Modelling and matching the airborne EM response of Harmony and Maggie Hays

David Annetts
CSIRO DEM, Australia
David.Annetts@csiro.au

Fred Sugeng
CSIRO DEM, Australia
Fred.Sugeng@csiro.au

Art Raiche
CSIRO DEM, Australia
Art.Raiche@csiro.au

SUMMARY

Using two examples, we show good matches between field and 3D modelling data. The 3D models were small enough to reduce runtimes, yet incorporate sufficient complexity to model complex environments more accurately than plate or layered-earth based models.

Time and effort involved in this modelling, although greater than for simple models, is not excessive, and can easily be accomplished on a PC-class computer.

Key words: Electromagnetic, airborne, 3D, modelling

INTRODUCTION

Often, interpreters of EM data use simple models, such as layered earths and inductively-thin plates or filaments to model field data, resorting to more complex 3D models only as a last resort. Because of the importance of including structure such as topography (Raiche et al, 2001) and the irregular regolith (Annetts et al, 2000), we suggest that using simple models at the start of an interpretation programme may be false economy of labour.

When 3D models are used from the outset, additional geological information can easily be incorporated if or when it becomes available. A particular advantage of 3D codes can be seen when trying to model a regolith that dips gently over the length of a flight line. Should the mean thickness be modelled, or should the dipping regolith be modelled as a stair step? With appropriate 3D codes, the dipping regolith can be incorporated directly, leaving interpreters free to concentrate on other anomalies.

Our aim is to show some of the advantages in using full 3D models in an interpretation.

CODE VALIDATION

It is traditional in papers concerned with modelling, to give a detailed validation of the codes used. The space restrictions of an extended abstract preclude this. However, the validity of our codes will become evident in the central body of this abstract when field data are modelled using methods such as the 3D finite element method (Loki / LokiAir), a 2.5D finite element method (ArjunAir) and a 3D thin sheet approximation (Leroi / LeroiAir).

Being able to model field data is perhaps the final arbiter of a code's validity, and this is of prime importance in this abstract.

DISCUSSION AND RESULTS

We illustrate the use of 3D modelling programs with two specific examples. In the first case, we model the response of the Harmony deposit as a simple example. As a more complex case, we model the response of the Maggie Hays deposit. In both cases, we seek reasonable agreement between field and model responses rather than attempting to model every nuance in the field data. Space limitations of an expanded abstract preclude detailed comparison of model components with field data.

Because EM responses typically contain cross-overs which significantly distort objective quantitative comparisons, we base modelling success upon visual inspection rather than a quantitative percentage difference between field and model data sets.

For timing purposes, all computations were carried out on 1.7GHz PCs running Linux.

THE HARMONY DEPOSIT

The Harmony Ni-S deposit (Stolz, 2000) is located near Leinster, WA and consists of 7.6 Mt with a Ni grade of 1.55%. The difficulty in detecting the ore zone at Harmony is two-fold. Firstly, it is situated between two very conductive dipping graphitic shale horizons, and secondly, at 70 m to the top of the conductive zone, it is reasonably deep. Figure 1 shows inline-component 25 Hz GEOTEM data through Line 2111 of the orebody and its host. In Figure 1, the flight direction is from East to West (Right to Left), and it is difficult to distinguish the response of the target zone from that of the two shale horizons. Wolfgram and Golden (2000) showed that if the depth to the top of the target zone was increased to 250 m, then its response fell below noise floors of common AEM prospecting systems rendering the target undetectable by common prospecting systems.

Figure 2 compares inline-component field data with the response from a model computed using LokiAir (Raiche et al, 2003). The model used is illustrated in section and plan (at RL = -80) views in Figure 3 and is quite coarse, employing some 44469 cells with a typical West-East length of 40 m. In Figure 3, both shale horizons and the central target zone run the entire extent of the model. Wolfgram and Golden modelled all three zones as conductances, but we based thicknesses of all bodies upon the simplified geological section in Figure 1 and used thicknesses of 80 m and 40 m for western and eastern graphite zones, and 40 m for the central target zone.

