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Mineral prospectivity analysis of the Wagga–Omeo belt in NSW

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SUMMARY

The Wagga–Omeo Belt in NSW has been a significant tin, gold, silver and copper producer. An analysis of the mineral prospectivity of the region has been undertaken by estimating the number of undiscovered deposits, estimating mineral endowment, and by predicting the likely locations of undiscovered deposits. Both spatial prediction (mineral prospectivity mapping – MPM) and quantitative resource assessment (QRA) were undertaken with a focus on tin mineralisation in the region.

Although this study is in progress, preliminary results from the analysis of the spatial pattern of known deposits using the weights of evidence method, indicate likely locations of undiscovered tin deposits.

Key words: Wagga, tin, prospectivity, endowment.

INTRODUCTION

In preparation for a major geological mapping program within the mineral endowed Wagga–Omeo Belt in central-southern NSW, the Geological Survey of New South Wales, in conjunction with the Centre for Exploration Targeting, a joint research centre between the University of Western Australia and Curtin University, is currently undertaking a mineral resources assessment of the region with a focus on tin mineralisation.

The association of tin deposits and provinces with highly fractionated granitoids has long been recognised in the central Lachlan Orogen in New South Wales, Victoria and northeastern Tasmania (Figure 1). The Wagga–Omeo Belt in eastern Australia is bounded to the east by the Gilmore shear zone and to the west by the Tabberrabbera Zone. It is dominated by Ordovican rocks composed of a lower unit of quartz-rich turbidites and an upper unit of black shale, overlain by a Lower Silurian turbidite succession (Fergusson 1998, Vanderberg et al. 2000; Fergusson 2003). Sedimentation within the central Lachlan Orogen took place from the Cambrian to Silurian and the turbidites were intruded by voluminous syntectonic Silurian granitic plutons (Foster et al. 1999; Fergusson 2003). The granitoids were deformed during the 490–440 Ma Benambran Orogeny (Scheibner and Basden 1998) and trend north-northwest along with the regional structural grain. Among them are the Koetong Supersuite granitoids, consisting of a range of compositions from unfractionated, mafic, S-type granites to highly fractionated granites enriched in Rb, Nb, F, Cs, Li, Ga, W, and Sn (Blevin and Chappell 1995; Walshe et al. 1995; Walshe et al. 2011). The Ardlethan Granite associated with the largest tin deposit in the Wagga Tin Belt, is the most fractionated component of the Koetong Supersuite (Walsh et al. 1995; Walshe et al. 2011).

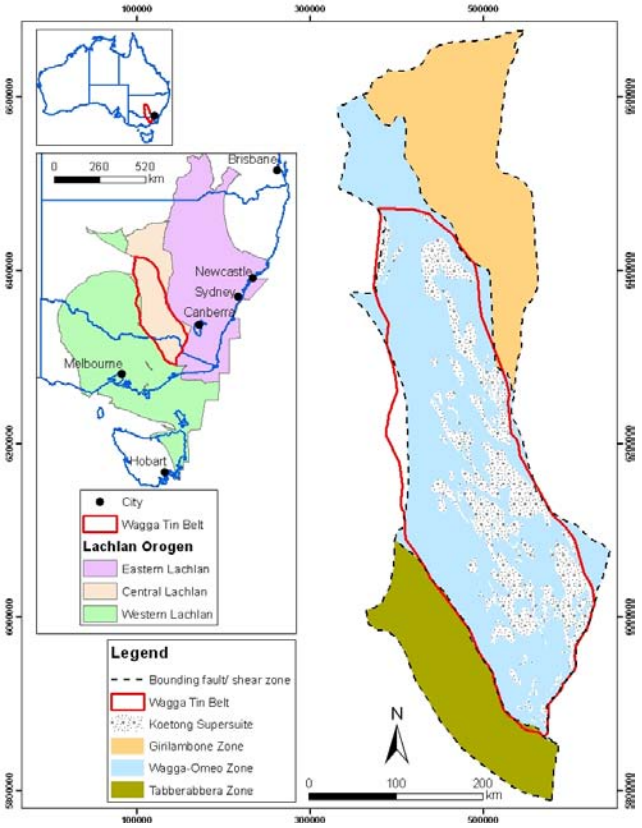


Figure 1. Location of the tectonic context of the Wagga–Omeo Belt (including the Wagga Tin Belt) in eastern Australia.

