Prospectivity models and GIS data for the exploration of epithermal gold mineralisation in New Zealand

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Assessing Mineral Potential

Assessment of mineral wealth and mineral potential is a key factor in encouraging mineral exploration in any country. Traditionally these assessments have been undertaken by national and state governments utilising published and unpublished geological survey information combined with permit-related data supplied by exploration companies. The results of the assessment are typically published but the underlying data have tended to remain distributed, in a variety of digital and paper-based formats, and are difficult for exploration companies or other third parties to acquire. Independent assessment of mineral potential is usually difficult, as potentially relevant exploration data can be held by several government agencies, and much of these data may be unpublished and unreferenced. This information has great value for any mineral company contemplating exploration in an area or country. The information serves to direct or guide companies to areas of potential where undiscovered mineral deposits may be located.

Up until recently mineral exploration data information has not been easily accessible in New Zealand. Much of the regulatory function including mandatory submission of exploration data is handled by Crown Minerals of the Ministry of Economic Development. Traditional geological survey data is managed by the Institute of Geological & Nuclear Sciences, a Crown-owned research organisation. Furthermore much of this information is either not digital or managed within a range of proprietry software. This acts as a disincentive for explorers to undertake exploration activity in New Zealand, because the costs involved in acquiring geological information for regional targeting are high.

Over the last decade, however, there has been substantial progress in organising mineral-related data in digital form. The adoption of Geographic Information System software (GIS) for geological data management by GNS, and more recently for mineral permitting by Crown Minerals, has been particularly beneficial. GIS offer versatile and efficient platforms for storing and analysing geological data, and are widely used as an exploration tool by the mining industry.

The purpose of this mineral prospectivity initiative, of which this CD is the second output, is to develop a product that could be used to highlight the mineral potential of New Zealand at a regional scale to the international exploration market. Like Australia and Canada, New Zealand has experienced a significant

downturn in exploration. As a consequence, many areas considered prospective during the exploration boom in the 1980s are now open to exploration. The aim of this project was to highlight these areas to explorers who may have discounted New Zealand as an exploration destination in the past, or are new to New Zealand. More importantly, the project delivers a new regional scale digital dataset, including geology, structure, geochemistry, geophysics, tenement information (current at June 2003), land use, national parks and historical prospect information that explorers will be able to use to assess and target gold mineralisation in New Zealand.

Scope and Aims of the Prospectivity Modelling

This project aims to highlight areas with promising potential for epithermal mineralisation and reduce risk for explorers entering New Zealand. This is intended to speed up the exploration process and allow a more focussed exploration effort. By combining one hundred years worth of data and information, held by Crown Minerals and GNS, with current knowledge from research by GNS, this project has identified many areas that show mineralisation potential. The prospectivity models, with their data coverage limitations, are not intended to find ore bodies for companies, but rather encourage companies to use their own knowledge to take advantage of the new data provided by this study. The study uses significant new geological knowledge from recent research carried out by GNS, which is summarised in a report by Christie & Brathwaite (2003) contained on this CD.

This report is not intended as a scientific publication, but rather to document and explain the geological and other GIS themes present on the CD, how to use them and provide comments on the significance of the results of the prospectivity modelling to future exploration in New Zealand. The epithermal gold GIS on the accompanying CD can be used by novice and expert GIS users alike. Inexperienced GIS users can browse the different geological data sets on the CD in relation to topographic and land tenure information. Expert GIS users can upload the GIS onto their own systems directly if using ESRI GIS software or convert the data files into their preferred GIS format.

All data files attached to the GIS vector and grid files can also be accessed using common database, spreadsheet and word processing software. The Arc-SDM software used for the prospectivity modelling and derivative grid files are also provided for those users who intend to carry out their own prospectivity analyses. All exploration models contain a certain amount of inherent bias due to the translation of any genetic model for mineralisation into an exploration model. Not all of the elements that form a genetic mineralisation model can be included in an exploration model as some data are not easy to collect, other data are expensive to collect and some data are used or discarded due to personal choice. The prospectivity models for epithermal mineralisation in this analysis are no different, and users are encouraged to carry out their own analysis using the data provided in this GIS. This project is the second part of a larger initiative to convert exploration data held both by GNS and Crown Minerals into a digital format. This study focussed on data collected at a scale of 1:20,000 and smaller and it not intended for detailed exploration at a prospect scale. Data coverage should be taken into account when assessing the mineralisation model results. The prospectivity models should only be used as a positive exploration tool for

near surface mineralisation, that is, absence of a spatial correlation does not negate an area's mineralisation potential, particularly where key datasets are not available.

Prospect-scale exploration targeting can be carried out if the more detailed exploration data, for example drilling information, soil sampling and trenching information, held by Crown Minerals are converted into digital data and incorporated into this GIS at a later date. Additional information from drilling results, seismic data and other geophysical data are required before an assessment of the potential for deeper mineralisation can be made.

It is hoped that the prospectivity modelling will also give all levels of government in New Zealand the on-going capacity to better manage and utilise the New Zealand mineral estate. This will hopefully lead to better-informed decisions regarding land and mineral resource use at the national and local government level.

Data

Many of the data themes on this CD have been derived from databases maintained by the Institute of Geological and Nuclear Sciences Ltd. These include:

- GERM (Geological Resource Map of New Zealand) - a mineral occurrence database featuring information on location, mining history, geological setting, and commodities.
- GMNZ - the digital version of the 1972 1:1,000,000 Geological Map of New Zealand published by the New Zealand Geological Survey. Only GIS-related modifications have been made, including rectification to a modern topographic base.
- QMAP - the comprehensively revised edition of the 1:250,000 Geological Map of New Zealand. QMAP is a fully digital, information-rich ArcInfo GIS dataset that currently covers half of the country and is planned to be complete by 2009.
- Petlab - recently compiled rock and geochemical database covering all of New Zealand. The databases are managed by GNS with data compiled from a variety of sources including published datasets, unpublished GNS databases and universities.
- Regchem – the regional geochemistry database of open-file mineral exploration analyses of stream sediment, rock chip and other samples.
- total magnetic intensity and resistivity anomaly maps - for Coromandel and Taupo Volcanic Zone, published and unpublished at varying resolution.

In addition

- Delta Gold have supplied a compilation of exploration geochemistry for a considerable part of the Taupo Volcanic Zone area. These data have been merged with the Regchem data in the area of interest.

There are more than one hundred new data themes provided on this CD (Appendix 1). However, New Zealand still lacks good regional coverage of some digital data that are taken for granted in other countries, states and

territories. Additional datasets that either need to be acquired or converted from paper form into digital form include:

- High resolution gravity
- High resolution EM
- High resolution DTMs
- High resolution radiometric data
- High resolution magnetic data
- Prospect-scale soil sample geochemistry
- Prospect scale drill geochemistry from all drilling methods (RAB, RC and Diamond)

Model definition

Defining the deposit model is the foundation phase for any prospectivity study. Accepted genetic models for epithermal gold mineralisation in New Zealand have been documented (Christie & Brathwaite 2003), and are provided on the CD as a separate PDF report. These models were used to constrain the data collected and complied from Crown Minerals exploration reports and GNS digital databases.

The specific geological and geochemical data that was compiled for use in the subsequent GIS prospectivity analysis are summarised in Table 2.