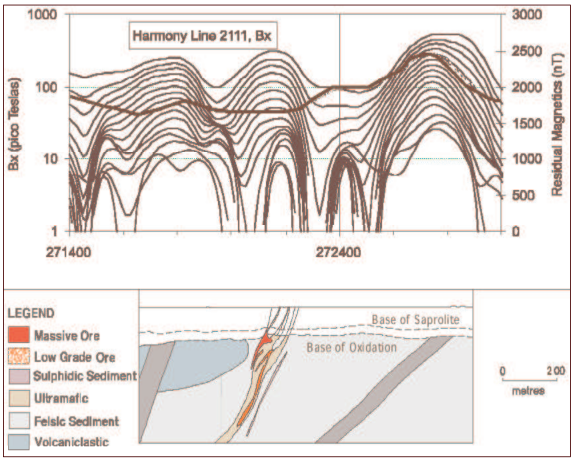


Figure 1. Inline-component 25 Hz GEOTEM data and simplified geological section of the Harmony deposit (after Wolfgram and Golden, 2001). The thick black trace plots the residual magnetic response.

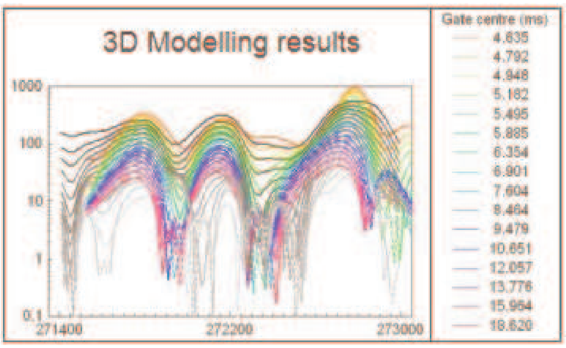
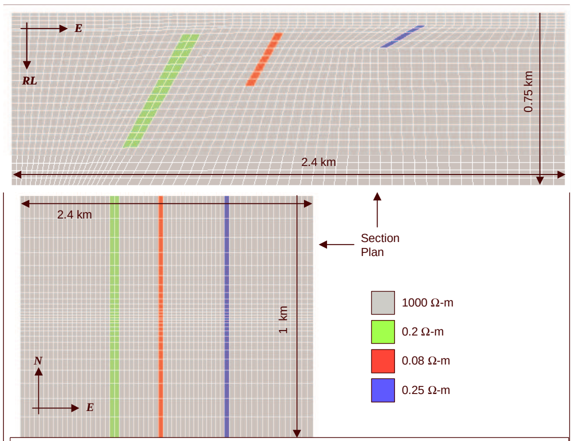


Figure 2. Comparison between 3D modeling (colour) anc field (grey) data sets for the Harmony deposit. Th underlying model used is illustrated in Figure 3. There i good agreement between the two data sets.

Agreement between LokiAir data and the field data in Figure 2 is excellent, and this validates the finite-element codes, but unsurprising given the success of Wolfgram and Golden using an even simpler model. There are some differences, particularly at the western and eastern ends for the traverse, and in the central region near 271900E and 272400E where the inline component response changes sign.

By way of comparison, inline-component field, full 3D, 2.5 D and 3D thin model responses at 1.38 ms are compared in Figure 4. The 2.5D model was taken through the centre of the model in Figure 3, and space limitations prevent including the 2.5D data. Differences between model and field data occur mainly between response peaks (for example, between 272200E and 272600E) indicating that some near-surface conductive units are not being modelled. In general, agreement between all data sets is good. That the full 3D response is higher than the 2.5D response indicates that the 3D model is under-discretised.

Time and memory requirements for these models were modest at 6 seconds per frequency and 80 MB for the 2.5D model and 32 seconds per frequency per station and 117 MB for the 3D model. Some 34 frequencies and 61 stations were used for both models. Time-domain results were computed using a Hankel transform technique described by Raiche (1999).