In this study total magnetic intensity (TMI), gravity, radioelement and digital elevation datasets, together with geological and metallogenic data themes were tested for their applicability in WofE modelling.These themes were combined using a log-linear formulation of Bayes's Rule to produce a response theme of posterior probabilities under the assumption of conditional independence (CI). Only those theme combinations (WofE models) that did not violate the key assumption of CI were retained. The CI tests are described by Bonham Carter (1994) Agterberg and Cheng (2004). The model fitting rates (proportion of deposits on high posterior probability cells) and prediction rates (proportion of deposits withheld from modeling that fall on the high probability cells) are calculated and a final model selected and appropriately symbolised.

The outcome described here is based only on the lithology and TMI theme only, as other themes were discarded due to conditional dependence/redundancy among the themes. Tin resources assessments within prospective area will be carried out using Zipf's law, coupled with information from selected geologically similar tin belts worldwide.

METHOD

The predictive estimation of mineral endowment has three main components: (i) estimating the number of undiscovered deposits, (ii) estimating undiscovered mineral endowment, and (iii) predicting the likely locations of undiscovered deposits. Although all three are required for a complete assessment, available methods generally embrace one or two of these components.

For instance, the weights of evidence (WofE) method is an effective widely used GIS-based technique for quantifying the spatial associations between mineral deposits and map themes and, based on the spatial quantifications, predicting the likely sites for new deposit discoveries. The WofE method, described in detail by Bonham Carter (1994), uses area-based conditional probabilities to determine spatial associations between known deposits and map themes (e.g. lithology, proximity to geological structures and magnetic susceptibility), also known as evidence maps. For each map theme, a positive weight (W^+) and a negative weight (W^-) are calculated. W^+ signifies that the presence of a map theme coincides with the presence of mineral deposit(s). The magnitude of W^+ is directly proportional to the number of deposits that falls on the map theme and inversely proportional to the proportion of area covered by the map theme. W^- is returned for those parts of the study area where deposits occur in the absence of the map theme and its magnitude is directly proportional to the number of deposits that occur outside the map theme and inversely proportion to the proportion of the study area outside the map theme.

The strength of the spatial association between a map theme and the pattern of known deposits is given by contrast,
$C = W^+ - W^-$. The more positive C is, the stronger the spatial association. However, the studentized contrast, obtained by dividing C with its standard deviation, is usually used for thresholding and reclassifying or generalizing themes.
Map themes from which prospectivity criteria (favourable geological settings) used in this study were extracted are the geological map (host rock type/lithology), faults map (faults), total magnetic intensity (TMI) image (host rock magnetic susceptibility), gravity image (host rock density) and ternary radiomelement (K/Th/U as red/green/blue) image. As described by Blevin (1998), tin-bearing granitoids have subdued magnetic susceptibility due to destruction by hydrothermal alteration but exceptions include chlorite–magnetite lodes and pyrrhotite-bearing lodes where magnetic anomalies are a manifestation of magnetitisation and pyrrhotitisation at both endo- and exo-contacts (Blevin 1998; Gongjian and Rui (1988). Blevin (1998) further notes that tin-bearing granites are generally radiogenic (high K and U), with high Th in I-type granites and low Th in S-type granites, and that zones of feldspathic and phyllic alteration exhibit high K. Gravity data are important regionally as gravity lows generally indicate granitoid batholiths at depth (Blevin 1998; Gongjian and Rui 1988).