Data compilation

The accompanying CD contains more than 110 new vector and grid GIS data themes that have not been readily accessible for exploration targeting of epithermal gold mineralisation in New Zealand. More importantly, the data are compiled at a national-scale, and some themes, especially the geochemical data themes, have not been viewed in this format or scale before. A significant amount of geological data and information was sourced from open file mining company technical reports held by Crown Minerals, and from various databases held by GNS, such as REGCHEM (regional stream sediment/soil geochemistry, GERM (mine, prospect, and mineral occurrence database), and Petlab (geochemical and rock sample database). GNS also compiled geological information (structure, lithology, quartz veins etc) from published and unpublished geological maps including the relevant 1:250,000 QMAP sheets. A detailed description of the project structure and GIS file metadata is given in Appendix 1 and required data with sources in Table 1.

Over 2600 new geochemical point data derived from 16 open-file reports held by Crown Minerals have been integrated with 5665 point data compiled by Delta Gold from 37 reports and existing data in the GNS REGCHEM database. These data included stream sediment and rock chip samples. This study emphasised capture of stream sediment data over the areas of interest, and consequently the rock-chip data coverage is less well represented in the area of interest, particularly the Coromandel region. The data selected from technical

reports were at scales appropriate for the study (1:20,000 and smaller), and for this reason prospect-scale drill hole data and soil geochemical data were not included. Several hundred hours were spent sourcing, assessing and entering the data, as well as carrying out quality assurance checks.

Relationship	Feature	Data source
Distribution of known deposits	Occurrences and past production	GERM
Lithologic associations	Host rock lithology	QMAP
Potential source rock influences	Volcanic and intrusive rocks	QMAP
Structural controls	Relationship to faults and lineaments	QMAP
	Relationship to calderas	QMAP
Regional geochemistry	Stream sediments*	Regchem
	XRF whole-rock	PetLab
	Rock chip	Regchem
Deposit geochemistry	Rock chip	Regchem
	Soil	Regchem
Topographic information	Spot heights and contours, DTM, roads, rivers, lakes and coast.	LINZ

* Stream sediments includes: stream sediment, pan concentrate and BLEG (bulk leach extractable gold) sample results that must be recorded and analysed separately.

Table 1: Information used in the GIS prospectivity analysis for epithermal gold deposits in New Zealand.

The paper-based data held by Crown Minerals in open file exploration reports provides an invaluable geochemical resource for a national or regional scale for mineral and environmental studies. This project has added value by capturing parts of this important national asset into a digital format that can be more easily used and updated in GIS and other information systems.

Data classification

As discussed by Christie and Brathwaite (2003), epithermal gold mineralisation in New Zealand occurs in three distinctive terrains and over two distinct time periods. Hence the study was subdivided into three distinct regions (Fig. 1): eastern Northland, Coromandel Peninsula and the Taupo Volcanic Zone (TVZ).

Data compiled prior to the prospectivity modelling stage were reclassified and adapted in accordance with the mineralisation models described by Christie and Brathwaite (2003). These derivative datasets were generated using spatial modelling techniques such as buffering, intersections, interpolation using inverse distance weighting or density algorithms, or from expert-assigned attributes of genetic significance stored in the GIS data tables. The key geological concepts included for the GIS prospectivity modelling in this analysis included:

- Host rock preference of known deposits
- Proximity to major faults and relationship to fault orientation
- Lithology (basalt, andesite, dacite or rhyolite; flows versus pyroclastic rocks)
- Age of host rocks
- Correlation with density of quartz veins

• Correlation with density of faults
• Geochemistry of host rocks
• Proximity to calderas and/or ring structures
• Proximity to or correlation with density of lineaments (Coromandel)
• Correlation with specific ranges of Au:Ag ratios
• Correlation with As in exploration geochemical surveys
• Topographic expression from DTMs and remote sensing data

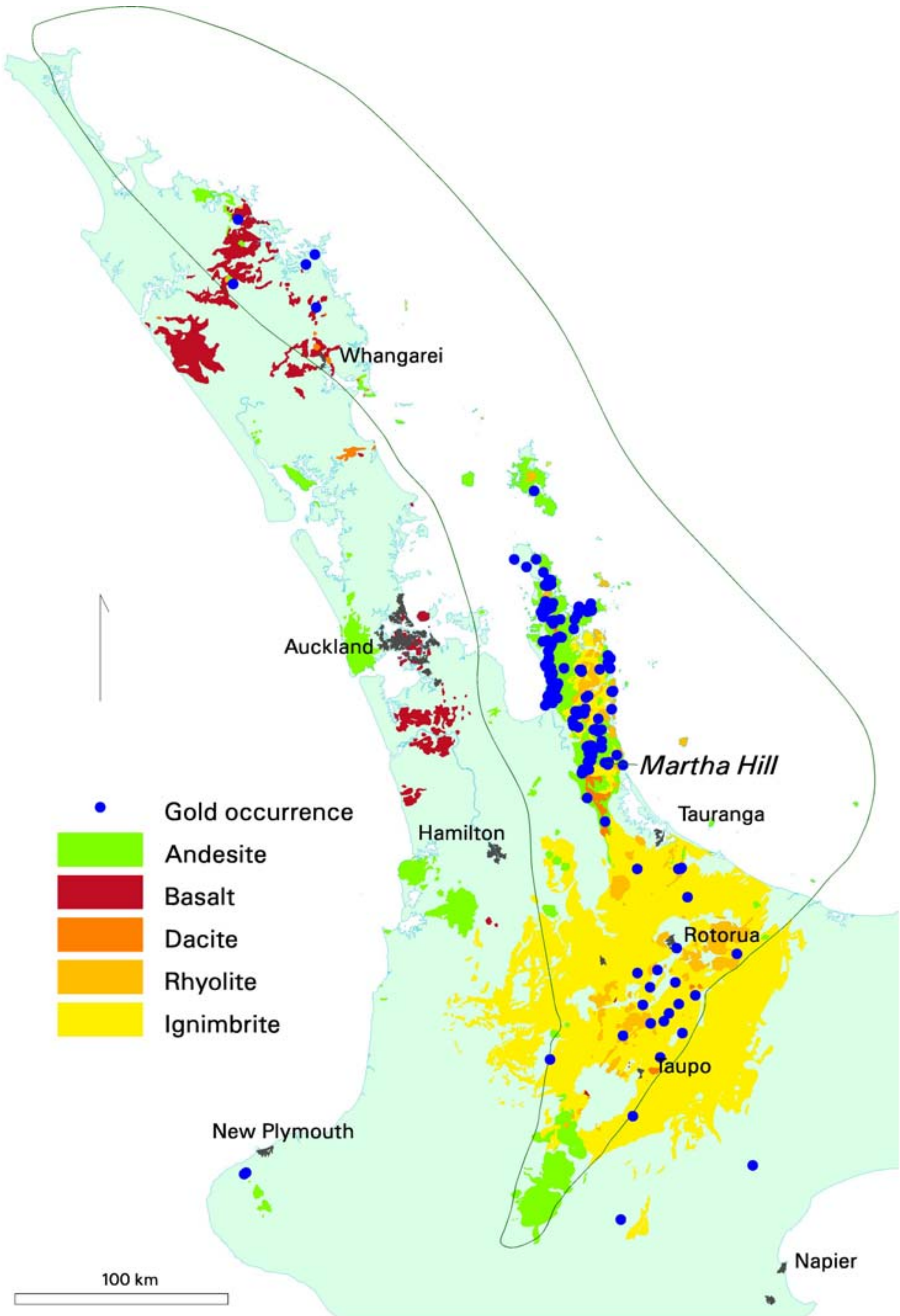

Figure 1: Location of gold occurrences (GERM database) in northern New Zealand, areas of Miocene-Recent volcanic rock, and the area of interest for epithermal gold covered in this study. The region's largest producing gold mine is Martha Hill (241 t Au).

