Prospectivity Modelling of Granite-Related Nickel Deposits Throughout Eastern Australia

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ABSTRACT

Spatial modelling has been used to determine potential locations of granite-related nickel skarn mineralisation throughout eastern Australia. It is believed that during granite intrusion, fluid can leach nickel from nearby mafic lithologies and combine with sulfur to form nickel sulfides. Currently exploration for this style of deposit has been limited to the region around the Avebury Deposit in western Tasmania. As the lithologies near Avebury are not unique it is feasible that similar deposits could exist elsewhere in Australia. The weights of evidence spatial data modelling technique was used to evaluate the wealth of geological data available over eastern Australia and included known economic deposits as training data to weight the themes of the model. These weighted themes were combined to create a prospectivity map showing areas favourable for granite-related nickel deposits. Several regions were identified by the model to have good potential to host nickel mineralisation similar to the Avebury deposit. These include areas located throughout New South Wales, Victoria, Tasmania, the Tasman District of New Zealand and, in particular, the Rockhampton region of eastern Queensland.

INTRODUCTION

Spatial modelling techniques, in particular weights of evidence modelling, have been used to determine potential locations of granite-related nickel skarn mineralisation throughout eastern Australia. This new style of deposit has recently been recognised and is associated with remobilisation of nickel from ultramafic host rocks during granite intrusion (Hoatson, 2005). The Avebury nickel deposit currently being mined by Allegiance Mining is an example of this style of mineralisation. Current exploration for this deposit type has been limited to the immediate region around the known Avebury deposit in Tasmania. However, as the lithologies near Avebury are not unique, it is believed that similar deposits could exist elsewhere in Australia or New Zealand. Prospectivity modelling using the weights of evidence technique is the perfect tool for identifying areas with similar geological conditions and has the potential to locate more billion dollar Avebury style nickel deposits.

MINERALISATION SYSTEM

This modelling has used the Avebury nickel deposit in western Tasmania (Howland-Rose, 2005) as a type example of this new style of nickel mineralisation (Figure 1). This nickel sulfide deposit is a skarn deposit formed when Cambrian ultramafic rocks were intruded by Carboniferous granite. It is believed that during granite intrusion associated fluids leached nickel from nearby mafic lithologies, which combined with sulfur in the granitic fluids to form nickel sulfides. The nickel sulfide deposits at

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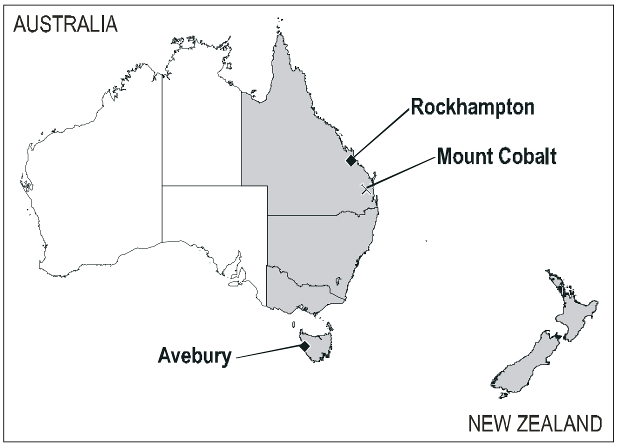

FIG 1 - Map of Australia and New Zealand showing the study area (dark grey regions), the Avebury type location, the Mount Cobalt Mine used to test the model and the Rockhampton region where follow-up exploration is being undertaken.

Avebury are located along the margins of folded and faulted ultramafic bodies, which are in contact with metamorphosed and altered sediments. These locations are where the mobilised fluids are trapped and concentrated nickel sulfides accumulate in the ultramafic hosts or in the adjacent metasedimentary units. The sulfides are also accompanied by variable amounts of magnetite derived from pyrrhotite during contact metamorphism giving a magnetic signature to the deposits.

