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Constrained Magnetic Modelling of the Wallaby Gold Deposit, Western Australia

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SUMMARY

The Wallaby Gold deposit is located 25km southwest of Laverton within the Eastern Goldfields Province of Western Australia. Gold mineralisation is hosted within a mafic conglomerate, intruded by a south-plunging magnetite-actinolite-epidote-calcite altered syenite pipe. Regions of low susceptibility within the pipe are associated with gold mineralisation.

Airborne magnetic data from the Wallaby Gold deposit was inverted using the University of British Colombia Geophysical Inversion Facility MAGINV3D code to produce a 3D model of the subsurface magnetic susceptibility.

Magnetic susceptibility measurements acquired at 1m intervals on diamond drill core were used to constrain the results of the inversion. This was facilitated using the Sparse Constraint Model Builder, which creates a physical property model based on existing geological, geophysical or geochemical measurements to then be applied within the UBC-GIF inversion code.

The constrained inversion defined regions of low magnetic susceptibility within the outer high magnetic susceptible zones of the alteration pipe and potential mine-scale structural features can be interpreted. This is useful information given the structural control on gold mineralisation at Wallaby and its association with regions of reduced magnetic susceptibility.

Key words: Wallaby gold deposit, magnetic susceptibility, constrained 3D Inversion

INTRODUCTION

The Wallaby Gold deposit is located 25km southwest of Laverton within the Eastern Goldfields Province (EGP) of Western Australia. Gold mineralisation is hosted within a mafic conglomerate, intruded by a south plunging (50^{O}) magnetite-actinolite-epidote-calcite altered syenite pipe (Miller, 2010). The Wallaby alteration pipe is characterised by a less magnetic interior and more magnetic exterior producing a twin peak magnetic anomaly (Coggon, 2003). Gold mineralisation at Wallaby is related to feeder structures in low to moderate magnetically susceptible zones associated with this syenite pipe (Coggon, 2003; Miller, 2011; Salier *et al*., 2004). The main regional ductile shears that are key controls on fluid mixing within the deposit include the Thet's Fault, and the Kahuna and Wedge Shears (Miller, 2005). The Chatterbox Shear is also thought to have controlled the location of the deposit and can be mapped north of Wallaby (Miller, 2005; Mueller *et al*., 2008; Salier *et al*., 2004).

Magnetic susceptibility models produced by Coggon (2000, 2003) define the geometry and magnetic susceptibility variations within the inner and outer alteration pipe. Neilson (2005) produced GoCad models based on the alteration halos and magnetic susceptibility information to confirm the link between regions of low magnetic susceptibility and gold mineralisation. The work described here aimed to refine the existing magnetic susceptibility models to better understand structures within the deposit, to identify low/moderate magnetic susceptibility regions that can be used as proxy indicators for gold mineralisation, and to map the potential lateral and depth extent of mineralisation, using a 3D constrained magnetic inversion.

Geophysical inversion provides a model of the subsurface physical properties. Due to the non-uniqueness of inversion, many solutions can be found to fit the observed data. Errors present in potential field data can also produce models that may not be geologically realistic. Mathematical, geological and petrophysical constraints, however, can be used to direct a geophysical inversion to a more realistic model of the subsurface. Williams (2008) developed the Model Builder for use with the University of British Colombia Geophysical Inversion Facility (UBC-GIF) potential field inversion codes including the magnetic inversion code MAGINV3D (Li &

Oldenburg, 1996). The Model Builder uses petrophysical, geological or geochemical information to create a pre-determined reference, initial or bounds model to constraint an inversion (Williams, 2008). Wallaby is a relatively well understood mineral deposit and is therefore a good case study to test the Model Builder's capabilities in helping define the 3D magnetic characteristics of the gold deposit.

METHOD AND RESULTS

A detailed airborne magnetic survey at 50 m line spacing was flown in 1998, and resolves a twin peak bullseye anomaly of 910nT over Wallaby. Before inverting the data it was reduced to pole and a 1st order linear trend removed and upward continuation of 20m was applied (Banaszczyk, 2011). An unconstrained MAGINV3D inversion of the potential field data was initially run, and the result compared with the known deposit features (Figure 1). The model matches the data, however it does not resolve any detail within the deposit itself nor correctly identify the plunge of the alteration pipe.

