

MINERAL POTENTIAL MAPPING AS A STRATEGIC PLANNING TOOL IN THE EASTERN LACHLAN OROGEN, NSW

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INTRODUCTION

The Geological Survey of New South Wales (GSNSW) is undertaking a statewide mineral potential mapping project driven by the need to provide justifiable land use planning advice to key government stakeholders and to highlight the exploration potential of the state's major mineral systems at a regional scale. Following delivery of mineral potential data packages for the [Southern New England Orogen](#) (Blevin et al. 2017) in 2017, and the [Curnamona Province and Delamerian Thomson Orogen](#) (Ford et al. 2018) in 2018, the eastern Lachlan Orogen was selected as the next area for a review of key mineral systems and mineral potential. The study area covers the Lachlan Orogen east of the Gilmore Fault and which hosts world-class porphyry Cu–Au and volcanic-associated massive sulfide (VAMS) deposits as well as economically significant polymetallic skarn and orogenic Au mineralisation (Figure 1).

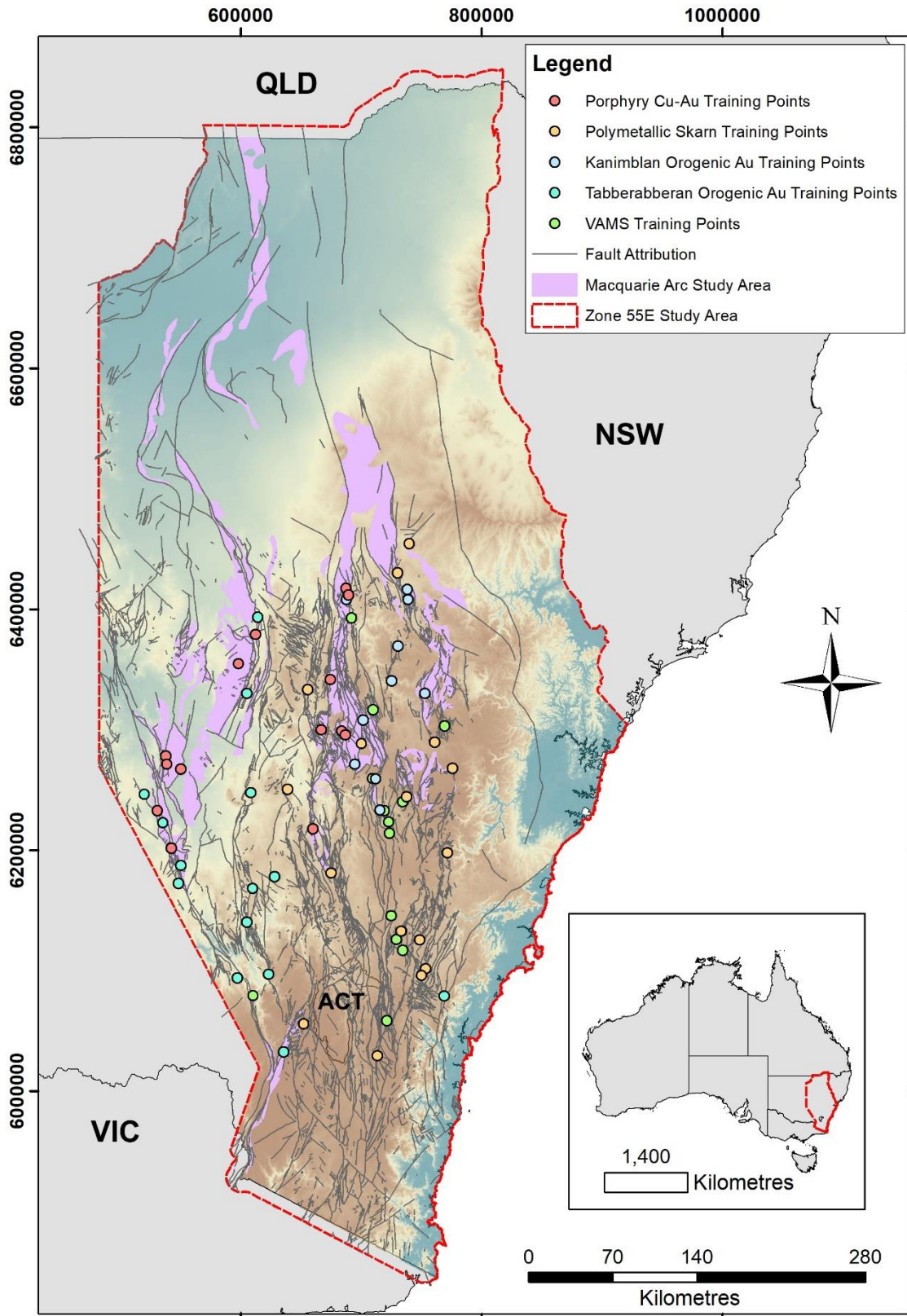


Figure 1. Map of eastern Lachlan Orogen study area showing the location of the mineral occurrences used to train the data-driven mineral potential models.