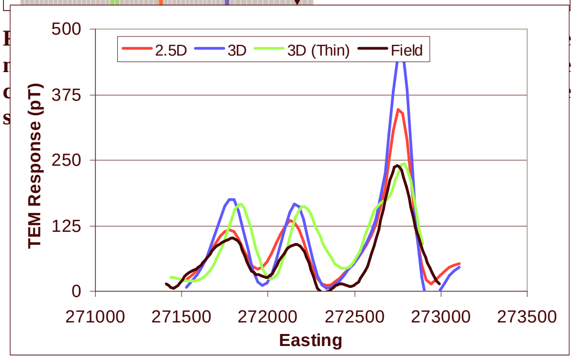


Figure 4. Comparison between field, 2.5D, 3D (thin) and full 3D data sets at 1.38 ms.

THE MAGGIE HAYS DEPOSIT

Located in an Archaean greenstone belt some 500 km east of Perth, Western Australia, the Maggie Hays deposit is complex, containing disseminated and massive Nickel Sulphides, estimated at 11.9 Mt at 1.47 % Ni. The deposit is blind and deep with disseminated zones at depths between 200 and 400 m and massive zones between 450 and 500 m, and situated near faulted BIFs. We did not attempt to model the magnetic permeability in any of the rock units, and this has the effect of reducing modelled amplitudes slightly. The regolith is conductive and has variable thickness. Peters and Buck (2000) conclude that the Maggie Hays North zone studied by Wolfgram and Golden (2000) was found by geophysical techniques, but that the central body, which is the subject of our modelling, was probably not. The Maggie Hays deposit is illustrated in Plane view in Figure 5, and we modelled Line 82700N (Figure 6).

Our simplified model of Maggie Hays section 82700N is illustrated in Figure 7. The model consisted of some 62073 cells, that had a typical West-East length of 40 m, and were shorter near boundaries between conductive units. Field data from two lines flown over the Maggie Hays deposit are reproduced in Figure 8. These lines straddle the section 82700N and were flown in different directions. Line 82815N (Figure 8A) was flown from West to East (Left to Right) while Line 82615N (Figure 8B) was flown from East to West.

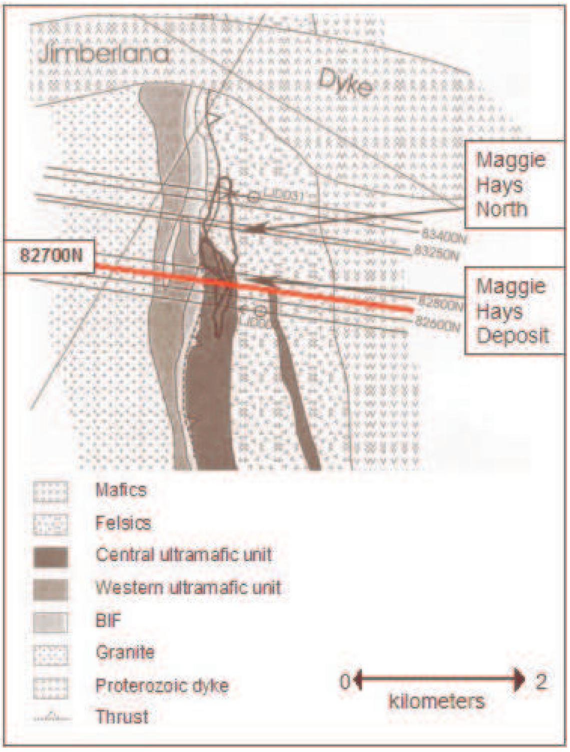


Figure 5. Plan view of the Maggie Hays complex (after Peters and Buck, 2000). Line 82700N is highlighted.

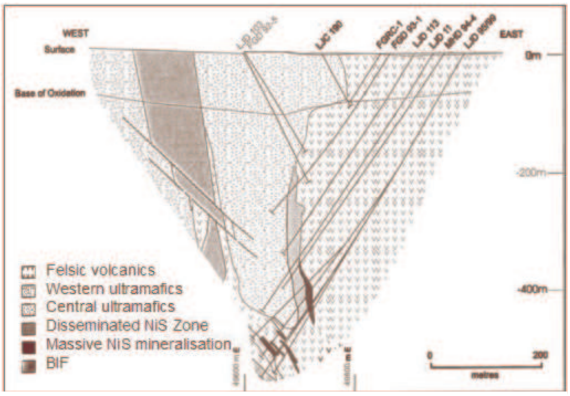


Figure 6. Section view of Line 82700 N at Maggie Hays (after Peters and Buck, 2000).

of 49500E is more conductive than the Eastern half of the model. Because we based model resistivities on values of inductive conductivity from a petrophysical analysis (Peters and Buck, 2000), our background is uniform, and any gradient in modelled data would have indicated an error in the code. Lack of a model background gradient also means that the anomaly at 49700E is much stronger in the model data set than in field data.

