Mapping the Punt Hill IOCG system using geophysical, geochemical and spectral methods – an integrated approach

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SUMMARY

Integrated data sourced from drill core geochemistry, spectral logs, petrophysical logs from available holes and geophysical data in and around the Punt Hill Copper-Gold prospect was used to characterise and map an IOCG system and predict prospective areas using a multi-disciplinary approach. Mineral assemblages associated with copper mineralisation were identified from geochemical analysis and spectral logs; density ranges associated with favourable mineral assemblages were noted and density inversions were fitted to these ranges in an attempt to predict similar densities in untested parts of the study area.

Mineral assemblages associated with both prograde- and retrograde-dominated assemblages were found to be associated with copper mineralisation at Punt Hill. Densities associated with the prograde mineralising event were generally higher than those associated with the retrograde mineralising event; both are higher than background density. This provided a basis for fitting the results of density inversions to the known data to map inferred prograde and retrograde alteration within the study area. Inversions were performed at both the regional and deposit scale and were used to identify as yet untested regions with density values that are consistent with known zones of mineralisation and therefore showing high potential for further copper mineralisation.

Key words: IOCG, skarn, inversion, geochemistry, spectral.

INTRODUCTION

South Australia hosts one of the world's great iron oxide copper gold (IOCG) terranes. Termed the Olympic Cu-Au Province (Skirrow et al. 2007), this belt is renowned as the host to Olympic Dam, the type example of breccia-hosted, hematite-rich IOCG deposits (Groves et al. 2003). The same thermal event resulted in variants of this deposit class throughout the Olympic Province and includes skarn-dominated mineralisation where these fluids interacted with calcareous lithologies. One such example is the Punt Hill Cu-Au project (Reid et al., 2011). While IOCG mineralisation sensu stricto is associated with significant accumulations of Fe oxide, prospects from the Punt Hill region represent an end-member of the broader IOCG deposit class.

Punt Hill is characterised by an extremely large skarn alteration system with associated Cu-Au-Ag-Zn-Pb and Rare Earth Element (REE) mineralisation. Skarn is developed within Palaeoproterozoic metasediments of the Wallaroo Group. Exploration in the project region has involved the use of potential field data (gravity and magnetics) to generate primary targets followed by diamond drill testing. To better understand and characterize the mineralisation in this district and investigate potential for exploration vectors that can provide additional targeting parameters, the Geological Survey of South Australia undertook a data integration project at tenement and deposit scale in the Punt Hill region. Importantly, this style of mineralization has not been characterized in the region and an exploration approach has not clearly been defined.

In this study, the GSSA use a multi-disciplinary approach to characterize regional as well as local scale alteration in the Punt Hill region. Results of this study provide an example of how integrating diverse data can be used to map mineral systems, recognise exploration vectors and improve the exploration approach.

METHOD AND RESULTS

The Punt Hill study incorporated a 50x50km area (Figure 1) in which data was collected from 118 drillholes including some 3000 geochemical samples, more than 5000 petrophysical measurements and over 17000 spectral measurements from 30 spectrally logged drillholes. Spectral scans of drill core were made using the semi-automated hyperspectral logging tool, HyLogger^{TM}. Selected samples were analysed for 65 elements by ICP as well as F by specific ion electrode. Drill hole sampling was accompanied by measurements of magnetic susceptibility and specific gravity.

Spectral, geochemical and petrophysical data were used to characterise dominant alteration assemblages (Figure 2). Copper mineralization was associated with alteration dominated by prograde and retrograde minerals including assemblages dominated by talc, amphibole, chlorite, garnet and pyroxene. These assemblages had magnetic susceptibility values of 0.0001-0.001 SI units and specific gravity values of 2.65-3.4 (Figure 3). These ranges are lower than what is expected in mineralization associated with Fe oxides. Although there was some overlap in density ranges between the prograde and retrograde assemblages, in order to facilitate density modelling the density ranges were taken to be mutually exclusive with a retrograde range of 2.8 – 3.1g/cc^3 and prograde 3.1 – 3.4g/cc^3 (Figure 3). These ranges were used to fit results of density inversions with the aim of mapping density ranges that may relate to skarn mineralisation away from drill holes and within the entire study area.

A regional density inversion with a 500m mesh size was completed over the entire Punt Hill region and a detailed inversion with a 25m mesh was performed over the data-rich Groundhog Prospect (Figure 1 and 4). For each inversion the Wallaroo Group (which is the host to mineralisation) was isolated based on a 3D geological model of the region. Within the Groundhog Prospect region (Figure 1 and 4), inferred prograde assemblages (with higher densities) were more abundant toward the south of the prospect and retrograde assemblages (lower densities) were more abundant to the north. Highest copper grades occurred where the model inferred there are an abundance of both prograde and retrograde minerals, which was consistent with what is seen in drill cores. This gave confidence that mapped prograde and retrograde skarn mineral assemblages from inversion modelling could provide targeting criteria within the region, namely density ranges that can be used to discriminate skarn alteration from background rocks and are distinct from values used to model hematite-rich bodies.