EASTERN LACHLAN OROGEN PROJECT

The eastern Lachlan Orogen, in NSW, was chosen for data-driven mineral potential mapping due to its historic production, known resources, operating mines, and potential for the discovery of new porphyry copper–gold, polymetallic skarn, orogenic gold, and VAMS systems.

New and improved pre-competitive geoscience datasets for the eastern Lachlan Orogen were compiled by the GSNSW. These datasets include:

- Seamless basement geodatabase that incorporates the best available geological data with comprehensive attribution of key characteristics relevant for understanding the formation of mineral systems. This includes reactive rock layers.
- An igneous metal fertility dataset derived from 6,133 whole rock geochemistry analyses.
- A metamorphic map geodatabase with feature classes for each of the key metamorphic events identified in the study area. This dataset defined the extent and grade of both regional and contact metamorphism for each event.
- A dataset of 1,727 radiometric age dates to constrain the geological units for key mineral systems.
- A fault dataset with detailed attribution of event timing and kinematics that provides context for understanding the structural evolution of the fault systems in the area.
- A dataset of 56,126 petrographic point observations with detailed attribution of alteration and mineralogy.
- Surface geochemistry assays for 12,763 major element analyses and 62,367 trace element analyses.
- Drillhole multi-element assays for 2,903,474 sample.
- Regional-scale geophysics including magnetics, gravity, radiometrics, and other derivative products such as ‘worms’.

In addition, the wealth of historical mineral occurrence data in the eastern Lachlan Orogen, with 12,169 occurrences mapped, enabled a robust data-driven mineral potential mapping study for key mineral systems.

Examination of the spatial relationship between known mineralisation and spatial variables that relate to the fundamental underlying mineral systems processes has resulted in the confirmation or re-evaluation of ideas about how, when, and where mineral systems formed. The results of the spatial analysis have highlighted new areas with potential for hosting specific mineral systems both at the surface and under cover. Results from the study are in a comprehensive report and [mineral potential data package](#) (Ford et al. 2019a) and summarised below.

MINERAL POTENTIAL MAPPING

Five mineral systems were selected for mineral potential mapping: Ordovician–early Silurian porphyry Cu–Au and related deposits hosted by the Macquarie Arc; Silurian–Carboniferous polymetallic skarn-type mineralisation; Kanimblan Cycle orogenic Au systems; Tabberabberan Cycle orogenic Au systems; and Tabberabberan Cycle VAMS-type systems.

For each system, between 10 and 16 deposits were selected as training points. These include: 14 porphyry Cu–Au and related deposits hosted by the Macquarie Arc; 16 polymetallic skarn deposits associated with Silurian to Carboniferous intrusions; 10 Kanimblan Cycle orogenic Au deposits (mainly in and adjacent to the Hill End Trough); 14 Tabberabberan Cycle orogenic Au deposits (mainly associated with the Gilmore Fault Zone and adjacent structures); and 14 VAMS deposits associated with Siluro-Devonian deepwater extensional basins (Figure 1). The mineral potential mapping was informed by mineral

system descriptions that were specific to the eastern Lachlan Orogen (i.e. Downes 2019a, b; Forster & Blevin 2019; Simpson et al. 2019). These descriptions highlighted key characteristics (timing of mineralisation, depositional environment, controls to mineralisation) and processes (source, transport, trap, deposition) specific to each system.

Weights-of-evidence was used to undertake detailed data-driven mineral potential mapping. This technique evaluates the spatial correlation between the location of a set of known events (training data) and the presence or absence of a characteristic or pattern (Bonham-Carter 1994). In the context of mineral potential mapping, weights-of-evidence tests the relationship between known mineralisation (i.e. training points) related to a specific mineral system and a series of spatial variables that represent spatial proxies for mineral system processes (Ford et al. 2019b). The correlation is evaluated from the relationship between the area covered by the presence of a specific feature and the number of training points located within that area, compared to the total number of training points. This technique allows for a rapid and non-biased assessment of many spatial variables that can then be used either individually or integrated to produce a mineral potential map. The weights-of-evidence analysis was undertaken using a recently updated ArcSDM plugin for ArcGIS (<https://github.com/gtkfi/ArcSDM>).

The source data provided by the GSNSW were converted into predictive maps layers that represent spatial proxies for key mineral system processes (source, transport, trap, deposition). The relevance of each mineral system process varies depending on the specific system. For example, the source for the porphyry system is better constrained (i.e. igneous metal fertility) than for the orogenic Au models. By contrast, the structural controls to orogenic Au systems are typically more straightforward.

RESULTS

In total, 923 spatial variables were tested across the five mineral system models. Some 656 spatial variables had a valid statistical correlation with their relevant training point data. Of these, 412 correlated well. This testing of the spatial variables, together with a geological understanding of key mineral system processes, identified the key variables required for predicting the location of each mineral system.

Mineral potential maps were made using a selection of maps for each system. Care was taken to ensure that each part of a mineral system (source, transport, trap, deposition) was mapped by at least one predictive map. For use in the mineral potential mapping, each key variable was reviewed to ensure a good statistical correlation was present, the map had good regional coverage, resulted in minimising duplication of map patterns, and was geologically valid. Each mineral potential map shown in Figures 2–6 highlights areas where the geological potential for each mineral system is higher than that prior to any evidence being integrated into the model. Final mineral potential maps were validated by evaluating the efficiency of classification from area-frequency plots, which measures how well the training points are classified by the model. If the efficiency of classification is above 90%, the model is typically considered to be successful.