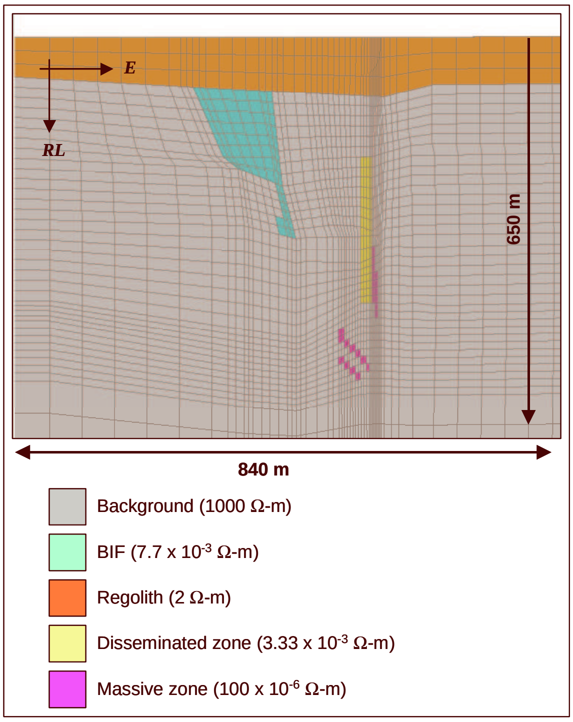


Figure 7. Detailed model schematic of Maggie Hays Line 82700N. Resistivity values were derived from Peters and Buck (2000).

Similarities between the two data sets are that Lines flown from East to West have an anomaly near the surface projection of the mineralised zone at 49700E. Furthermore, both the lines flown from East to West show a broad low near 49500E corresponding to the location of the BIF's. For both field and model data sets, lines flown from West to East give indications of neither the BIF's or the mineralised zone. Differences in model response with reversed flight direction suggest that ground-based surveying might have more success with large fixed loops placed east of 49600E.

CONCLUSIONS

We have successfully modelled the EM response of two orebodies using complex models. Such modelling is certainly more time consuming and memory intensive than using simple approximate models. However, the use of complex models from the outset means fewer assumptions need to be made concerning uniformity of the regolith and the thickness of other conductive units.

From modelling AEM data at Harmony, we have shown good agreement between field data and model data using different methods. Success was less apparent at Maggie Hays although modelled sections exhibited important similarities to field data.

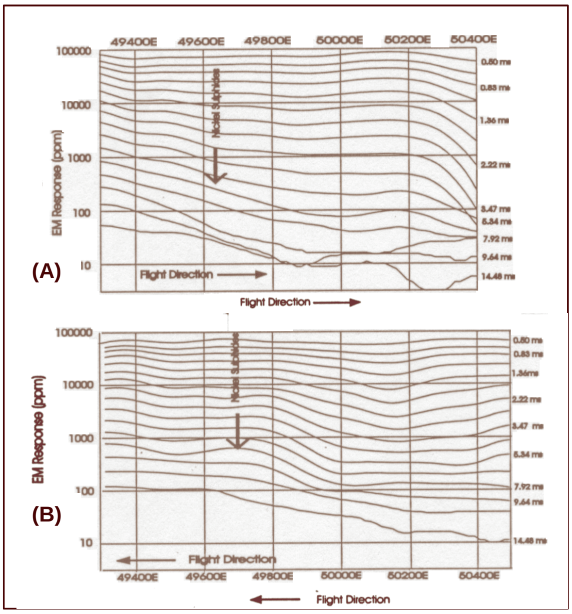


Figure 8. Inline-component 25 Hz GEOTEM data from lines 82815N (A) and 82615N (B) at Maggie Hays (after Peters and Buck, 2000). These lines straddle the section in Figure 6 and flight direction is indicated.