A total of 191 hydrothermal tin localities (deposits and occurrences), of which 109 are in New South Wales and 82 in Victoria, were used in this study. Deposits were considered to be any past or presently mined tin localities of any size. Occurrences are any other recorded sites where at most only insignificant shallow exploratory workings have been recorded. Based on these definitions, the final dataset has 132 mines (65 in New South Wales and 67 in Victoria) and 59 occurrences (44 in New South Wales and 15 in Victoria).

RESULTS

The generalisation of map themes in this study was carried out using values of studentized contrast. For example, faults are potential conduits of hydrothermal fluid flow required in tin mineralisation. Figure 2 suggests that a suitable distance threshold for dichotomising the proximity to faults theme is 12 km so that distances within 12 km of faults are favourable to tin prospectivity and those beyond are unfavourable.

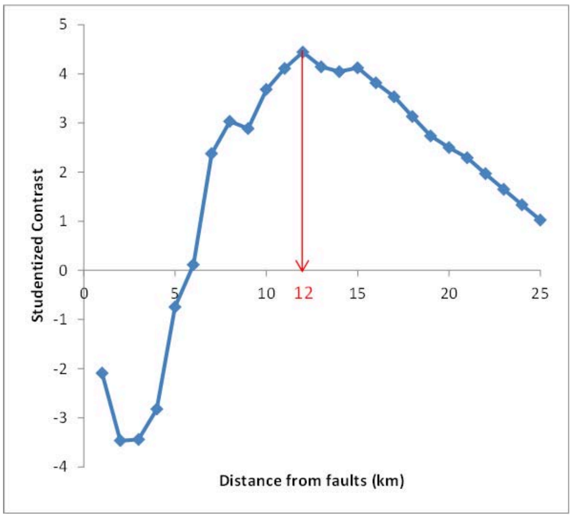


Figure 2. Studentized contrast values for incremental distances from regional faults within the Wagga Tin Belt. The spatial association of tin deposits with faults is maximised within a 12 km buffer around the faults.

TMI, gravity, radioelement and elevation datasets are generalised into multi-class, rather than binary themes. Each dataset was converted to an integer raster, reclassified into 10 natural break classes of image pixel values (reclassified from original grid values of physical measurements). The reclassified image was subjected to initial weights calculation to facilitate generalisation of the prospectivity criteria for WofE modeling. Plots of the studentized contrast values used in this generalization are shown in Figure 3. The ternary radioelement image, for example, attained the highest studentized contrast value of 5.3 in class 10 covering pixels in the range 232–255 which implies relative high concentrations of all three radioelements – potassium, thorium and uranium (Figure 3c). Apart from class 9 which had a weak positive association and class 1 with no association, the rest of the classes (classes 2–8) exhibited negative association with tin deposits. TMI, gravity and SRTM images were similarly generalised as depicted in Figure 3A, 3B and 3D.