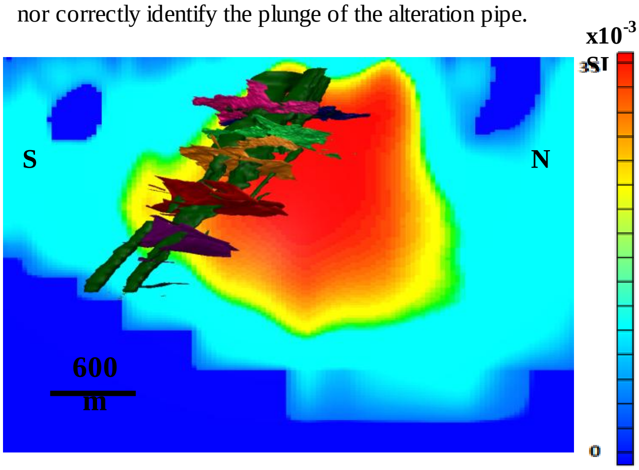

Figure 1. Unconstrained UBC-GIF inversion of the Wallaby deposit with the known alteration pipe and gold lodes overlain for comparison.

A physical property model was then created, facilitated by the Model Builder, from more than 335,500 magnetic susceptibility measurements taken at 1m intervals on diamond drill core. The physical property measurements provide a direct link between the known geology at Wallaby and the constraints to be applied in a MAGINV3D inversion. Buffers applied within the Model Builder were used to extrapolate individual magnetic susceptibility measurements away from single points into regions where there are no constraints available (Williams, 2008).

The physical property model (Figure 2), defines the dip of the alteration pipe, the outer high and inner low magnetic susceptible regions and variations in magnetic susceptibility down to approximately 1.5 km. The Chatterbox Shear Zone, Thet's Fault and the Wedge Shear can also be interpreted, making this model geologically realistic for constraint of a 3D inversion.

This physical property model was applied as a bounds and reference model in a MAGINV3D inversion. An initial model was found to make little difference to the inversion result compared to a reference model constraint. The physical property models and subsequent constrained inversions were trialled iteratively using the Model Builder functions (Williams, 2008) and MAGINV3D inversion parameters (Li & Oldenburg, 1996). Models were trialled initially using a coarse mesh (X: 100m Y: 100m Z: 50m) with the final models created and inverted using a fine mesh (X: 25m Y: 25m Z: 12.5m).

To test how well the physical property model and inversion results represent the Wallaby geology, the models were visually assessed, and forward and residual calculations were performed. The inversions constrained using the physical property model applied as a reference model produced a more geologically realistic model of the Wallaby deposit and these fine mesh results are presented here (Banaszczyk, 2011).

The forward calculation from the physical property model produced a dynamic range slightly less (562 nT) than that of the original aeromagnetic data. This is expected, however, since regions where limited or no magnetic information is available (outside the alteration pipe) the model fills these areas with zero values.

The physical property model applied as a reference model in a MAGINV3D inversion provides the magnetic susceptibility constraints for the 3D inversion (Figure 3). The result defines the less magnetic interior of the alteration pipe in detail and the more magnetic exterior to approximately 1 km depth. Regions of low magnetic susceptibility are defined within the outer high magnetic susceptible zones and potential mine-scale structural features can be interpreted within the alteration pipe. The decrease in mesh size has, however, increased the uncertainty in the model. A large high northern magnetic susceptible region has been modelled at approximately 500m depth (point 6). The known magnetic alteration of the Wallaby deposit is constrained to the altered pipe (Coggon, 2003; Miller, 2005) and the dynamic range from the forward calculation is slightly less than that of the original magnetic data (793 nT). These features suggest that where limited or no constraints are available in the reference model the inversion seems to be compensating by modelling an unrealistically high magnetic susceptible region outside the alteration pipe, rather than at depth where extension of the alteration would be expected (point 5). While this northern high is unrealistic, the detail within the pipe, dip and known interior and exterior magnetic susceptibility variation are useful for interpretation. At points 1 and 2, zones of low magnetic susceptibility are constrained by surrounding high magnetic susceptible regions. Points 3 and 4 are also regions of low to moderate magnetic susceptibility, however they are unconstrained at depth (point 3) and to the south (point 4). While slightly less detail may be apparent in the inversion at depth (below approximately 700 m) where limited constraints are present, the physical property model itself and the inversion results provide useful information.