Computed density values from the inversion modelling were systematically lower than the range of values measured from the drill core. A best fit between the regional inversion and measured values was obtained by setting a density threshold that inferred retrograde densities in the northern portion of the Groundhog Prospect drillhole cluster and prograde densities in the southern portion. Using this approach, the inverted density ranges were scaled to fit modelled values from the Groundhog Prospect data (Figure 5) and the location of inferred prograde and retrograde alteration densities could be mapped on a regional scale. These results highlight the margin of inferred retrograde and prograde alteration fronts and are potential areas for future exploration. For the detailed Groundhog Prospect inversion, the finer mesh size made it possible to fit the inverted density range to the zone shown in Figure 4 and Figure 6a, where prograde and retrograde mineral assemblages occurred together, and density ranged from 3.05 – 3.2g/cc^3. The result is displayed in Figure 6b and predicts where similar density ranges exist to those that hosted copper mineralisation.

Regional magnetic inversion results mapped deep magnetic bodies, particularly in the south western portion of the study area (Figure 7). Although best Cu intersections in the Punt Hill prospects were not associated with significant quantities of magnetite, it had been noted that prospects are commonly spatially associated with residual magnetic anomalies. The regional magnetic inversion results showed that these anomalies are sourced from below the known mineralisation and may represent magnetite grown in fluid pathways. This significant finding is an example of magnetic inversion results being used to map mineral systems and contribute to the regional understanding of mineralisation and fluid flow.

CONCLUSIONS

When mineral assemblages associated with a mineral system are well understood and there is sufficient constraint on their petrophysical properties, magnetic and density inversion models can provide a powerful predictive capability. The Cu-Au mineralisation in the Punt Hill region is associated with density ranges that are distinctly above average values. Inversion models in this region are useful to assess regional prospectivity where there is little other constraining data. A consequence of large cell sizes used in inversion models is that it can be difficult to match modelled to observed data. In this study, scaling was used to fit results of inversions at two scales to results measured and mapped from a data-rich region. The regional density inversion was used to identify possible zones of interest within the broader region, while the detailed inversion results provided more specific vectors toward potential drill targets. Regional magnetic inversion results mapped distinct magnetic zones below the Groundhog Prospect and are interpreted to represent fluid pathways that link the skarn mineralization to IOCG mineral systems known in the region.