MODELLING TECHNIQUE

The weights of evidence (WOE) spatial data modelling technique was used in this study to evaluate the wealth of geological data available over the study area. This technique requires expert knowledge about the deposit mineral system, uses databases of geological information that include geological mapping, geochemistry and geophysics, and importantly includes known economic deposits as training data to weight the model themes. The main geological features from the Avebury mineral system model have been used to develop predictive themes from available digital data. Sources such as the geological surveys in Australia and New Zealand provided geological data in digital GIS databases. These data were then developed into themes by spatial modelling techniques such as buffering, intersections, interpolation, density algorithms, or from expert assigned attributes of genetic significance. The WOE modelling technique combines these weighted themes to create a prospectivity map showing areas favourable for granite-related nickel deposits.

As a first step in the spatial correlation calculation, a 200 by 200 metre grid was generated over the study area (Figure 1). This grid size represents the minimum scale that the data should be viewed at and the modelling used a unit cell size of 100 km^2, which is intended to represent the approximate size of the mineral system. Fourteen mineral deposit locations for hard rock nickel mineralisation with an association with younger felsic intrusives were extracted from the mineral occurrence databases as a training data set and these occurrences mainly come from the Avebury area in Tasmania. The training data and unit cell give a prior probability of 0.0005; ie there is a 0.0005 chance of finding an Avebury nickel sulfide deposit in any 100 km^2 block in the study area before any knowledge about the geology or geochemistry is applied. The Mount Cobalt nickel prospect in the Gympie area of Queensland, which is currently being drilled for Avebury style nickel sulfide, was excluded from this training data so the area could be used as an independent test of the modelling results.

Spatial correlations between the training data and geological themes were calculated using the WOE spatial modelling techniques of Bonham-Carter (1994). This was done using the spatial data modeller extension (Sawatzky *et al*, 2004) developed for ESRI's ArcGIS software. The modelling technique is a Bayesian statistical approach that allows the analysis and combination of data to predict the occurrence of events. It is based on the presence or absence of a characteristic or pattern and the occurrence of an event. The spatial correlation of a theme in the model can be calculated by using the relationship of the area covered by the theme being tested and the number of training data points that fall onto it. This produces a W+ result based on training points falling on the theme and a W- result based on training points falling where the theme is absent. A W+ value greater than zero indicates a positive correlation with the theme, whereas a W- less than zero indicates a negative association with the non-theme area. The contrast, which is the difference between W+ and W-, gets higher with an increase in the correlation between the theme and the training data (ie a theme that correlates well with the selected training data for Avebury nickel sulfide mineralisation will have a high contrast value).

Sixteen predictive themes were developed from the available digital data. From these, seven were chosen as having the best regional coverage, a significant spatial association with the mineralisation model, and where possible not to duplicate predictive map patterns to reduce the effects of conditional independence (Table 1). The final geological themes were selected for this model based on their correlation (C) and their level of uncertainty (studentised contrast). The uncertainty is calculated from the standard deviations of W and C (Ws and Cs), from which the studentised value of the contrast (StudC) can then be calculated (the ratio of the standard deviation of the contrast (Cs) to the contrast (C)). StudC gives an informal test of the hypothesis that C = 0 and as long as the ratio is relatively large, implying the contrast is large compared with the standard deviation, then the contrast is more likely to be real. This ratio is best used as a relative indicator of spatial correlation, rather than an absolute sense. In this study a strong correlation is inferred from C values > 3.0 and StudC values > 1.5. The final seven weighted themes were combined and a gridded response theme was generated that represents the intersection of all the input themes in a single integer grid. The resulting grid has then been classified into areas of prospectivity and used to target regions in Eastern Australia and New Zealand for follow-up investigation.

RESULTS

This model highlights the importance of geology and geochemical data sets as predictors of mineralisation and has identified several regions that are prospective for nickel sulfide mineralisation. Nickel and zinc geochemistry, fractionated intrusives, structural control by lower order faults and serpentinised ultramafic lithologies are identified as being particularly important for locating mineralisation. Regions identified by the model to have good potential to host nickel mineralisation similar to the Avebury Deposit have been located throughout eastern Queensland, New South Wales, Victoria, Tasmania and in the Tasman District of New Zealand. Importantly, the Mount Cobalt site near Gympie in Queensland, which was excluded from the training data, and the Avebury deposit in Tasmania have been found as highly prospective supporting the validity of this model as a predictor for nickel sulfide mineralisation.