The first stage of the prospectivity modelling is to quantify the spatial correlations of these data (and their derivatives) to the "training" data layer of historic occurrences of epithermal Au mineralisation in eastern Northland, Coromandel Peninsula and the Taupo Volcanic Zone.

Spatial Modelling Methodology

As a first step in the spatial correlation calculation, a 100 by 100 metre grid was generated over the three areas of interest (nlandtrain.shp ; corotrain.shp ; tvztrain.shp). The size of the grid was chosen to represent the minimum probable extent that would be covered by an economically viable epithermal gold deposit. These areas were defined for the low sulphidation epithermal vein models defined by Christie and Brathwaite (2003). A high sulphidation model was not created as there are no training data (deposits of this type) known in New Zealand at present. As noted by Christie and Brathwaite (2003) there is potential for this style of mineralisation in all three areas and an expert system prospectivity model using a Fuzzy Logic Model could be created using the data provided on the CD. Similar models could also be created to test the potential for porphyry copper-gold mineralisation and sediment-hosted epithermal gold mineralisation in these areas.

Mineral deposit locations for hard rock gold mineralisation were extracted from the GERM mineral deposit database. Following data validation, the prospect database was then reviewed, checking data and excluding all prospects with unrelated gold mineralisation. A training data set was then subset from this database for each regional area (nlandtrain.shp ; corotrain.shp ; tvztrain.shp). Nine training data points were used in the Northland area, including the Puhipuhi prospect where epithermal mineralisation has been intersected in drilling by previous explorers. The Coromandel training dataset consists of 161 prospects, including the world class Martha Mine currently operated by Newmont Mining, the recently closed Golden Cross mine and the historic Karangahake mine. The TVZ, by comparison, is relatively under explored with only four significant gold occurrences identified in the region. These include the Ohakuri and Broadlands systems where significant bedrock gold mineralisation has been identified by previous explorers.

Spatial correlations were calculated using the Weights of Evidence technique of Bonham-Carter (1997), using the Spatial Data Modeller extension developed for ESRI's ArcView 3.3 GIS software (Kemp et al 2001). A unit area of 0.7 km^2 was used in these calculations assuming the known deposits have a 0.7 km^2 sphere of influence. As described by Bonham-Carter (1997), the spatial correlation (prior probability) of a feature can be calculated by using the relationship of the area covered by the data variable being tested and the number of training data points (nlandtrain.shp ; corotrain.shp ; tvztrain.shp). This produces a W+ result for when the feature is present and a W- result when the feature is absent (Appendix 2 and PMNSpatialDataTable.xls on the CD for the detail). A contrast value C is then calculated from the difference. The standard deviations of W (Ws and Cs) are calculated, 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).

W+	spatial correlation - prior probability of a (training set) feature being present
Ws+	standard deviation of W+
W-	spatial correlation - prior probability of a (training set) feature being absent
Ws-	standard deviation of W-
Contrast	difference between W+ and W-
Cs	standard deviation of the Contrast
studC	studentised Contrast: the contrast divided by its standard deviation.

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. Ideally a StudC value larger than (-)1.5 can be considered as a positive or negative correlation (Bonham-Carter 1997). 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 value > 2.0, StudC value >3.0
- moderate correlation inferred from C value between 1.0-2.0, StudC value between 3.0-1.5
- weak correlation inferred from C value between 0.5-1.0, StudC value between 1.5-0.5
- poor correlation inferred from C value between < 0.5, StudC value <0.5.

Spatial correlation results

The results from the spatial correlation analysis are listed in Appendix 2, the file PMNSpatialDataTable.xls and summarised according to the most important exploration criteria for each region in Tables 2, 3 and 4. The summaries have been compiled to highlight the most important exploration parameters for each deposit model. This was done to put the genetic models for epithermal gold mineralisation into an exploration context. The results from the spatial analysis can therefore be used to develop realistic models to help targeting during more detailed scale exploration in the respective areas.

The spatial correlation analysis was subdivided into general geologically related themes, which are discussed below:

- Structural geology
- Geology, Stratigraphy, and Hydrothermal Alteration
- Geochemistry
- Geophysics

Structural geology

Quartz veins and faults (and derivative datasets such as specific orientation ranges, intersections of combinations of these, age, movement sense, density) were buffered using the methodology described by Partington et al. (2001) to determine the optimum distance for the greatest number of prospects from the feature or features. Each data layer was coded with relevant attributes and processed using ArcView and the ArcSDM extension software (Kemp et al., 2001) to assess the spatial correlation of each modified variable with a training data set. The fault data were also combined into individual faults to test their relationship with mineralisation. The quartz veins and faults from the 1:250 000 scale datasets were tested.

Exploration Data	Comment
Normal and reverse faults	Fault structural control is important at a local scale, particularly Pliocene age, although thrust faults do not appear to have any association with Au mineralisation.
Hg deposits	Hg has a strong association with gold mineralisation. Hg is more common in the Northland region and is a good pathfinder element for Au.
Quartz-adularia-sericite and argillic alteration	Strong relationship of Au mineralisation with alteration. Alteration mapping and use of geophysical interpretation is a very important exploration tool.
Density of quartz veins.	Spatial association of Au with quartz vein density is limited by current mapping. Better prospect scale mapping is required.
Eruption breccias.	Good short range spatial correlation with hydrothermal eruption features. Good relationship with features that can be mapped on the ground and/or geophysical interpretation.
Sinters.	Good long range spatial correlation with sinters, which agrees with the exploration model. Good relationship with features that can be mapped on the ground and/or geophysical interpretation.
Host rock.	Mainly andesite or greywacke. Like the Coromandel, there seems to be a strong preference for andesites, which seem to have a possible rheological and/or geochemical control on mineralisation. Andesites can be mapped on the ground or with geophysical techniques.
Stream sediment geochemistry, especially Au, Ag and As.	Good spatial association with standard geochemical exploration techniques, which agree with the exploration model. Key elements are Au, As and Ag with BLEG appearing to give the most accurate results.

Table 2: Key geological and geochemical criteria for exploration for epithermal gold mineralisation in order of greatest spatial correlation in the Northland region.

The faults in all three regions were tested independently for spatial association with epithermal gold mineralisation, and gave good spatial correlations (Appendix 2; PMNSpatialDataTable.xls on the CD). The Coromandel region gave best spatial correlations, which may relate to the abundance of training data. The Northland area gave better spatial correlations when the thrusts in the fault data set were excluded (Appendix 2; PMNSpatialDataTable.xls on the CD). The TVZ region has a weaker association with faulting (Appendix 2; PMNSpatialDataTable.xls on the CD), which may relate to the small size of the training data and the large number of faults mapped. More data are required, especially the timing of structures with respect to mineralisation. This is also true for the Coromandel and Northland regions.