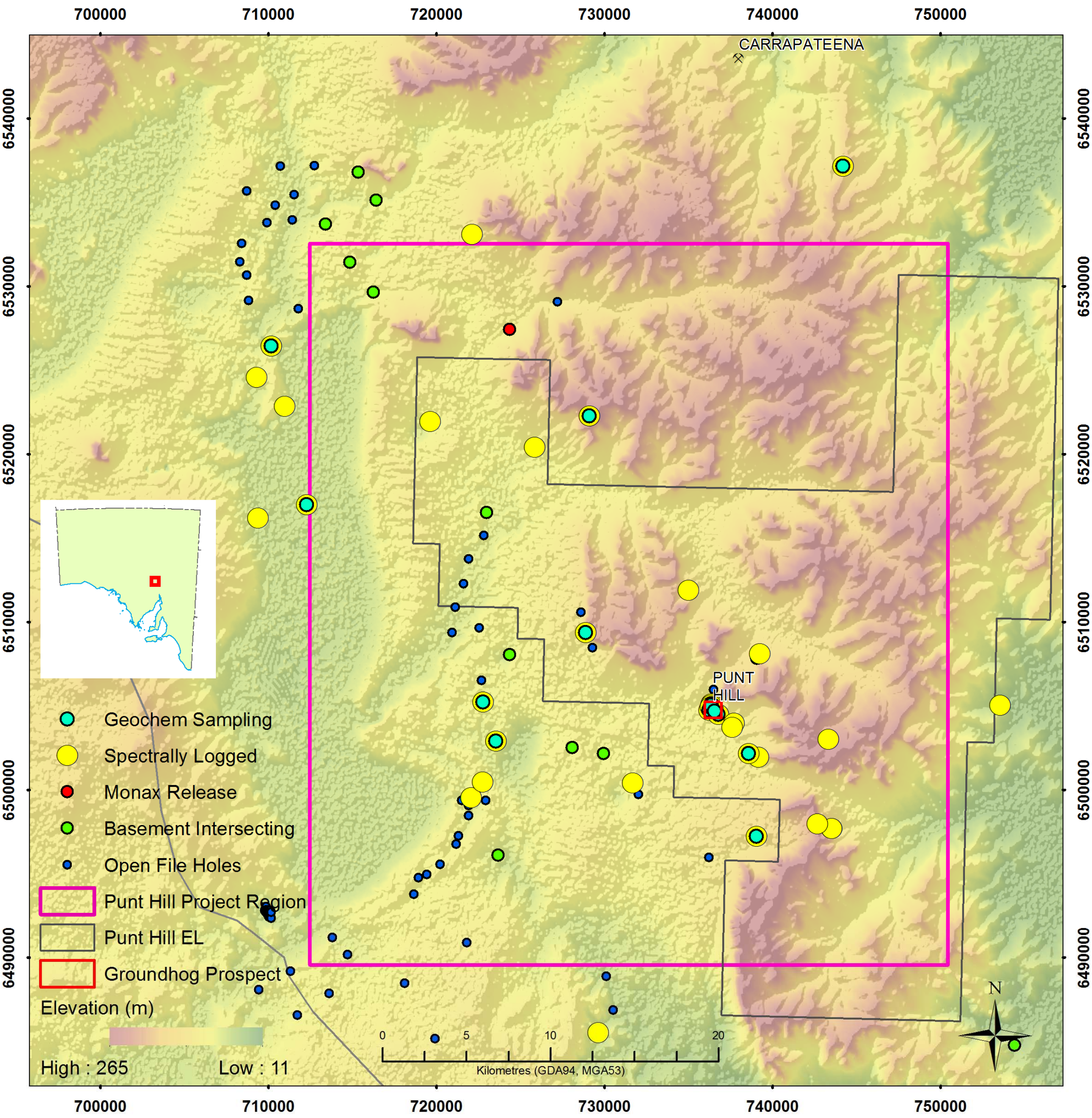

Figure 1: The Punt Hill study region, showing the location of the regional Punt Hill inversion (magenta rectangle), locations of drillholes sampled for the project and detailed Groundhog prospect inversion (red box). The digital elevation model (DEM) is in the background.