Rockhampton in Central Queensland (Figure 1) is an example of a prospective region identified by the modelling in this study. The total area of prospective ground in the Rockhampton region is 10 848 km^2 and of this 547 km^2 is considered highly prospective by the modelling for nickel mineralisation (Figure 2). Rockhampton has 15 known nickel mineral occurrences including production from lateritic nickel deposits (eg the Marlborough Preston Deposit) and two hard rock sulfide nickel occurrences. The area also hosts several serpentinites, younger granites with associated

TABLE 1

Grid themes used in the weights of evidence spatial model.

Theme	Description	Spatial correlation	Confidence
Rock chip Ni	Areas with values in rock samples >1200 ppm Ni.	6.85	6.20
Stream sediment Zn	Anomalous Zn in stream samples >660 ppm Zn.	3.09	4.68
Faults	Distance from third order faults.	3.03	4.60
Granite-nickel	Distance from ultramafic units that are older than and within 25 km of a granite that has >1200 ppm Ni.	7.13	11.29
Ultramafic-nickel	Distance from ultramafic units that have associated Ni mineral occurrences that are older than and within 25 km of a granite.	6.93	8.92
Granite fractionation	Distance from fractionated granites as defined by anomalous uranium content that are within 25 km of an ultramafic unit that is older than the granite.	3.22	5.64
Magnetics	Distance from magnetic highs.	1.96	3.26

sulfide minerals, third order faulting and has rock samples up to 0.7 per cent Ni and 4.5 per cent Zn. Six tenements over available prospective regions in Rockhampton were acquired by Accord Mining (Pty) Ltd for follow-up exploration (Figure 2). This research will provide more information about the nickel sulfide potential of the area and preliminary work includes detailed geological mapping, rock chip sampling, geochemical soil surveys and new high resolution magnetic surveys.

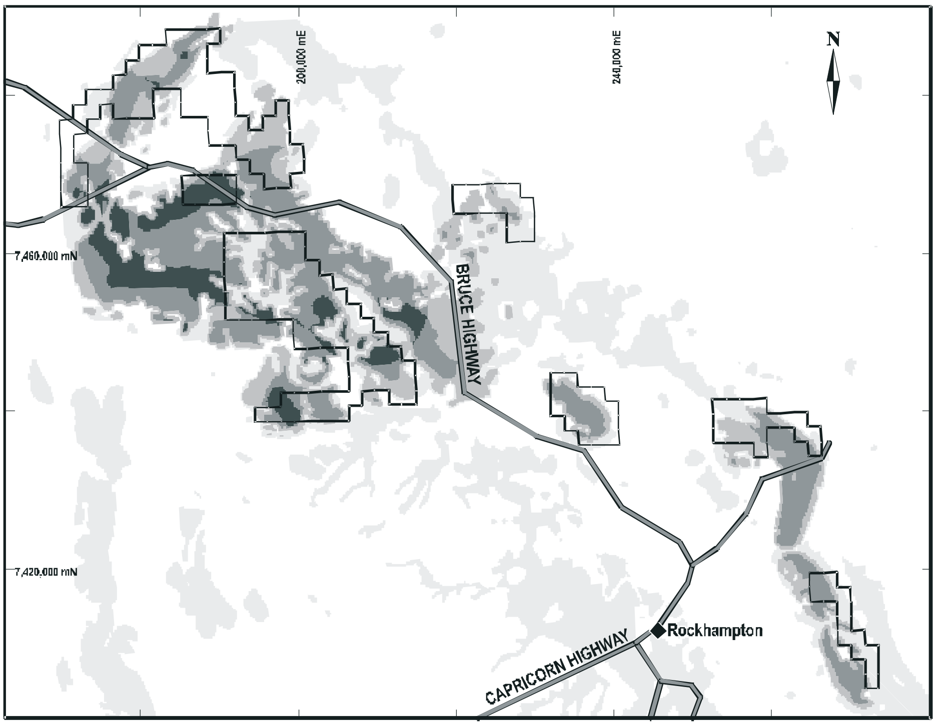

FIG 2 - Prospectivity modelling results for the Rockhampton region increasing from prospective (light grey) to highly prospective (black) overlain by Accord Mining tenements (black outlines).

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