Exploration Data	Comment
Faulting, including fault orientations, fault density, and fault intersections	Fault structural control is important at a local scale With Au mineralisation related to N and NE-trending faults. Age of faulting also important.
Density of quartz veins	Spatial association of Au with quartz vein density limited by current mapping. Better prospect scale mapping is required to identify areas of epithermal veining.
Stream sediment geochemistry, especially Au, Ag and As	Good spatial association with standard geochemical exploration techniques. The better data coverage for the Coromandel has increased spatial correlations with As, Sb, Ag, Au and Cu geochemistry giving the best correlations. BLEG stream sediment sampling appears to give the most accurate results.
Rock chip geochemistry	The data coverage is not good enough to assess the suitability of this technique. However, areas with good data coverage do correlate with areas of mineralisation, especially Ag, Au and As.
Quartz-adularia-sericite and argillic alteration	Strong relationship with alteration. Geophysical interpretation of demagnetised areas gives a better spatial correlation than the alteration mapping. Alteration mapping and use of geophysical techniques is a very important exploration tool here.
Host rock	Strong preference for andesites, which seem to have a possible rheological and/or geochemical control on mineralisation. Andesites can be mapped on the ground or using geophysical techniques
Hg mineralisation	Good spatial correlation with Au mineralisation.

Table 3: Key geological and geochemical criteria for exploration for epithermal gold mineralisation in order of greatest spatial correlation in the Coromandel region.

Exploration Data	Comment
Faults	Structural control is important at a local scale, but there is not enough information to distinguish between mineralised and non mineralised faults. Suggestion of an association of mineralisation with E-trending jogs in relation to the regional NE trend of the faults.
Resistivity anomalies	The resistivity anomalies are interpreted to relate to zones of recent hydrothermal activity. The association with mineralisation agrees with the deposit model for the TVZ.
Proximity to margins of calderas	Good spatial correlation with volcanic features. Good relationship with features that can be mapped on the ground and/or geophysical interpretation.
Alteration	Strong relationship with alteration. Geophysical interpretation of demagnetised areas gives a better spatial correlation than the alteration mapping, which has does not have a regional coverage. Alteration mapping and use of geophysical techniques is a very important exploration tool in the TVZ region.
Rock chip, especially Au, Ag and As	Good spatial association with standard geochemical exploration techniques, which agree with the exploration model. Key elements are Au, As and Ag, .
Stream sediment geochemistry, especially Au, Ag and As	Good spatial association with standard geochemical exploration techniques, which agree with the exploration model. Au, As and Ag are recommended with BLEG appearing to give the most accurate results.

Table 4: Key geological and geochemical criteria for exploration for epithermal gold mineralisation in order of greatest spatial correlation in the TVZ region.

Fault intensity maps were developed by creating a point every 100 metres along the individual faults and gridding the density of points, using the kernel method in Spatial Analyst extension of ArcView. These fault intensity maps gave high spatial correlations in the Coromandel region (Appendix 2; PMNSpatialDataTable.xls on the CD; corofltdenrc), but no spatial correlations in the Northland and TVZ regions. The density of faulting here seems to provide a better association with mineralisation than distance from or along particular faults in the Coromandel region. The density of data in the Northland region and the lack of training data may explain the lack of correlation in the Northland region (Appendix 2; PMNSpatialDataTable.xls on the CD). In contrast, mineralisation in the TVZ region is not related to areas of higher density of faulting (Appendix 2; PMNSpatialDataTable.xls on the CD).

The faults in all three regions were subdivided into four classes according to their trend and the spatial correlation with the training dataset has been calculated with distance from the each class of fault trend (combinedfaults.shp; Appendix 2; PMNSpatialDataTable.xls on the CD). Mineralisation in the Coromandel region has a good spatial correlation with NE-trending faults and faults with a dip-slip sense of movement (Appendix 2; PMNSpatialDataTable.xls on the CD). There is not enough data in the Northland region to further subdivide the faults associated with mineralisation. There is a suggestion in the TVZ region that mineralisation may be related to E-trending bends in the regional NE trending fault systems (Appendix 2; PMNSpatialDataTable.xls on the CD). There is not enough information to further subdivide the faults in the TVZ region.

The relationship between mineralisation and intersections of faults of differing trends was investigated by creating a point theme of intersections using ArcView (Fltintnenw.shp, Fltintnee.shp, Fltintnen.shp, Fltintne.shp, Fltintnwn.shp, Fltintnwe.shp and Faultint.shp) and buffering around the intersection points. A correlation matrix for the results for this analysis for the Coromandel region is given in Table 5. Most epithermal gold deposits are found within 3,200 metres of a fault intersection in the Coromandel region. The fault block mesh created by intersecting N-trending, NE-trending and NW-trending faults may have a significant control on mineralisation. NE-NW fault intersections appear most important at a regional scale with a possible NE-E fault intersection control at a local scale worthy of further investigation (Table 5). The spatial correlations for the Northland and TVZ regions are weak or not present due to a lack of data in the Northland region and few fault intersection mapped in the TVZ data. The lack of fault intersections in the TVZ region may relate to the regional scale of the mapping or may be a real feature that requires further investigation.

	1 N	**2 NE**	**3 E**	**4 NW**
1 N	NA	5400m, 0.9	5400m, 1.1	1200m, 1.2
2 NE		NA	600m, 2.2	2600m, 1.6
3 E			NA	9200m, 1.0
4 NW				NA

Table 5: Coromandel fault intersection spatial correlation matrix showing optimal distance from intersection points and correlation contrast (C).

Geology, Stratigraphy and Hydrothermal Alteration

The deposit model for epithermal gold in New Zealand suggests that there is a significant host rock control on the type of gold mineralisation (Christie and Brathwaite 2003). Lithological and stratigraphic controls on mineralisation for all regions were tested using the QMAP data theme (geolpoly.shp). The various rock type and stratigraphic attributes were recoded to numeric values and tested for spatial correlations with known mineralisation. There is a strong host rock control on mineralisation in both the Coromandel and Northland regions with andesitic lithologies giving significant spatial correlations as suggested by the mineralisation

model. Cover rocks (sand and gravel) have, not surprisingly, a strong negative spatial correlation. The TVZ region has no significant lithological spatial association with mineralisation, due to the poor training data and/or the regional nature of the mapping.

Epithermal gold mineralisation is commonly associated with broader zones of alteration, caused by volcanic and hydrothermal processes. Alteration mapping has been carried out in all three regions at a variety of scales and variable detail (altnpoly.shp). The alteration type attribute was recoded to numeric values and some of the alteration types combined. As predicted by the mineralisation model all three regions have significant spatial associations with alteration. However, these data proved of limited value at a regional scale in Northland and the TVZ region due to areas of missing data. Additional regional scale alteration mapping would provide a valuable tool for explorers. The Coromandel region has the best alteration mapping coverage and has significant spatial correlations between quartz-adularia-sericite and argillic alteration. There is a weak negative correlation with propylitic alteration. The Northland region has a limited coverage of alteration mapping, but has similar results to the Coromandel region when an analysis is made of proximity to alteration types using buffering. The alteration types have good spatial associations with mineralisation at a more regional scale, with argillic alteration having the closest proximity to known mineralisation. Alteration mapping in the TVZ region is limited in extent and restricted to areas of clays and active hydrothermal activity. There is not enough data or a large enough training dataset for these data to be used.