DISCUSSION & CONCLUSIONS

Gold mineralisation at Wallaby is associated with regions of low to moderate magnetic susceptibility which occur within the Wallaby alteration pipe. Aeromagnetic data inverted using the MAGINV3D inversion algorithm provides a representation of this variation in the form of a 3D model. Magnetic susceptibility constraints, applied in the form of a reference model have significantly improved this 3D model result. The Model Builder is a useful tool for developing a constraining physical property model from magnetic susceptibility measurements taken along diamond drill core. The physical property model also provides a useful exploration tool defining the distribution of magnetism within the Wallaby deposit, the plunge of the alteration pipe and major structural features.

The constrained inversion provides a reasonable representation of the subsurface magnetic susceptibility distribution at the Wallaby deposit. When using a fine mesh with many cells to create a detailed inversion, however, there is an inherent increase in uncertainty. A compromise needs to be made dependent on the number of constraining physical property measurements, the number of cells in a mesh, and the resolution of detail required from an inversion. A relatively large cell size provides an efficient model for defining large features and may be all that's required as an exploration tool (Banaszczyk, 2011).

The inversion results resolve an unrealistic high magnetic susceptible region north of the alteration pipe. Further testing with the Model Builder and UBC-GIF inversion codes may decrease or eliminate this artefact to achieve a more geologically realistic inversion solution. Suggested parameters to test within the Model Builder include:

- Using a depth weighing on the physical property measurements to increase the detail modelled at depth.
- Applying smallness weights; used to indicate the reliability of the estimated reference model properties, to the magnetic susceptibility measurements to try and increase the reliability of each measurement and decrease the smooth model effect creating the unrealistic high magnetic susceptible region.
- Decrease or increase the buffer sizes in the physical property model to see if there is potential for less low magnetic susceptible material, or more high magnetic susceptible material to be resolved, respectively.
- Trial slightly larger cell sizes to decrease the uncertainty in the solution (e.g. X: 50 m Y: 50 m Z: 25 m).

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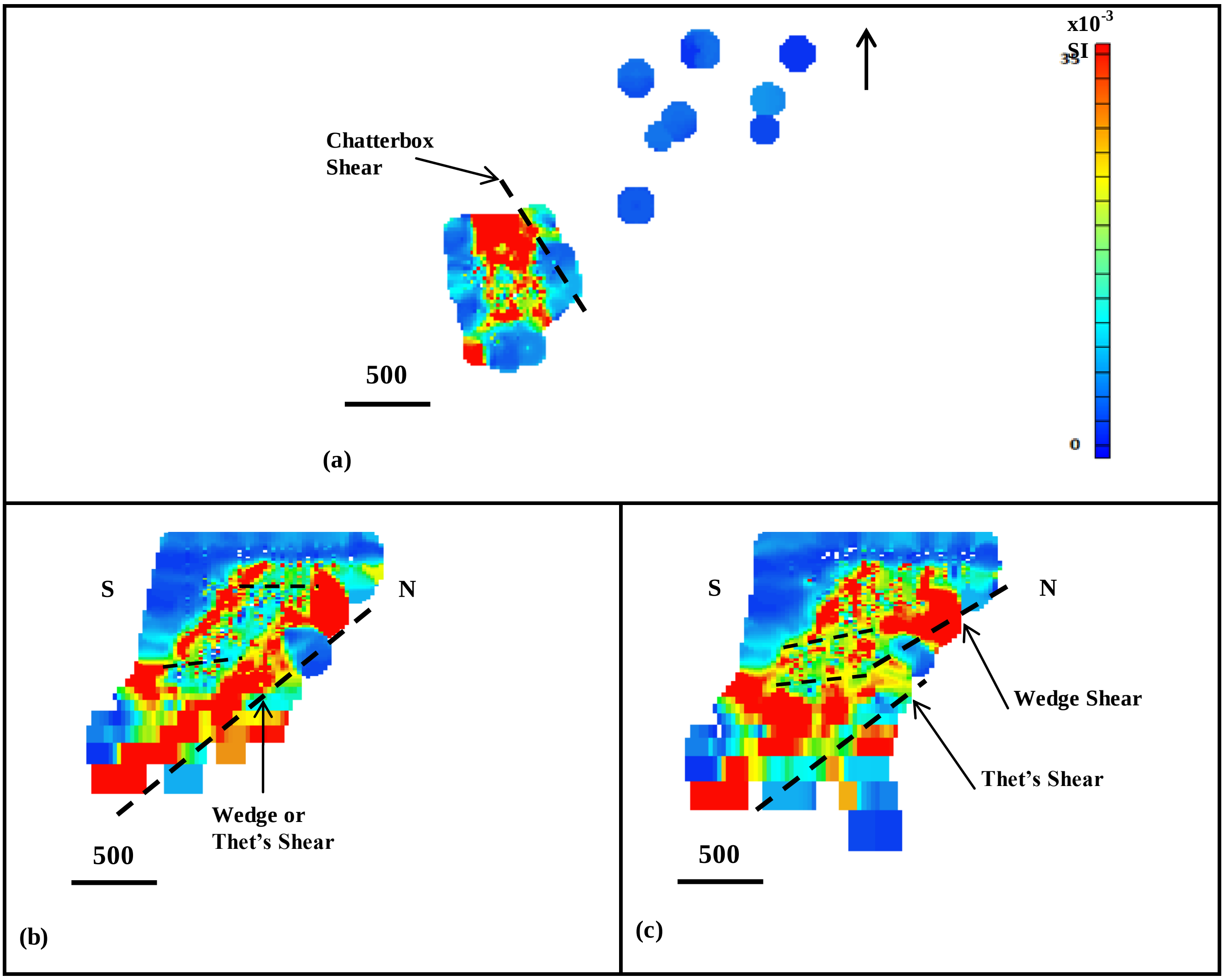