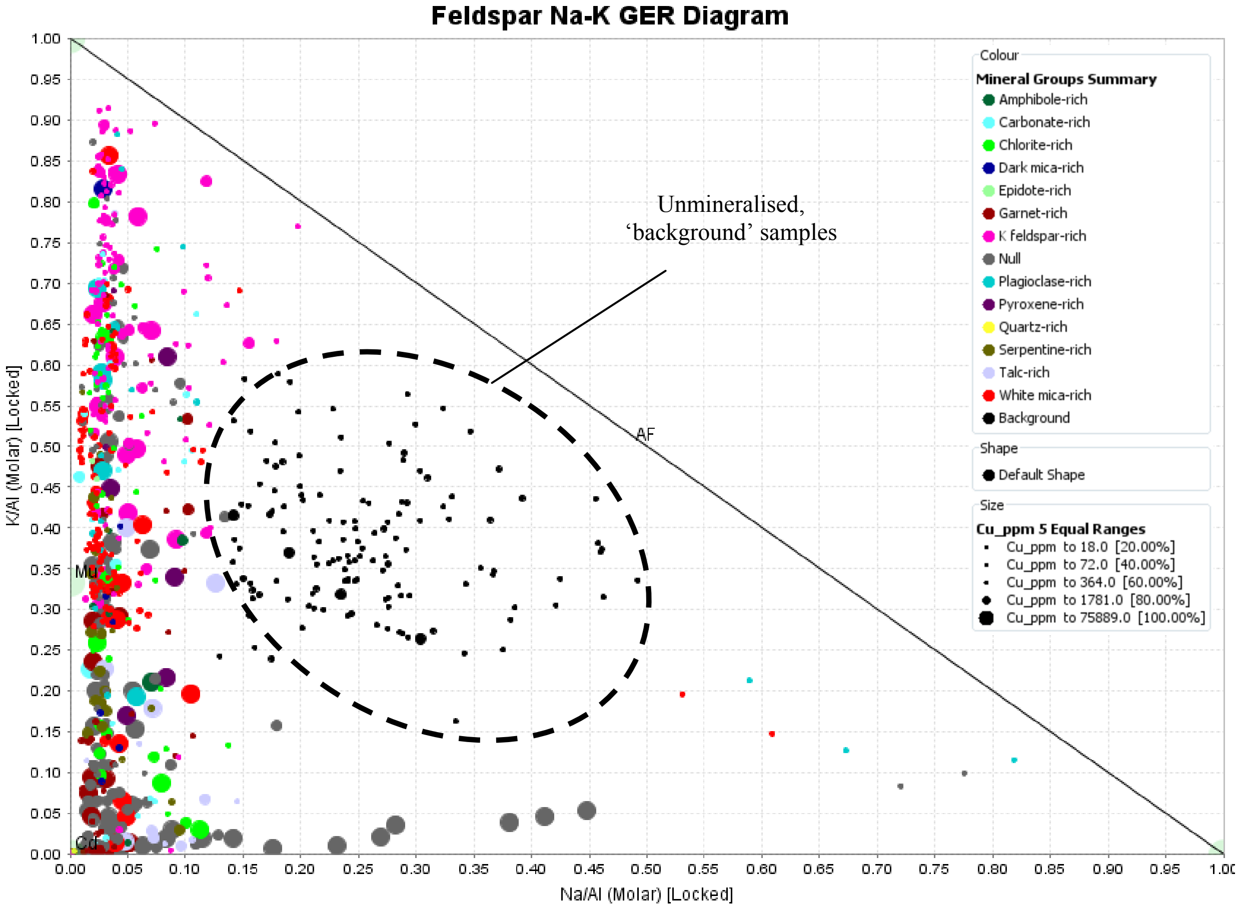

Figure 2. Feldspar GER diagram showing alteration assemblages derived from a combination of spectral and geochemical data. This plot of K/Al versus Na/Al values was used to define samples with minimal alteration. Alteration styles could then be associated with petrophysical measurements on the same sample.