Other volcanic features such as proximity to sinters, volcanic vents, hydrothermal vents, presence of eruption breccias and proximity to calderas have variable coverage, but provide useful information at a local scale. There is no spatial association with these features in the Coromandel Region. The TVZ region has good spatial associations with eruption breccias at a short range and sinters at a more regional scale. The spatial association of mineralisation in the TVZ with caldera margins and current hydrothermal activity may be expected in a region with modern volcanic activity.

Epithermal gold deposits are commonly associated with large additions of silica in the form of quartz veins. Quartz veins host many of the high-grade shoots in most epithermal deposits. However a large proportion of the veins are usually sub-economic or barren. Despite this, the presence of a high density of quartz veining can define areas of fluid flow within and along regional scale structures. A quartz vein density map was created by using the quartz vein data layer (coroqvdenrcl). There is good data coverage in the Coromandel, limited data coverage in Northland and no data in the TVZ region. The linear quartz vein theme was converted from polylines to regular points every 100 metres along the line defining the quartz vein. A density map was then created using the Spatial Analyst density gridding tool, using the kernel technique with a 2 km search radius. Data are probably biased by outcrop distribution and historical production. The quartz vein density map and buffered quartz vein proximity maps give very strong spatial correlations with mineralisation in the Coromandel region and quartz vein buffer theme in the Northland region. There are not enough data in the TVZ region to test the relationship between quartz veins and gold mineralisation. Additional quartz vein data from exploration reports and future geological mapping should be collected to complete the data coverage for all three regions.

Geochemistry

Exploration geochemistry is used to find chemical element enrichment that commonly occurs around a mineral deposit. The enrichment may be part of a primary envelope, that is, related to host rock alteration by hydrothermal fluids, and/or a secondary dispersal pattern, developed by weathering and erosion of the deposit. The primary envelope and secondary pattern typically form pronounced geochemical anomalies that present a larger exploration target for mineralisation than would be provided by the economic mineral deposit itself. The geochemical information used in this study was restricted to those trace elements traditionally expected to be associated with epithermal gold deposit (Ag, As, Au, Cu, Hg, Pb, Sb, W and Zn Appendix 1; petl_key.shp; regchem.shp). Geochemical anomalies were defined using a standard statistical approach used to analyse anomaly levels in exploration geochemical data. The geochemical anomaly maps used in the study are a positive indicator of an area's mineral potential and no areas are discounted because of a lack of geochemical coverage.

The geochemical dataset has been subdivided into themes according to element and by sample method (ssmultielement.shp, ssau.shp; ssblegau.shp; ssfineau.shp; sspanconau.shp; rockchipme.shp; rockchipau.shp). The summary statistics for each theme, excluding missing data (=0.00), were calculated using the Gstats extension in ArcView 3.3 (Table 6). Anomalous threshold values from log cumulative probability plots of each theme (except W) were taken from inflection points. The anomalous rock chip datasets were then modelled into 1 km^2 cells of influence taking the highest value in each cell to test for a spatial correlation with known mineralisation. The anomalous stream sediment themes were combined with the regional river catchment theme (basinpol.shp) to create a derivative catchment geochemistry theme (basinchem.shp). Average, maximum, count and standard deviation statistics were calculated for each catchment in each theme and joined as attributes to the catchment polygons. The catchments were then classified as anomalous using the anomaly thresholds for each element and converted to grid files for modelling (rcanomag; rcanomas; rcanomau; rcanompb; rcanomsb; rcanomzn; rcanomhg; ssbasinag; ssbasinas; ssbasinau; ssbasincu; ssbasinpb; ssbasinsb; ssbasinzn and ssbasinhg). The stream sediment Au anomaly grid was created by combining all the different anomaly thresholds for each sample and analytical technique for Au into anomalous and background datasets. Table 6 summarises the chosen anomaly thresholds used to create the geochemical anomaly themes.

The spatial correlations for the pathfinder elements are given in Appendix 2 and in detail in the file PMNSpatialDataTable.xls on the CD. In general the expected geochemical associations of Ag, Au and As gave very good correlations with known gold occurrences in areas with good data coverage. The best spatial association with anomalous stream catchments is for Ag, As and Au in the Coromandel region. As predicted by the mineralisation model base-metals have a less significant spatial association, suggesting there may be a metal zonation related to the greater depth of erosion in the Coromandel region. There is a limited spatial association with gold occurrences in the Northland and TVZ regions, but both areas contain several significant regionally anomalous areas not associated with known mineralisation. Limited data has been collected around the known areas of mineralisation in both Northland and the TVZ regions and this should be addressed as an exploration priority.

The rock chip data set is less useful than the stream sediment data as the coverage is poor for the Coromandel region and a little better for the TVZ and Northland regions. Again, significant areas of anomalous geochemistry exist independent of the known prospects that require follow-up. The Coromandel region has additional data available in company reports that needs to be converted into digital data. Additional regional scale data needs to be collected from the Northland and TVZ regions.

Data	Units	Max	Average	SD	Total	Lower	Upper
RK Ag	ppm	333	1.3	10.9	4,098	1.5	9
SS Ag	ppm	3,470	1.6	42.6	12,092	1.2	11
RK As	ppm	32,900	115	665	3,263	128	570
SS As	ppm	61,000	31	846	5,214	47	240
RK Au	ppb	60,300	77	1,212	4,083	0.6	13
SS Au	ppb	44,700	49	603	8,378	3	60
SS Pan Con Au	ppb	2,450,000	5,050	62,771	1,834	8	1,340
SS BLEG Au	ppb	3,500	6.8	83	1,958	2.7	18.5
SS Fine Au	ppb	4	0.13	0.56	65	0.2	0.3
RK Cu	ppm	39,000	47	1,161	2,101	29	67
SS Cu	ppm	2,300	23	35	9,302	37	90
RK Pb	ppm	51,000	95	1,491	1,984	22	147
SS Pb	ppm	1,050	20	30	8,020	35	70
RK Sb	ppm	13,000	12	224	3,468	12	47
SS Sb	ppm	40	0.5	2.5	3,487	0.7	6
RK W	ppm	2,900	insufficient	insufficient	11	insufficient	insufficient
SS W	ppm	5	insufficient	insufficient	3	insufficient	insufficient
RK Zn	ppm	142,990	342	5,308	2,036	62	170
SS Zn	ppm	2,910	65	65	8,332	83	122
RK Hg	ppm	130,000	58	2,641	2,423	2.9	25
SS Hg	ppm	2,400	25	169	516	14	200

Table 6: Summary statistics for chosen geochemical themes used in the study.

RK = Rock chip sample

SS = Stream sediment sample

Pan Con = pan concentrate sample.

BLEG = bulk leach extractable gold sample.