For the porphyry Cu–Au mineral system, the prospective area covers 15.2% of the Macquarie Arc, and the highly prospective area only 0.13%. The efficiency of classification is 96.0%, however one training point (Kaiser prospect) falls outside of the prospective area. For the polymetallic skarn mineral system, the efficiency of classification was 99.4%, and all training points are within the prospective area, which covers 6.7% of the study area. The highly prospective area covers just 0.12% of the study area and predicts the location of 10 of the 16 training points. The prospective area for the Kanimblan Cycle orogenic Au model covers 4.3% of the study area and has an efficiency of classification of 99.8%. The highly prospective area covers 0.16% of the area and contains 7 of the 10 training points. The Tabberabberan Cycle orogenic Au model has an efficiency of classification of 98.6%, with

the prospective area covering 10.7% of the study area, and the highly prospective area 0.20%. One of the training points (Harden) is located outside of the prospective area. For the VAMS model, the prospective area covers 8.3% of the study area and contains all of the training points. The highly prospective area covers just 0.44% of the study area and contains 10 of the 14 training points.

The amount of available data and subsequently the number of predictive layers available to inform any mineral system model decreases in areas of poor or absent exploration data and markedly so in areas under thick alluvium or basin cover. This leads to a decrease in the statistical confidence that can be applied to each mineral potential map in such areas of decreased data availability, ultimately to the point where meaningful modelling is impossible. To address this issue a series of unique condition and data confidence maps have been generated for each mineral system. These assign a confidence value to mineral potential map outputs across regions where data availability is highly variable. Unique conditions maps show the number of predictive maps for which any unique condition is favourable for a given mineral system. The data confidence maps show areas where the confidence that the calculated post probability for each modelled system is not zero (e.g. Figure 7). Other maps produced show variance due to missing data for the post probability (i.e. mineral potential) map and the total standard deviation due to the weights and the missing data for the post probability map. These maps, including overlay maps of geological cover onto the mineral potential maps, allow for the validity of the mapped mineral potential results which are functions of data density (availability) to be satisfactorily assessed – an important consideration for mineral potential mapping undercover.

DISCUSSION

The key output from the Eastern Lachlan Orogen Mineral Potential Mapping Project is the [Eastern Lachlan Orogen Mineral Data Package](#) (Ford et al. 2019a). This dataset contains all the GIS files used in the mineral potential mapping process for the five mineral systems. It includes the training points, study areas, predictive maps, weights tables, and mineral potential maps with their corresponding unique conditions. Additionally, the package contains the spatial data table which documents the files and processes used to generate them as well as a summary report. The [data package](#) and the underlying mineral system models will be available through the [GSNSW DIGS system](#).

The Eastern Lachlan Orogen Mineral Potential Data Package allows individual predictive maps, generated for each mineral system, to be used independently. This provides information about how each map relates to the specific system. As previously noted, the modelling was driven by the need to provide justifiable land use planning advice to key government stakeholders in NSW and to highlight the exploration potential of the eastern Lachlan Orogen at a regional scale. This guided the selection of predictive maps included in each mineral potential model. However, a different sub-set of maps could be used to create new mineral potential maps that delineate prospective areas more suited to exploration targeting. New predictive maps and subsequent mineral potential maps can be created when existing source data are updated, new data becomes available, or new understanding of the mineral systems generates new ideas to be evaluated.

Importantly, the mineral potential maps (Figures 2-6) identified new areas with strong geological potential for hosting relevant mineralisation and were successful at predicting the location of the known deposits/occurrences which were not included as training points for each mineral system. Areas highlighted as having strong geological potential for relevant mineralisation away from training point data include:

- Porphyry Cu–Au: areas west of Glendale–Junction Reefs and northwest of Peak Hill are indicated to be moderately to highly prospective (Figure 2).
- Polymetallic skarn: areas around Cow Flat, Young Granodiorite and south of Jerangle are indicated to have moderate to high prospectivity (Figure 3).

- Kanimblan Cycle orogenic Au: the areas west of Hill End, north Stuart Town and Sunny Corner are shown to be moderately to highly prospective (Figure 4).
- Tabberabberan Cycle orogenic Au: the area southwest of Forbes–Parkes and to the southwest of Tomingley are shown to be moderately to highly prospective (Figure 5).
- VAMS: the area between Mount Costigan and Wet Lagoon, and parts of the Tumut Trough are shown to be moderately to highly prospective (Figure 6).

Comparison of the mineral potential maps with historic exploration intensity maps (defined by the number of days held under mineral exploration licence since 1962) indicates that there remain some prospective areas that are relatively underexplored within the eastern Lachlan Orogen for each mineral system. These areas with moderate to high prospectivity, but with less historic exploration activity, may represent future exploration opportunities.