Figure 2. Physical property model of Wallaby built using the Model Builder and based on magnetic susceptibility measurements from diamond drill core. Plan view section (a) and north south cross sections (b) and (c). Structural interpretations have been annotated.

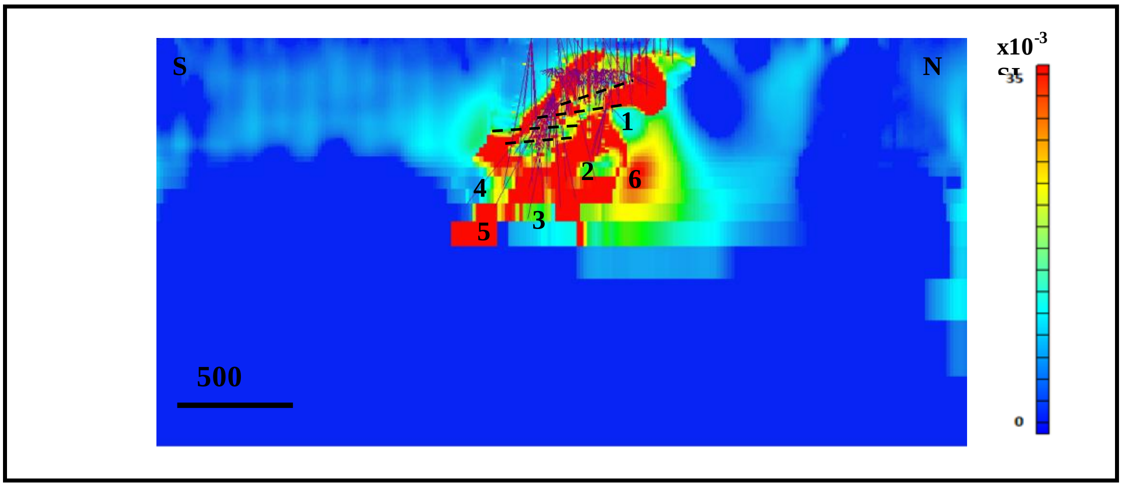

Figure 3. Cross section through the fine mesh constrained UBC-GIF inversion of Wallaby. Drill traces have been overlain, and potential structures have been interpreted. The numbered features are referred to in the text