An attempt was made to use the whole rock geochemical data from the GNS Petlab database (petl_maj.shp) to develop host rock geochemistry maps for the three regions to test for host rock geochemical controls and possibly identify subtle alteration halos. The whole rock geochemical data were joined to the Qmap geology polygon theme using a similar methodology as was used to create the geochemical catchment theme (lithchem.shp). Unfortunately the data coverage is not good enough for these themes to be used in the spatial

modelling. These themes could be used independently of the prospectivity models for exploration. These data could also be used to identify missing data for follow-up sampling

Geophysics

The Coromandel and TVZ regions have a significant amount of geophysical data, including aeromagnetics and resistivity data sets. These data were collected at a variety of scales and for different purposes. The data have not been merged into seamless geophysical themes, due to the differing resolutions and quality of the data. Geological interpretation of all the geophysical data has been completed for this project including an interpretation of alteration typified by demagnetisation, caldera locations, resistivity anomalies and magnetic anomalies (calderap.shp, resanomp.shp, maganoms.shp and maganomp.shp). Most of the geophysical data either gave similar spatial correlation results to the geological mapping data except for magnetic features that have no spatial associations. Interpreted alteration zones related to demagnetised zones (in Appendix 2 and in detail in the file PMNSpatialDataTable.xls on the CD) have a better spatial correlation than the mapped argillic alteration theme (in Appendix 2 and in detail in the file PMNSpatialDataTable.xls on the CD). The geophysical data and subsequent interpretation provided additional information on structure and alteration at a regional scale. More importantly, these data give a regional coverage and information at depth, and are especially useful in areas of thin cover. All three regions need additional modern geophysical surveys, including airborne gravity, at both regional and prospect scales.

Prospectivity modelling results

Prospectivity modelling, using weights of evidence techniques (cf. Bonham-Carter et al. 1988; Bonham-Carter 1997; Agterberg et al. 1993; Partington et al. 2001), has been carried out over all the areas of interest at approximately 1:250 000 scale. The themes used in the prospectivity modelling for each model and their weights of evidence StudC values are listed in Tables 7, 9, and 11. The most important spatial variables that should be used during any more detailed prospect scale exploration for epithermal gold mineralisation are listed in Tables 2, 3 and 4 respectively. The accepted genetic model for the formation of epithermal Au style mineralisation was used to constrain the input data themes for the analysis along with their spatial correlation to known mineralisation. The scale of the analysis is not intended to target mineralisation at prospect scale, but rather, provide information for the exploration industry to be used to target for tenement acquisition. More detailed data, such as prospect scale geological mapping, soil sample geochemical information and drill assay data, are needed for prospect scale work. These data can be acquired by new exploration and by converting existing data into digital format from exploration reports held by Crown Minerals. Users are encouraged to create their own models by experimenting with different combinations of the derivative raster grid files provided on the CD.

A prospectivity model has been developed for each region using ArcSDM software through Spatial Analyst extension in ArcView. Once the prior probabilities for each theme have been calculated, the themes were all converted into binary grid themes where possible to reduce the processing time. A post probability model for each region can be calculated by combining the various themes using their spatial correlations as weights. These are calculated by weighting the values of each cell in the themes according to their prior probabilities and then adding the weighted values of each theme together (Bonham-Carter 1997). The number of variables used was also kept to a minimum to reduce the potential for conditional independence between the selected themes as discussed by (Bonham-Carter 1997).

Northland prospectivity model

A model for the prospectivity of epithermal gold mineralisation in Northland has been constructed using the grid themes listed in Table 7. The model was created using the Calculate Response menu in ArcSDM and selecting the grid themes listed in Table 7. The model consists of a grid response theme containing the intersection of all of the input themes in a single integer theme. Each row of the attribute table contains a unique row of input theme values, the number of training points, area in unit cells, sum of weights, posterior logit, posterior probability, and the measures of uncertainty (See attribute table NLPmap1.dbf and NLPmap1woe1.dbf on the CD). The variances of the weights and variance due to missing data are summed to give the total variance of the posterior probability. The response theme can be mapped by any of the fields in the attribute table. Various measures to test the conditional independence assumption are also reported (Table 8). Conditional independence is a significant problem in this model, especially between the geological themes, with a value of 0.26. Consequently the posterior probabilities should be thought of as relative favourabilities or rankings within the Northland region. The normalised probability attribute gives a much better measure of probability, but still overestimates the actual probability value.

Grid theme	Description	Variables	C	StudC
Nlfltage	Fault age	4	6.94	0.69
Hganom	Distance from Hg mineralisation	2	6.37	7.69
Nlsio2buf	Quartz-adularia-sericite alteration zones	2	4.66	6.49
Nlargbuf	Argillic alteration zones	2	6.01	8.00
Nlerptbuf	Distance from eruption breccias	2	4.37	5.21
Nlsintbuf	Distance from sinters	2	4.45	6.21
Nllith	Lithologies	11	6.58	0.65
Nlstrat	Stratigraphy	47	9.09	0.63
Ssbasinau	Anomalous Au Catchments	2	6.94	0.69

Table 7: Grid themes used in the Northland prospectivity model with their prior probabilities.

	HGANOM	NLSIO2BUF	NLARGBUF	NLERPTBUF	NLSINTBUF	NLLITH	NLSTRAT	SSBASINAU
Nlfltage	0.75	1.30	1.30	0.40	0.00	1.87	2.93	0.00
Hganom		0.00	0.00	0.18	2.13	0.80	1.42	0.83
Nlsio2buf			4.50	0.67	0.50	0.00	0.00	0.70
Nlargbuf				0.67	0.50	0.00	0.00	0.70
Nlerptbuf					0.67	1.67	1.78	0.83
Nlsintbuf						1.58	1.33	0.05
Nllith							6.11	0.83
Nlstrat								0.83

Table 8: Chi^2 test of conditional independence for the Northland model. Those values <0.015 in red indicate a dependence between themes that results in significant conditional dependence in the model.