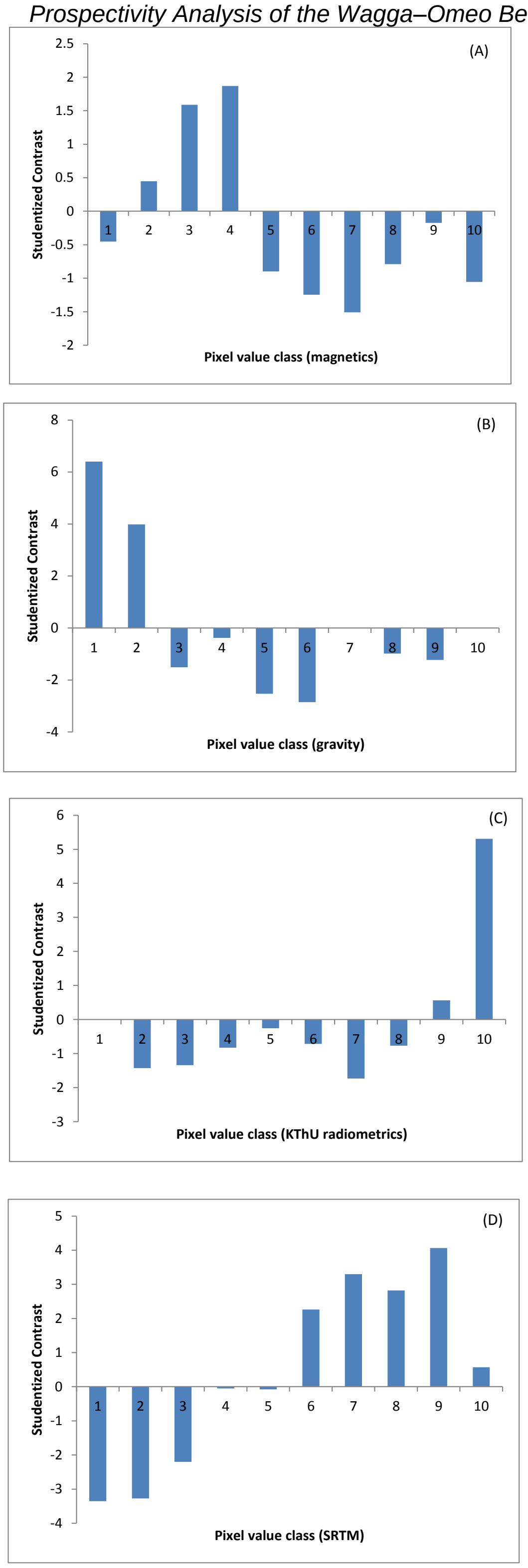


Figure 3. Studentized contrast values (A) TMI, (B) gravity, (C) radioelement and (D) SRTM elevation images.

In this study, 17 response themes were generated from 17 different combinations (WofE models) of evidential themes. Only three of these models, (i) lithology + TMI, (ii) Koetong Supersuite contacts + TMI + K/Th/U radioelements, and (iii) Koetong Supersuite + TMI + K/Th/U radioelements passed the conditional independence (CI) tests described by Bonham Carter (1994), and Agterberg and Cheng (2004).

The preliminary prospectivity map presented as Figure 4 is a reclassification of the response theme from the model lithology + TMI. The initial response theme consists of pixels (cells), each of which has a posterior probability value. Cells with the same value constitute posterior probability zones. If the zones are ranked in order of descending posterior probabilities, smaller high probability zones occupy the top part of the list and larger low probability zones the bottom part. Cumulative (descending posterior probability, ascending cell counts) area percentiles can be calculated for such a list so that, for example, the 50th area percentile dichotomises the target area into a more prospective (higher posterior probability) half and a less prospective (lower posterior probability) half. Similarly, the 5th percentile separates the most prospective 5% cells (in the smaller, higher probability zones) from the less prospective 95% cells (in the larger, lower probability zones) of the target area. In general the dichotomy is between the more prospective *x*% versus the less prospective (100– *x*) % cells of the study area.