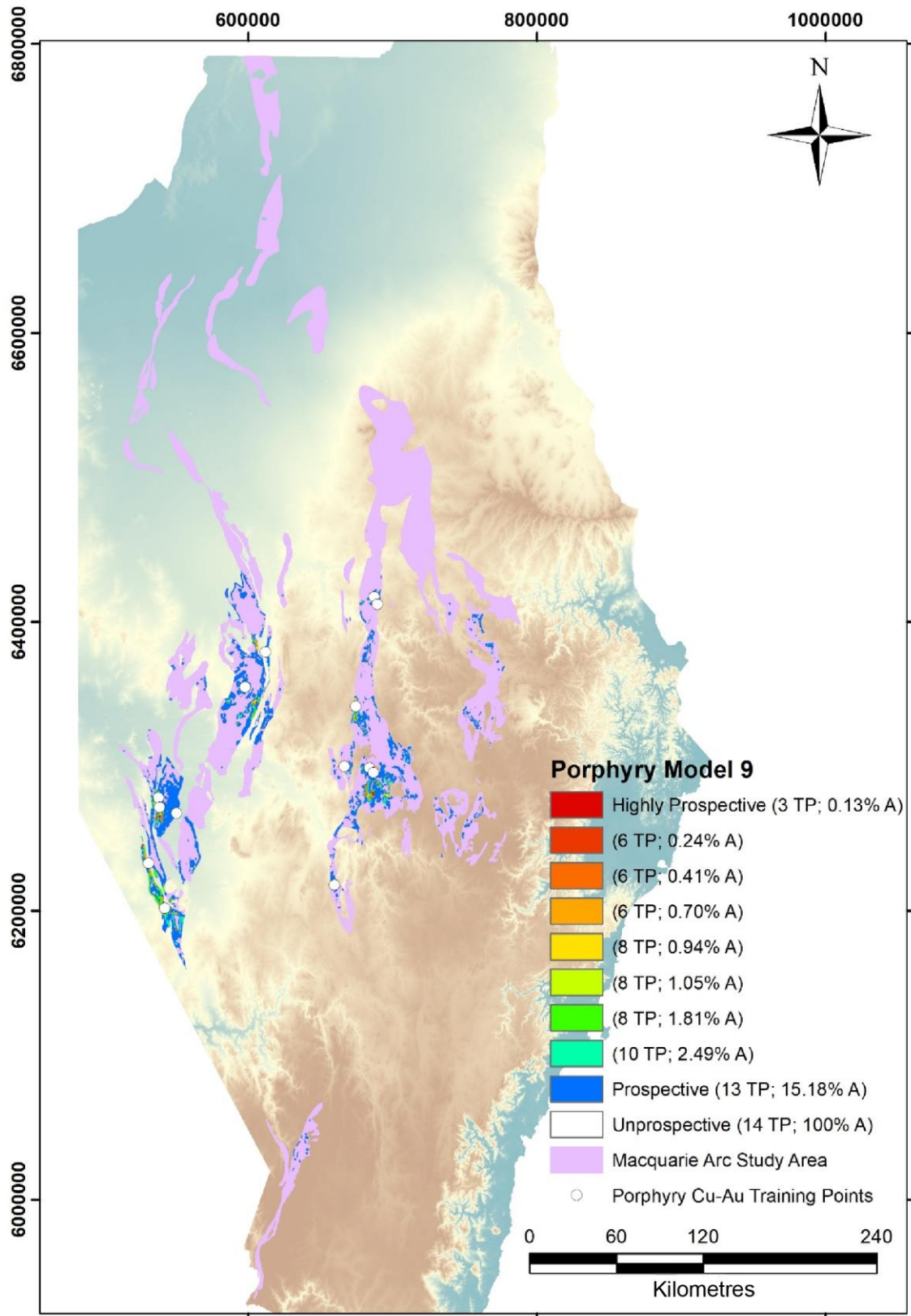


Figure 2. Porphyry Cu–Au mineral potential results for the Macquarie Arc, showing the cumulative number of training points (TP) and percentage of study area (A) captured by each class.