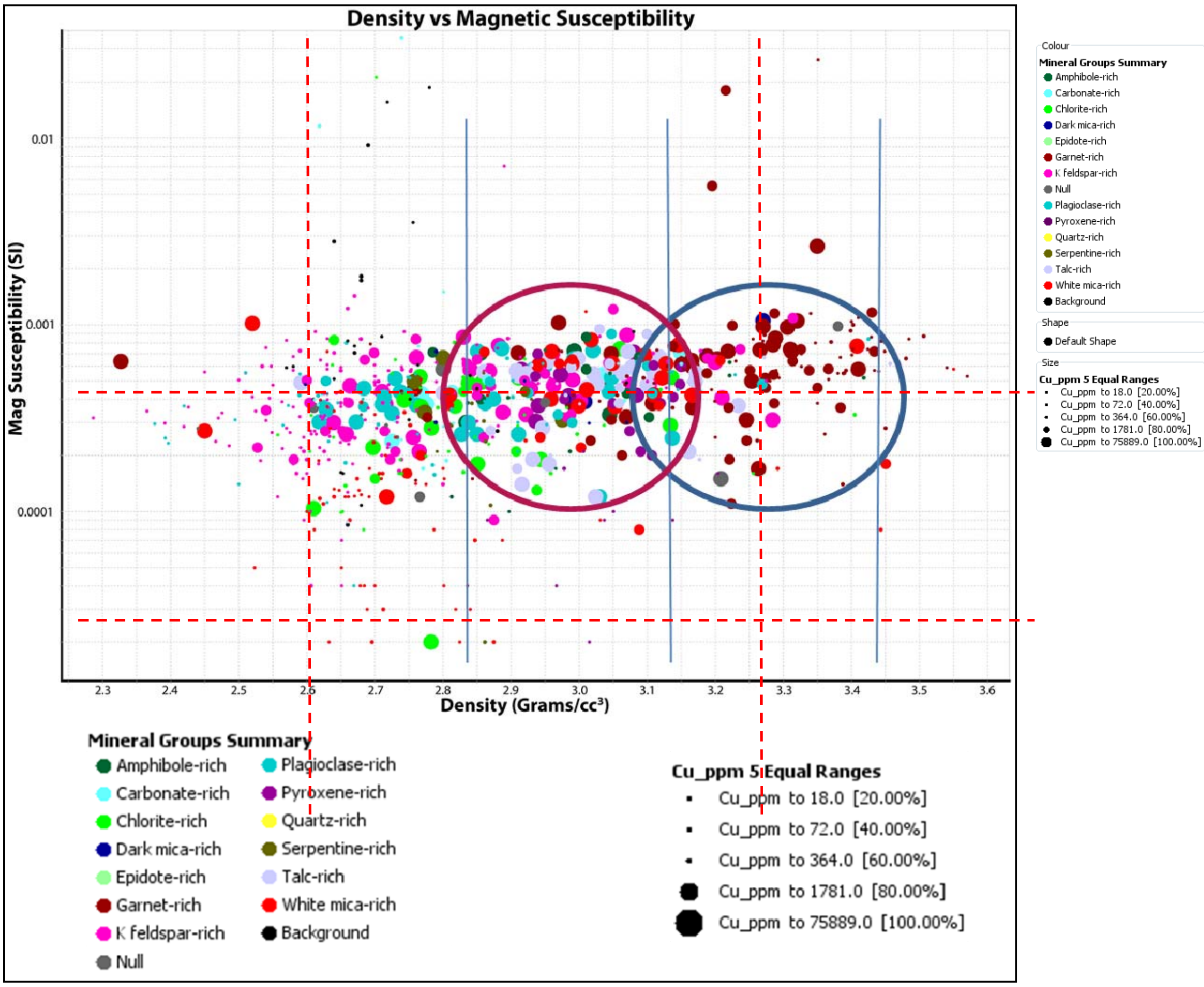

Figure 3. Mineral groups displayed by Cu ppm, density and magnetic susceptibility. At Punt Hill, prograde altered rocks have a moderately high density in the range of approximately 3.1 – 3.4 g/cc3. Retrograde overprinted rocks have a density range of approximately 2.8 – 3.1 g/cc3. Reasonable discrimination was observed between prograde and retrograde assemblages. Densities below 2.8 are considered to be background.