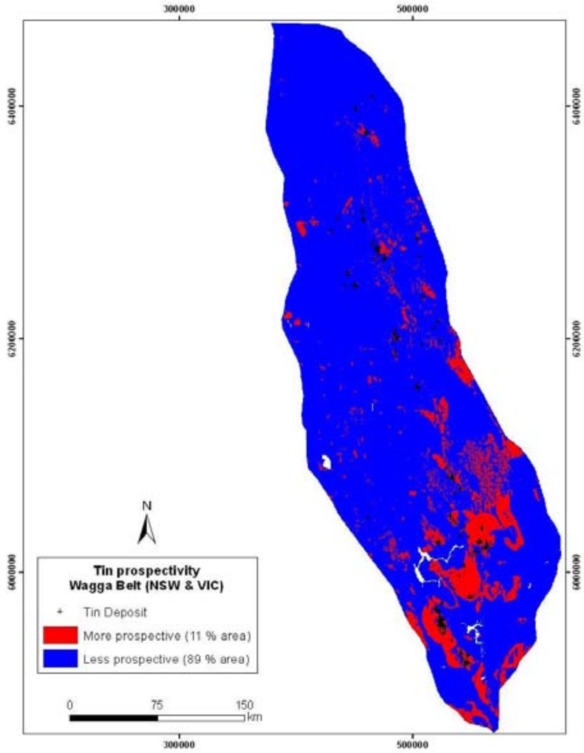
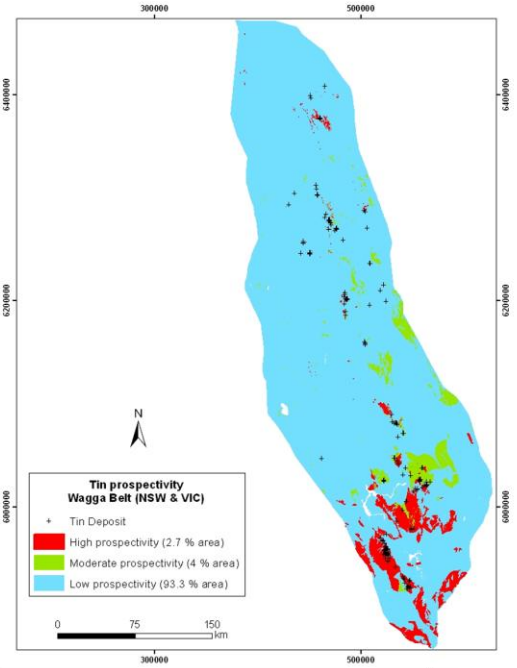


Figure 4. Binary tin prospectivity map for the Wagga Tin Belt based on model (i) lithology + TMI.

Figure 4 is a prospectivity map consisting of a more prospective (11% area) and less prospective (89% area) dichotomy of the Wagga Tin Belt. The more prospective 11% area represent cells in the study are wherein the probability of finding tin deposits is higher than the 89% less prospective cells. Any number of probability (and area percentile) thresholds can be used, although a binary map such as Figure 4 may be required for categorical yes/no, present/absent decisions. A ternary high/low/moderate tin prospectivity map of the Wagga Tin Belt, also based on the lithology + TMI model is shown in Figure 5. For comparison, Figure 6 shows existing tin deposits on a greytone image of the TMI.

Figure 5. Ternary tin prospectivity map of the Wagga Tin Belt derived from the lithology+ TMI WofE model.



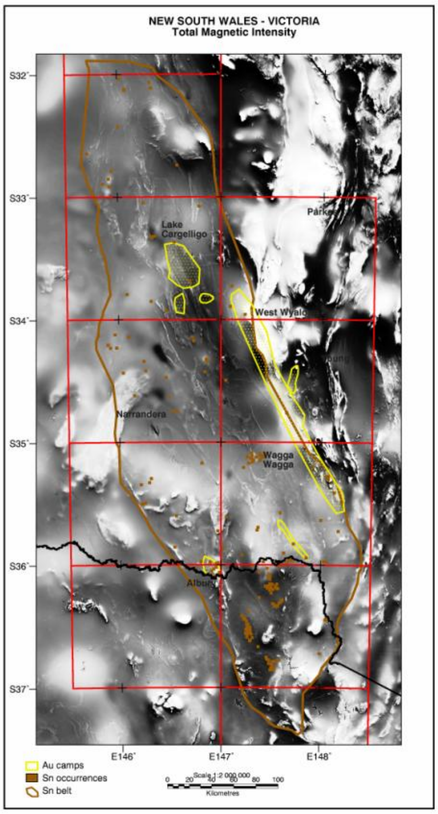


Figure 6. Existing tin deposits on a greytone TMI image.

CONCLUSIONS

Preliminary findings suggest that the WofE model based on lithological and magnetic maps outperforms all other combinations from the six themes utilised in this study as a predictor of undiscovered tin deposits in the Wagga Tin Belt. The model identifies 11% (8456 km^2) of the Wagga Tin Belt where the likelihood of new hydrothermal tin deposit discoveries is highest. WofE modeling to produce and validate the final prospectivity map is ongoing. Estimation of tin resources on the final prospectivity map will be carried out using Zipf's law and analogy from a selected geologically similar tin province.

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