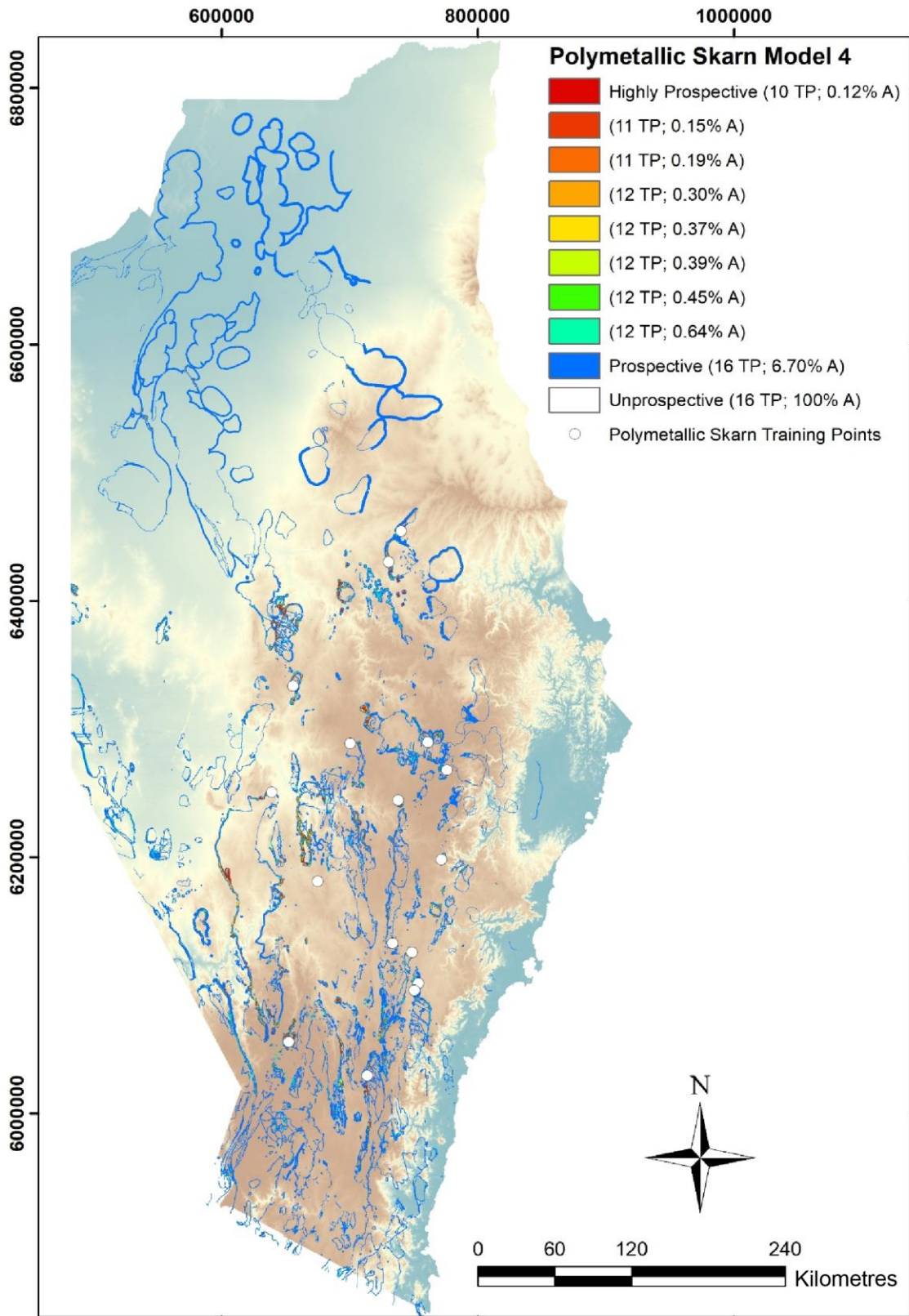


Figure 3. Polymetallic skarn mineral potential results for the eastern Lachlan Orogen study area, showing the cumulative number of training points (TP) and percentage of study area (A) captured by each class.