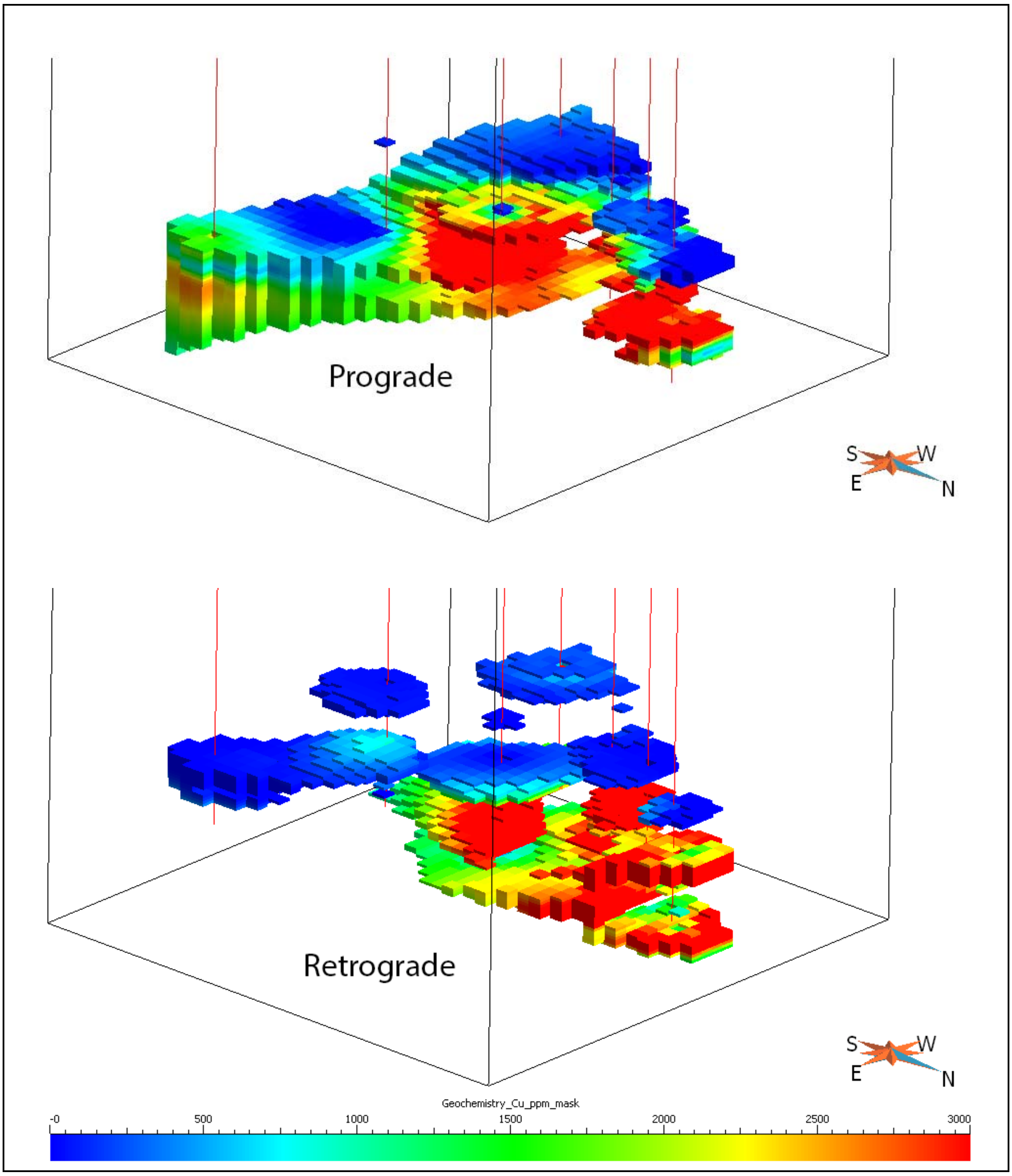

Figure 4: 3D view of the Groundhog prospect skarn alteration. Red vertical lines indicate drill holes. Density and copper abundance have been interpolated within an envelope around the seven drillholes (buffered to approximately 100m) within the Groundhog Prospect. Voxels representing prograde alteration (top, 3.1 – 3.4g/cc^3) and retrograde alteration (bottom, 2.8 – 3.1g/cc^3) are displayed, coloured by copper abundance. The modelling shows copper mineralisation is most prominent in the overlap between prograde and retrograde alteration at the northern end of the model.