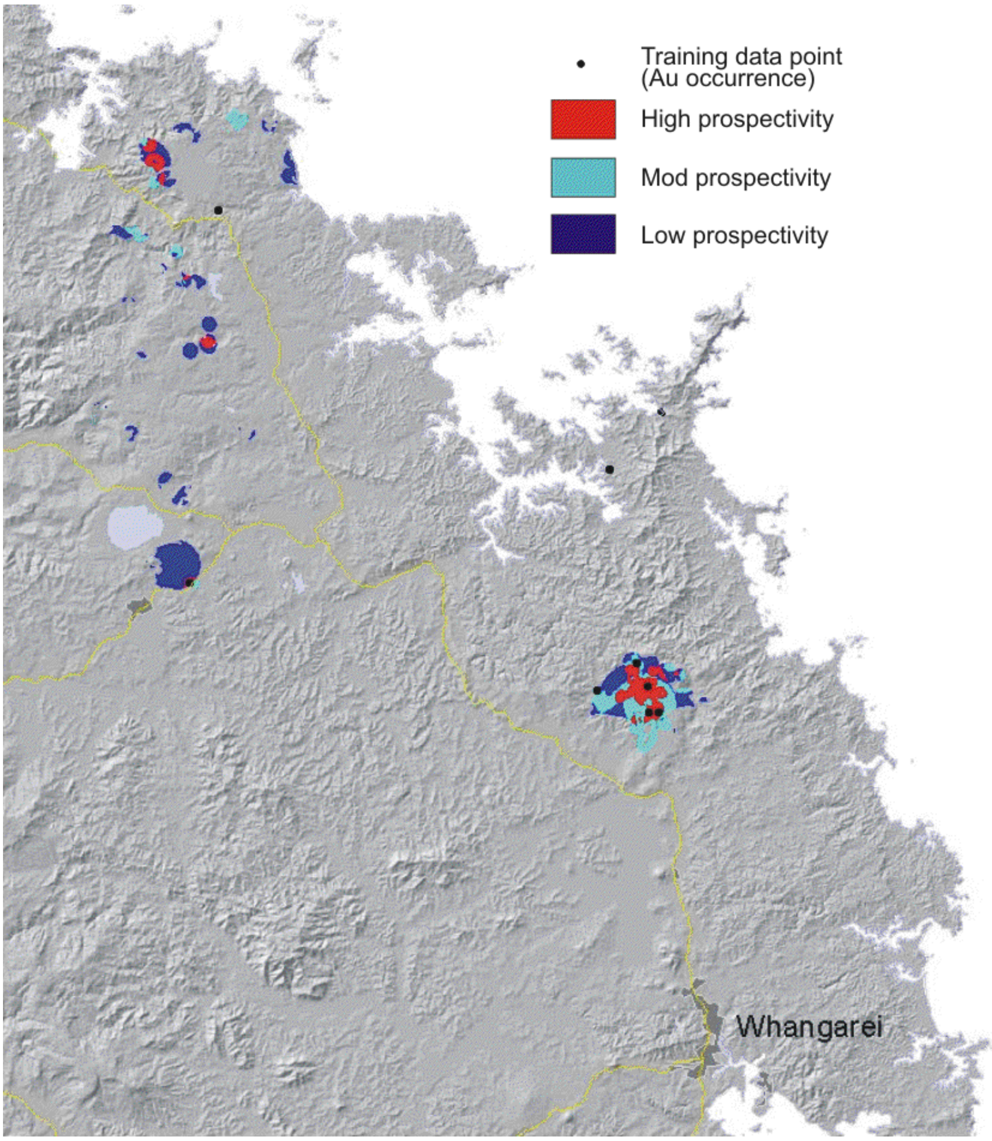

Figure 2: Epithermal gold prospectivity map for the Northland region.

The epithermal gold mineralisation prospectivity modelling for the Northland region has identified several prospective areas despite gaps in several databases and limited training data (Fig. 2). The Puhipuhi area stands out, but several new areas with no historic mineral occurrences have also been highlighted, especially in the northeast of the region (Fig. 2). The most prospective areas are around normal and reverse faults associated with mercury mineralisation and argillic alteration. Lithology appears to also control mineralisation as does the proximity of eruption breccia. Geochemical prospecting is an important technique that should be used further in the region, with As, Ag, Hg and Au important pathfinder elements. There are areas of anomalous geochemistry that require follow-up that lie outside the current prospective areas (rcanomag, rcanomas, rcanomau, rcanomhg, ssbasinag, ssbasinas, ssbasinau, ssbasinsb and ssbasinhg). The area in the northeast is also highlighted, independently of the prospectivity model, by rock chip geochemistry and stream sediment geochemistry.

The Northland prospectivity model has successfully reduced the initial search area at a regional scale and identifies areas with similar combinations of geological and geochemical variables that occur in areas of known epithermal gold mineralisation. As discussed above, the prior probability values from the prospectivity analysis can be used to prioritise the potential for individual prospects or historic mining districts. These have been added to the attributes in the minerals.shp theme on the CD and as a new thematic layer of ranked prospects.

Coromandel prospectivity model

A post probability model has also been calculated for the Coromandel region by combining the various data themes using their spatial correlations as weights. A model for the prospectivity of epithermal gold mineralisation was constructed using the grid themes listed in Table 9. These themes were chosen as having the best regional coverage, a good spatial association with known mineralisation, to represent the current mineralisation model, and where possible not to duplicate data themes.

Grid theme	Description	Variables	C	StudC
Corostrdenrc	Fault Density	3	4.21	20.62
Coroqvbuf600	Distance from Quartz veins	2	4.45	24.54
Corolith	Lithologies	9	4.66	0.47
Corofltint	Fault intersection	2	2.50	14.03
Ssbasinas	Anomalous As catchments.	2	2.51	9.22
Ssbasinau	Anomalous Au catchments.	2	1.69	7.88
Coromagalt	Alteration zones interpreted from magnetic data	11	2.27	13.63
Corofltrend	Fault trend.	2	2.27	7.98

Table 9: Grid themes used in the Coromandel prospectivity model with their prior probabilities.

Various measures to test the conditional independence assumption are reported (Table 10). Conditional independence is a significant problem in this model, especially between the geological themes, with a value of 0.29. This is not unexpected as most geological datasets and geochemical data sets have some form of interrelationship. Consequently the posterior probabilities should be thought of as relative favourabilities or rankings within the Coromandel region. The normalised probability attribute gives a much better measure of probability, but still over-estimates the actual probability value.

ETHEME	COROQVBUF6	COROLITH	COROFLTINT	SSBASINAS	SSBASINAU	COROMAGALT	COROFLTTRE
Corostrdenrc	0.0000	0.8622	0.0000	0.2519	0.9877	0.0000	0.0000
Coroqvbuf600		0.9983	0.8627	0.3276	0.5802	0.0000	0.0000
Corolith			0.8322	0.9998	0.8137	0.0000	0.8698
Corofltint				0.3941	0.0000	0.3915	0.0000
Ssbasinas					0.8931	0.1998	0.8740
Ssbasinau						0.6478	0.5474
Coromagalt							0.0000

Table 10: Chi^2 test of conditional independence for the Coromandel model. Those values <0.015 in red indicate a dependence between themes that results in significant conditional dependence in the model.

The epithermal gold mineralisation prospectivity modelling for the Coromandel region has identified large areas of prospective ground in the region (Fig. 3). The geological and geochemical data and training data coverages are good at a regional scale in the Coromandel region, giving a more complete model. The historic mining centres stand out, but several new areas with no historic mineral occurrences have also been highlighted (Fig. 3). The most prospective areas are around area of high density faulting, mainly dip-slip and are close to quartz veins in areas of argillic alteration. Deposits also appear to be controlled by fault intersections and NE and NW trending faults. Lithology appears to also control localisation of mineralisation with andesitic lithologies important. The data coverage for both As and Au stream sediment geochemistry allows the use of catchment anomaly maps to define regional areas of interest in the model. Like the Northland region, geochemical prospecting is an important technique that can be used for regional work, with As, Ag, Hg and Au again important pathfinder elements. The rock chip geochemical datasets are incomplete for the region and additional data needs to be digitised from the open file reports held by Crown Minerals. Again, there are areas of anomalous geochemistry that require follow-up that lie outside the current prospective areas (rcanomag, rcanomas, rcanomau, rcanomhg, ssbasinag, ssbasinas, ssbasinau, ssbasinsb and ssbasinhg), especially rock chip data.

There is a good correlation between the geochemical data themes, such as anomalous Ag catchments, and the highly prospective areas in the model. The prior probability values from the prospectivity analysis can be used to prioritise the potential for individual prospects or historic mining districts. These have been added to the attributes in the minerals.shp theme on the CD and as a new thematic layer of ranked prospects.