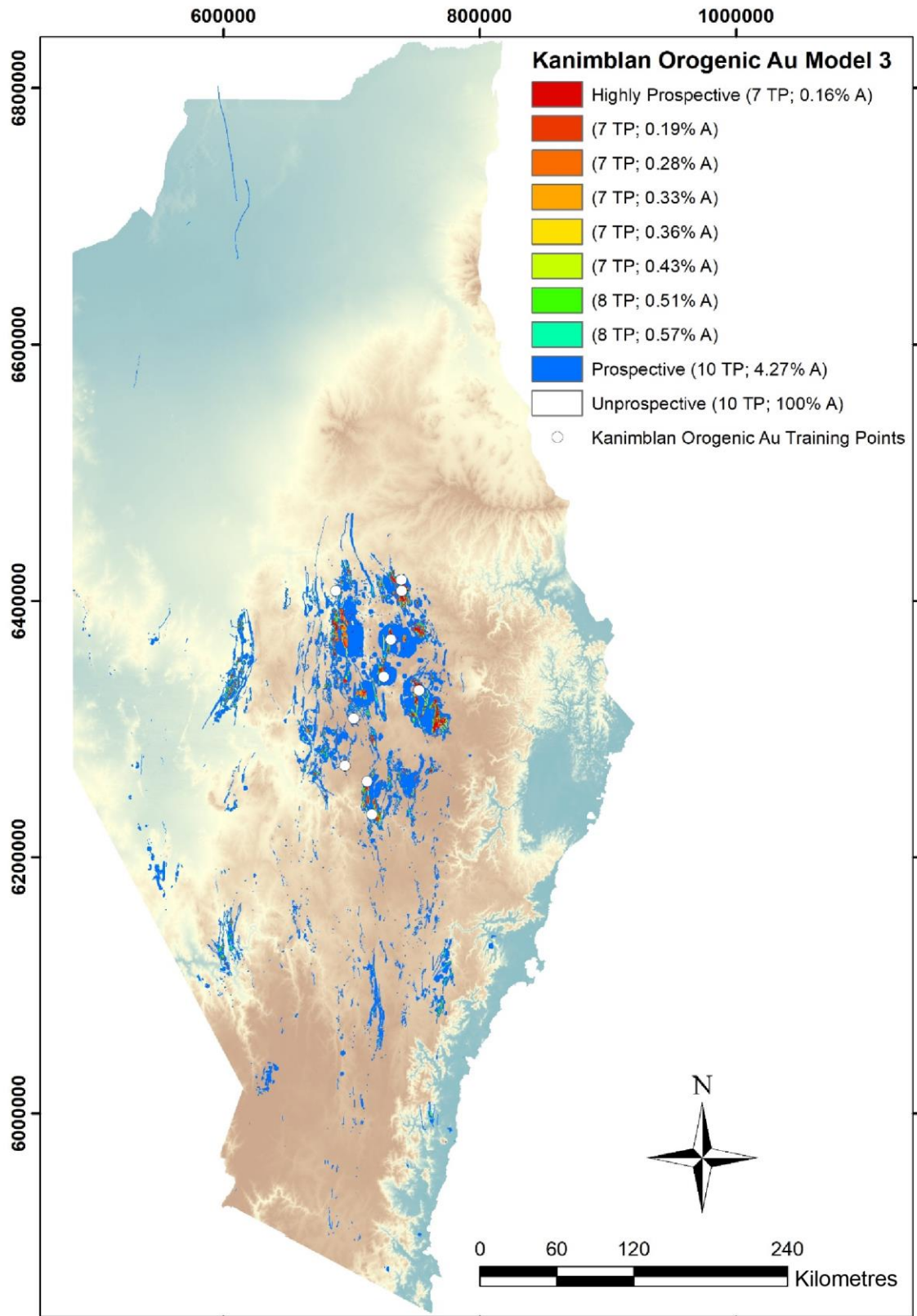


Figure 4. Kanimblan Cycle orogenic Au mineral potential results for the eastern Lachlan Orogen study area, showing the cumulative number of training points (TP) and percentage of study area (A) captured by each class.

