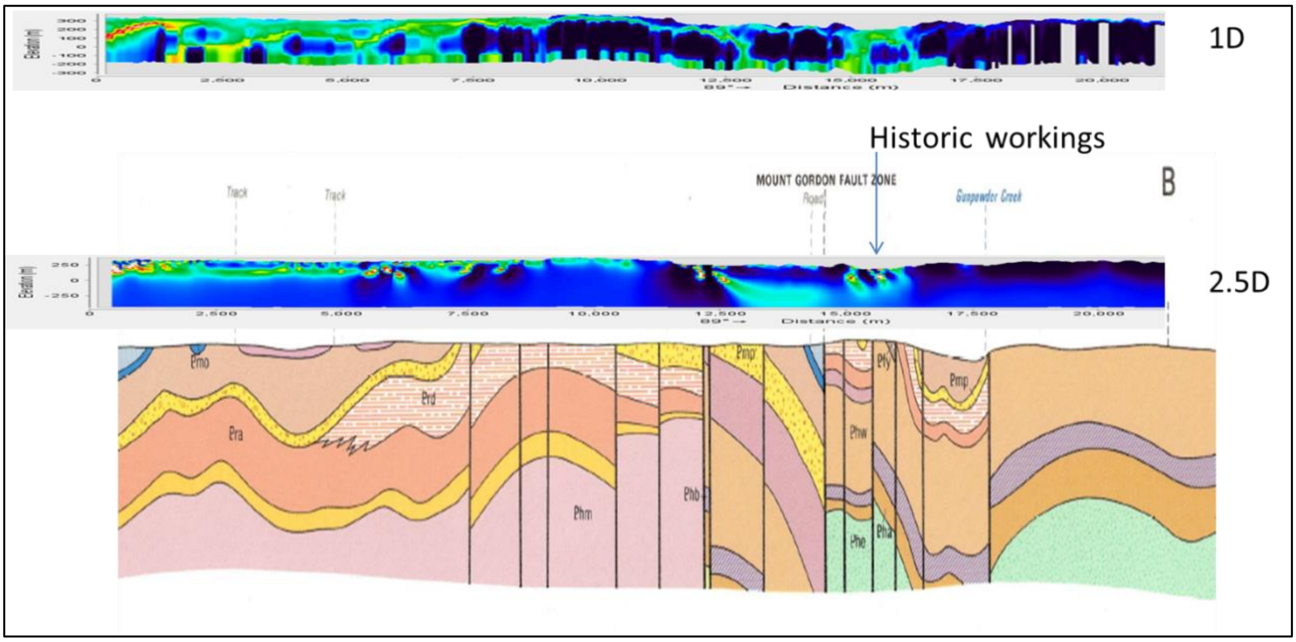

Figure 7. Results of 1D and 2.5D inversions from Line 2026001 over the Mount Gordon Fault Zone. Images are of log conductivity. The 2.5D inversion result shows clearly defined moderate to steeply-dipping conductors associated with the

Whitworth Quartzite (Phw) which hosts the major copper deposits in the region. Depth range on conceptual geological section ~3000m.

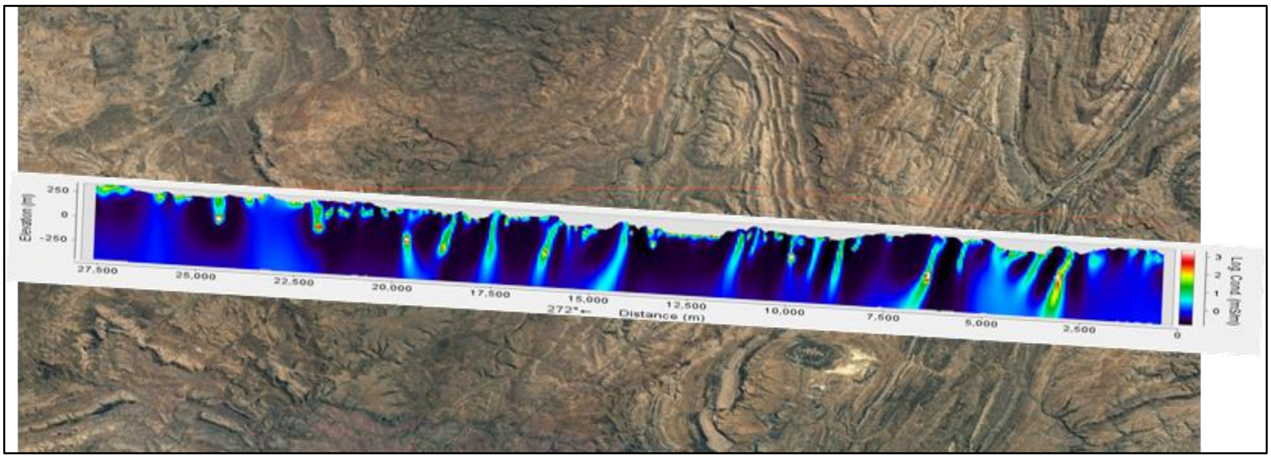

Figure 8. 2.5D inversion section of log conductivity from the Mammoth Mines area, showing steeply-dipping conductors and possible exploration targets. The folded surface geology can be directly translated to anticlinal or synclinal features, with conductive marker beds indicating the near surface fold limb dips.