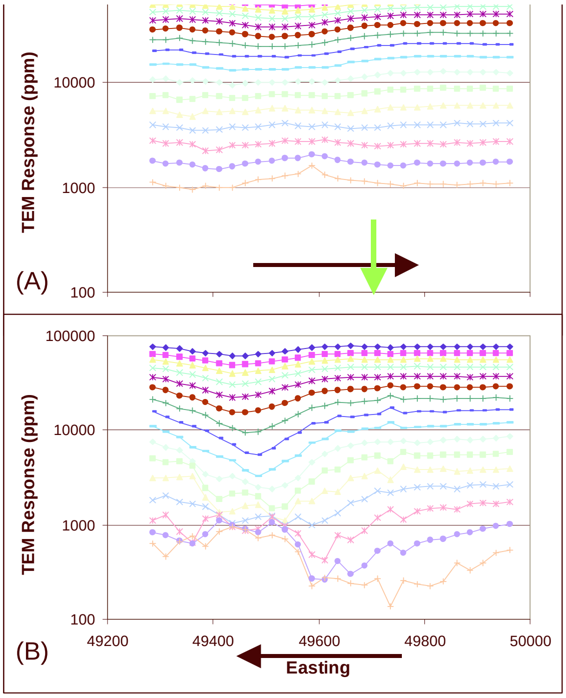


Figure 9. Modelled data for Line 82700N. Both sections were based on the model in Figure 7 but Figure (A) was flown from West to East while Figure (B) was flown from East to West. The mineralized zone is apparent only when flown from East to West. The vertical arrow denotes the locaion of the mineralized zone.

Current codes are easily able to model quite complex responses on desktop PCs. The extra information and versatility that comes from using 3D more than outweighs their longer runtimes and great memory requirements. If strike lengths are significant, then 2.5D models can be used instead of 3D models, cutting run times even further. We recommend that 3D modelling be used in preference to simple models where the host environment has a moderate level of complexity, for example, when topography or a variably-weathered regolith is significant.

REFERENCES

Annetts, D., Sugeng, F., Macnae, J. and Raiche, A., 2000, Modelling the airborne electromagnetic response of a vertical contact, Exploration Geophysics, 31, 115-125.

Peters, B. and Buck, P., 2000, The Maggie Hays and Emily Ann Nickel deposits, Western Australia: A geophysical case history, Exploration Geophysics, 31, 210-221.

Raiche, A., 1999, A flow through Hankel transform technique for rapid accurate Green's function computation, Radio Science, 34, 549-555.

Raiche, A., Sugeng, F., and Soininen, H., 2003, Using the Loki 3D finite element program to model EM dipole-dipole drillhole data, ASEG 16th Geophysical Conference and Exhibition.

Raiche, A., Annetts, D. and Sugeng, F., 2001, EM Target responses in complex hosts, ASEG 15th Geophysical Conference and Exhibition.

Stolz, E., 2000, Electromagnetic methods applied to exploration for deep Nickel Sulphides in the Leinster Area, Western Australia, Exploration Geophysics, 31, 222-228

Wolfgram, P. and Golden, H., 2001, Airborne EM applied to Sulphide nickel – examples and analysis, ASEG 15th Geophysical Conference and Exhibition.

ACKNOWLEDGEMENTS

It is our pleasure to acknowledge the sponors of AMIRA Project P223E *viz*. BHP Billiton Minerals Discovery, WMC Exploration, Rio Tinto Exploration Pty. Ltd., FUGRO Airborne Surveys, Sumitomo Metal Mining Corporation, Western Metals Resources, Geological Survey of Finland, DSTO, Pasminco Ltd., MIM Exploration Pty. Ltd., Anglo American Prospecting Services Pty. Ltd, AngloGold Australia Ltd, De Beers Australia Exploration Ltd. and Aurion Gold Ltd.