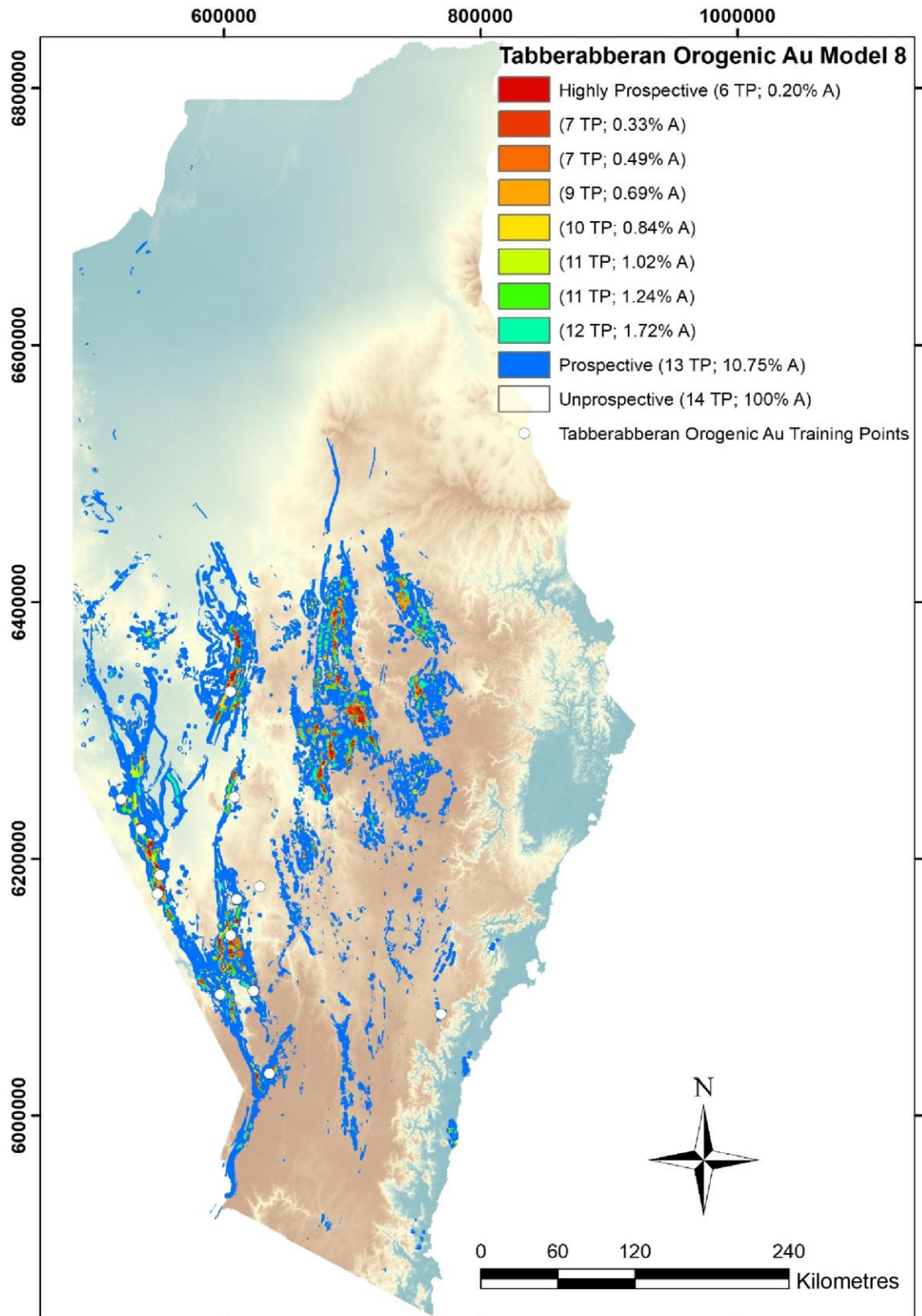


Figure 5. Tabberabberan Cycle orogenic Au mineral potential results for the eastern Lachlan Orogen study area, showing the cumulative number of training points (TP) and percentage of study area (A) captured by each class.

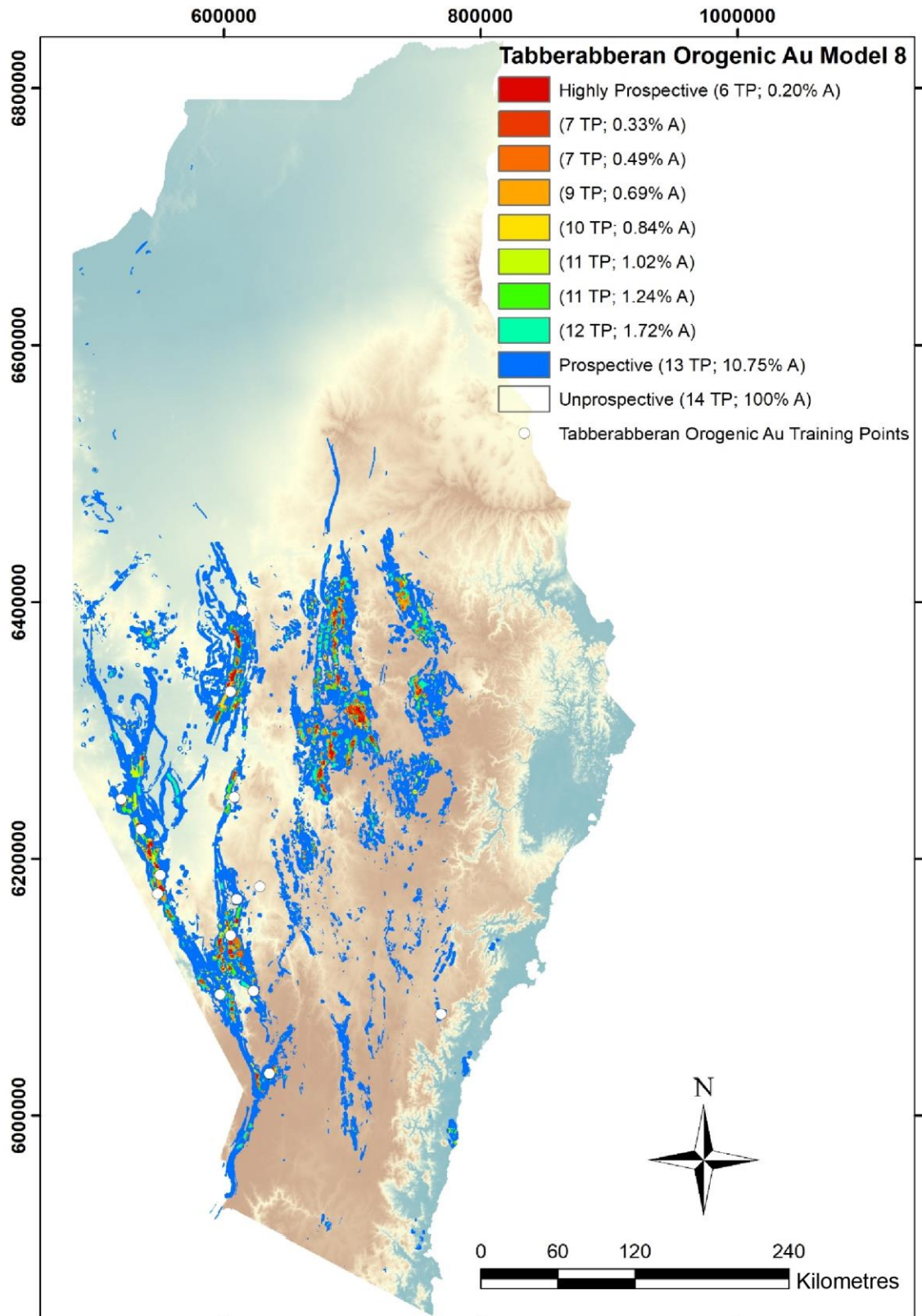


Figure 6. Volcanic-associated massive sulfide mineral potential results for the eastern Lachlan Orogen study area, showing the cumulative number of training points (TP) and percentage of study area (A) captured by each class.