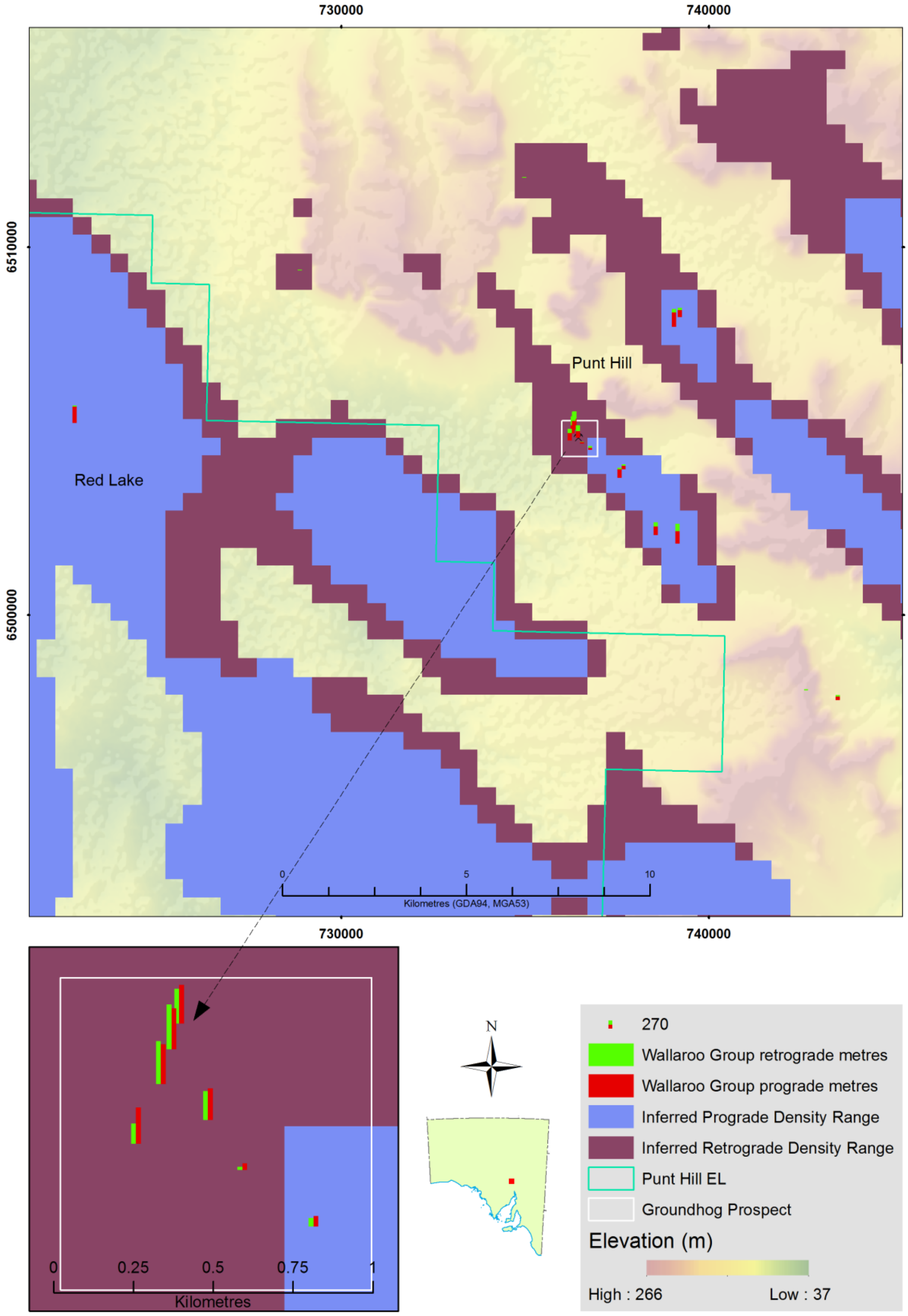

Figure 5: Unconstrained density inversion within the Wallaroo Group metasediments at Punt Hill. Prograde mineral assemblages have been identified at the Groundhog Prospect with a density range of 3.1 – 3.4g/cc^3; retrograde mineral assemblages have been identified with a density range of 2.8 – 3.1g/cc^3. The regional inversion results were fitted to the density ranges at the Groundhog Prospect (Figure 4). Blue regions are inferred densities ranging from 3.1 – 3.4g/cc^3; maroon regions are inferred densities ranging from 2.8 – 3.1g/cc^3. The Green and red bars illustrate the relative proportion of prograde and retrograde mineral assemblages in each hole – retrograde proportion increases from south to north.

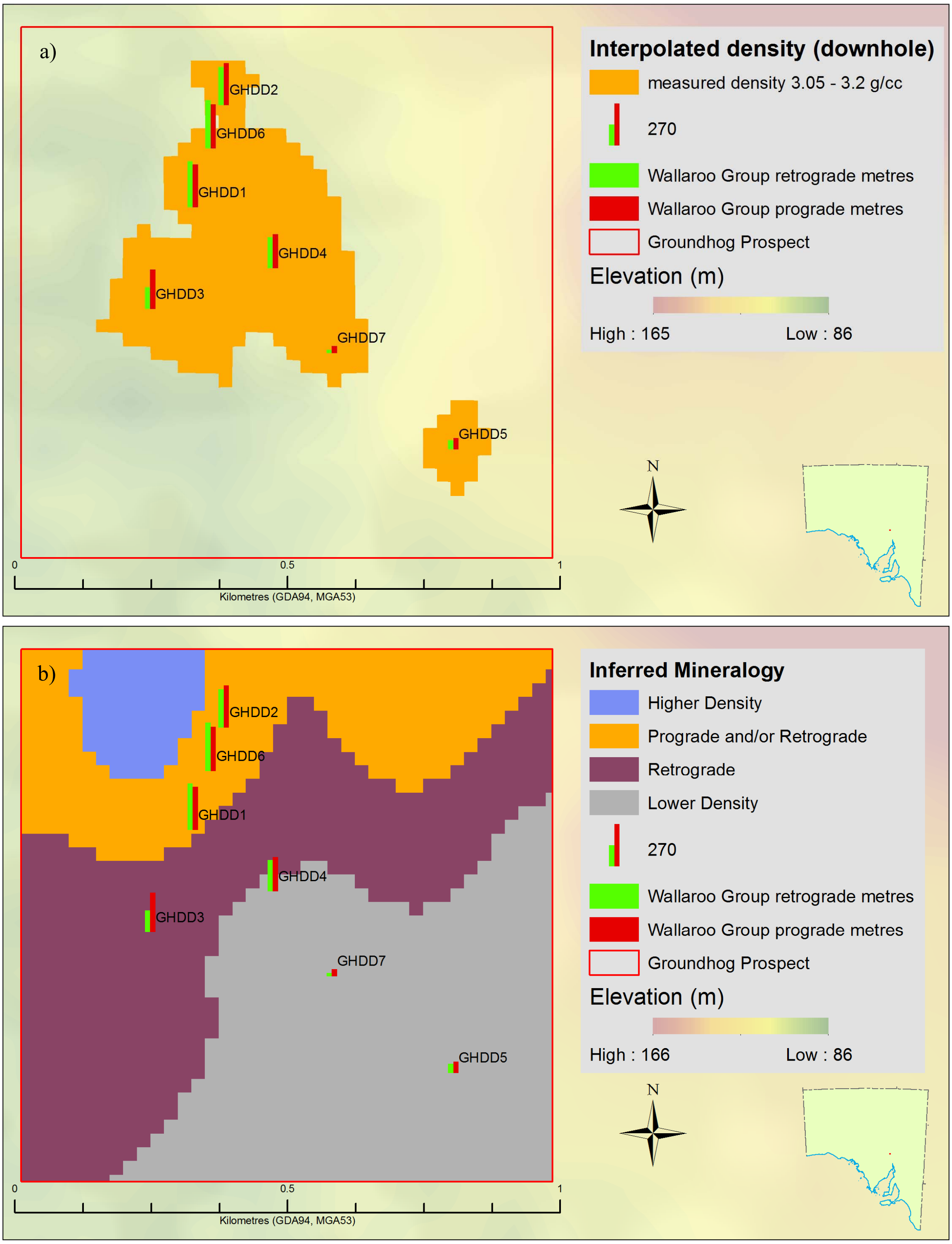

Figure 6: a): Interpolated density measurements from drillholes at Groundhog prospect. The density interpolation has been clipped to the drillhole envelope and is a subset of density with the range of 3.05 – 3-2 g/cm3. This density range coincides with regions that have an abundance of both prograde and retrograde mineral assemblages. b): Groundhog Prospect density inversion fitted to petrophysical density measurements and abundances of prograde and retrograde mineral assemblages. Contiguous density populations from the inversion model were selected that coincided with the drillholes that returned the highest proportions of combined prograde and retrograde mineral assemblages, which also matched measured density ranges of combined prograde and retrograde mineralised zones. The inversions infer the gold region is the most favourable target zone, followed by the maroon region. The red and green bars represent prograde and retrograde mineral assemblage abundances measured in metres of mineral per drillhole within the Wallaroo Group.

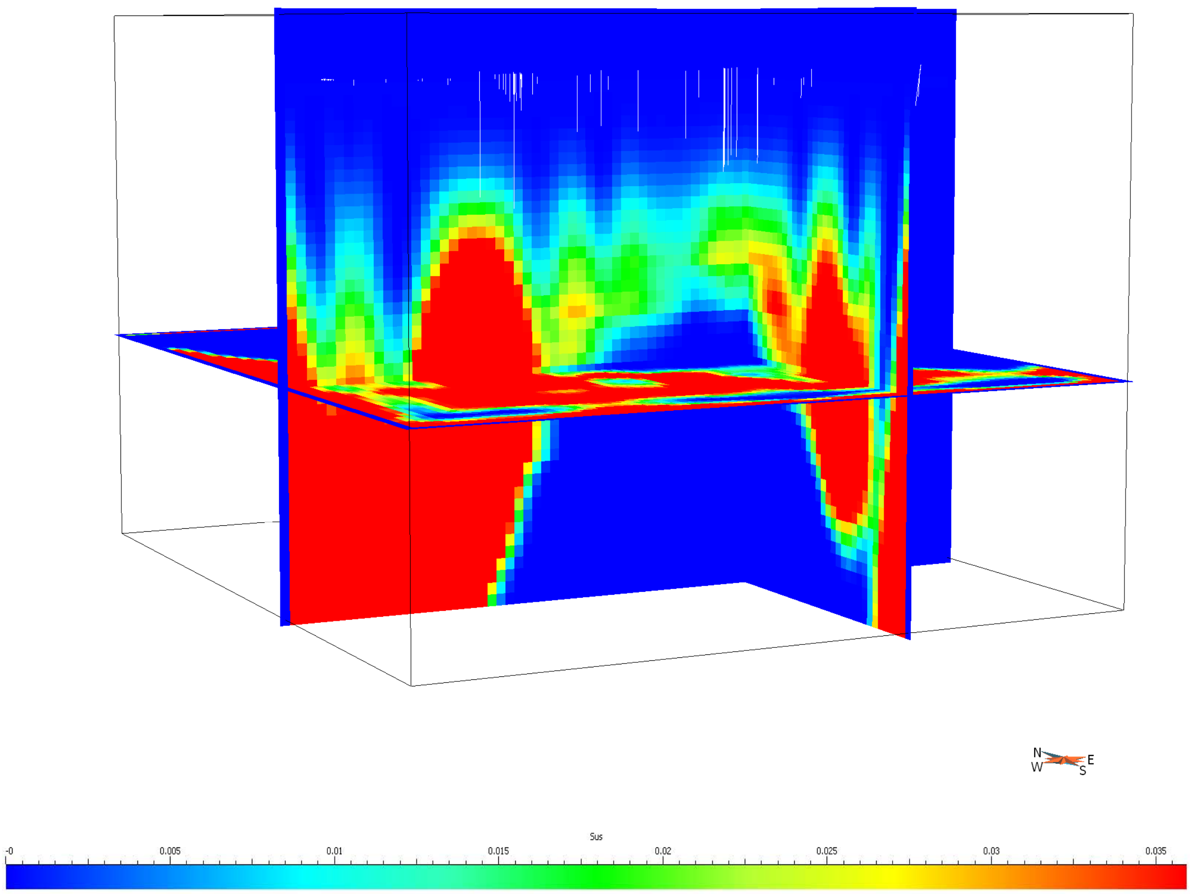

Figure 7: The Punt Hill study region magnetic susceptibility inversion model looking north-east. The z plane of the model is located at 3000 metres depth. The x and y planes have been positioned to cut through the Groundhog prospect and show areas of increased magnetic susceptibility from ~1.3km. Existing drillholes are displayed (white lines from surface). Base of model is at 5240 metres. Vertical exaggeration is 5 times. The scale is in SI units. Areas in red represent values greater than 0.036 SI units.

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