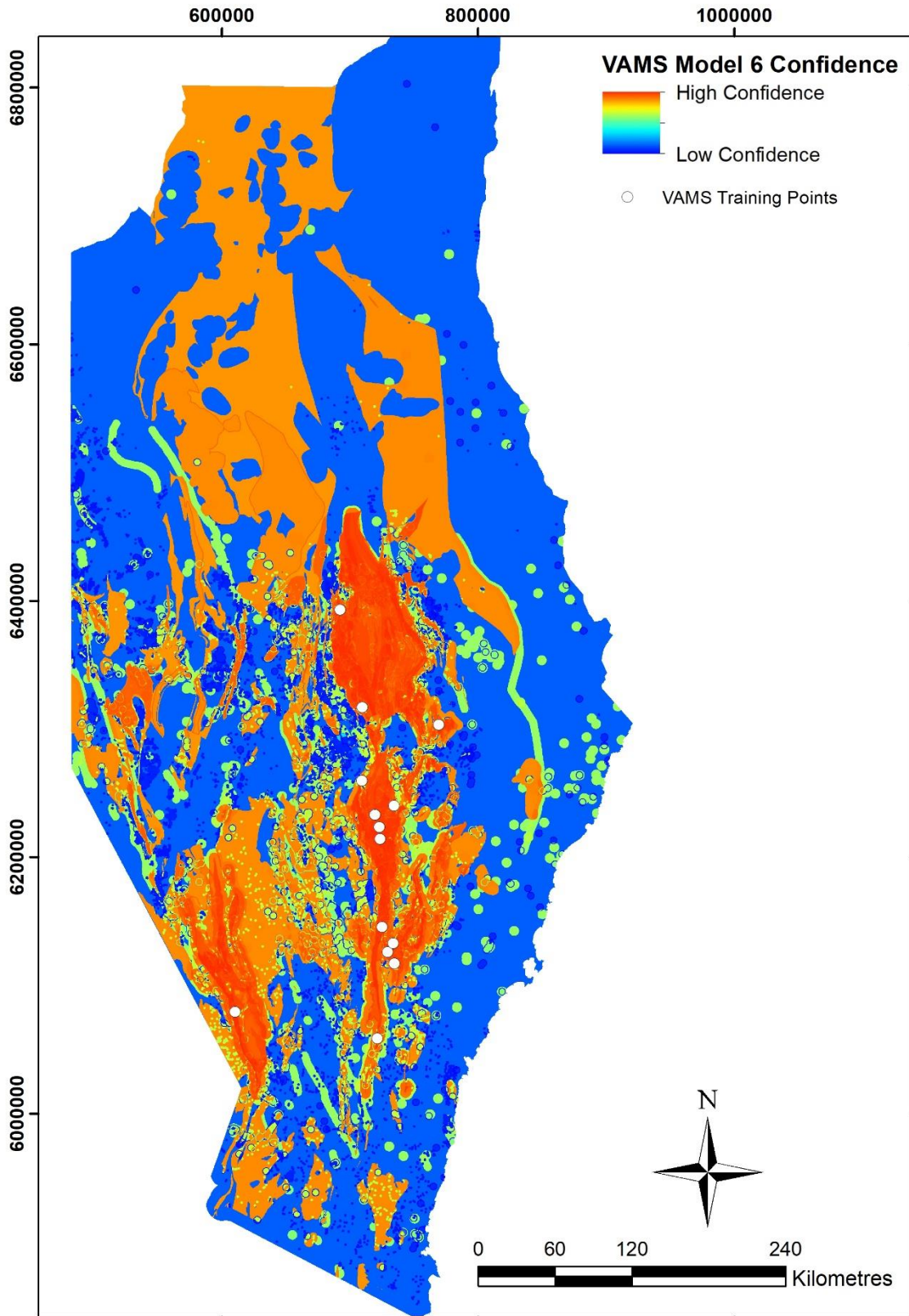


Figure 7. Volcanic-associated massive sulfide data confidence map. The map represents the confidence that the posterior probability for the VAMS mineral potential map in Figure 6 is not zero and approximates a student's t-test.

CONCLUSIONS

The Eastern Lachlan Orogen Mineral Potential Mapping Project, a successful collaboration between the GSNSW and Kenex Ltd, has highlighted prospective areas in the eastern Lachlan Orogen for several important mineral systems. The mapped geological potential for porphyry Cu–Au, polymetallic skarn, Kanimblan Cycle orogenic Au, Tabberabberan Cycle orogenic Au, and VAMS mineral systems in eastern Lachlan Orogen is statistically valid and has been evaluated for the purpose of strategic land use planning and decision making by key government stakeholders, and to highlight the exploration potential of the eastern Lachlan Orogen at a regional scale. Importantly, some of the identified prospective areas are away from known/mapped mineral systems and highlight exploration potential in areas that remain relatively underexplored. The maps provided in the Eastern Lachlan Orogen Mineral Potential Data Package can be adapted to produce more detailed mineral potential maps for mineral exploration targeting.

The success of this project has been critically dependent on the combined expertise of the GSNSW staff, who have comprehensive understanding of the mineral systems, and the modelling expertise of Kenex Ltd, in addition to the wealth of high quality pre-competitive source data provided by GSNSW.

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