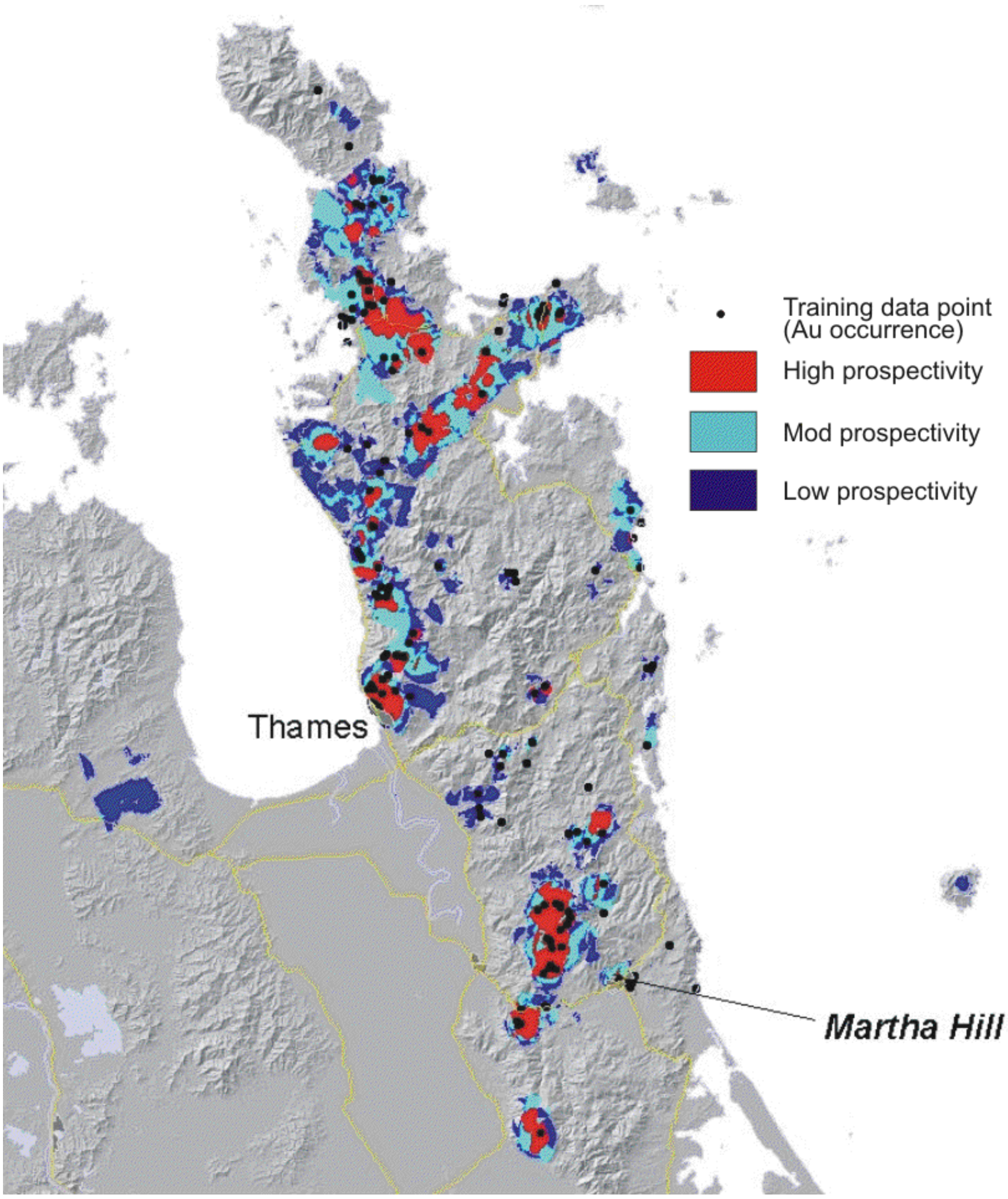

Figure 3: Epithermal gold prospectivity map for the Coromandel region.

The controls on epithermal gold mineralisation appear quite similar for the Coromandel and Northland regions, taking account that the regions are generally at different depths of erosion. Combining both these datasets and their training data could potentially make the geochemical data in the Northland region more useful.

TVZ prospectivity model

A post probability model has also been developed for the Taupo Volcanic Zone by combining the various data layers using their spatial correlations as weights. The TVZ is the least well explored of the three regions and has no historical gold production. There are four areas containing known epithermal gold mineralisation that enable a prospectivity model to be developed, albeit to a limited level. Several features show positive spatial correlations with the training dataset; resistivity anomalies, alteration interpreted from aeromagnetic data, and proximity to caldera margins. Anomalous silver and arsenic rockchip geochemistry is less well correlated. The spatial correlations of these features are significant enough to create a first-pass post probability Weights of

Evidence model. This model, however, is limited by available training data and it may be more appropriate for an expert prospectivity model to be calculated, using the grid data themes provided on the CD with the fuzzy logic modelling technique described by Bonham-Carter (1997). As with the previous models, the number of variables used was kept to a minimum to reduce the potential for conditional independence between the selected themes as discussed by (Bonham-Carter 1997).

Grid theme	Description	Variables	C	Stud C
Tvzresanom	Resistivity anomalies	2	3.04	3.04
Tvzmagalt	Alteration interpreted from magnetic data.	2	2.79	2.41
Rcanomag	Anomalous Ag rock chips	2	6.21	0.62
Rcanomas	Anomalous As rock chips	2	5.72	0.57
Tvzcaldedge	Distance from caldera margins	2	2.55	2.21
Tvzlith	Lithologies	5	4.17	0.29

Table 11: Grid themes used in the TVZ prospectivity model with their prior probabilities.

The variances of the weights and variance due to missing data are summed to give the total variance of the posterior probability. Various measures to test the conditional independence assumption are also reported (Table 12). Conditional independence is less of a problem in this model with a value of 0.44. However, the posterior probabilities should still be thought of as relative favourabilities or rankings within the TVZ region due to the incomplete data coverages.

	TVZMAGALT	RCANOMAG	RCANOMAS	TVZCALDEDG	TVZLITH
Tvzresanom	1.0000	1.0000	1.0000	1.0000	1.0000
Tvzmagalt		1.0000	1.0000	0.5050	0.9787
Rcanomag			1.0000	1.0000	1.0000
Rcanomas				1.0000	1.0000
Tvzcaldedge					0.9787

Table 12: Chi^2 test of conditional independence for the TVZ model. Those values <0.015 in red indicate a dependence between themes that results in significant conditional dependence in the model.

As discussed above the epithermal gold mineralisation prospectivity map for the Taupo Volcanic Zone region should be treated with care, but it does provide some interesting insights into the prospectivity of the TVZ region for epithermal gold (Fig. 4). The Ohakuri and Whakarewarewa areas stand out as prospective (Fig. 4). The Ohakuri area has a weak stream sediment geochemical signature compared to rock chip anomalies and the prospectivity model. Care should be taken when using stream sediment geochemical sampling techniques in the TVZ and anomaly levels should be checked. There are several geochemically anomalous areas at a regional scale in the TVZ, especially As, Ag and Au, that lie outside of the more prospective areas.

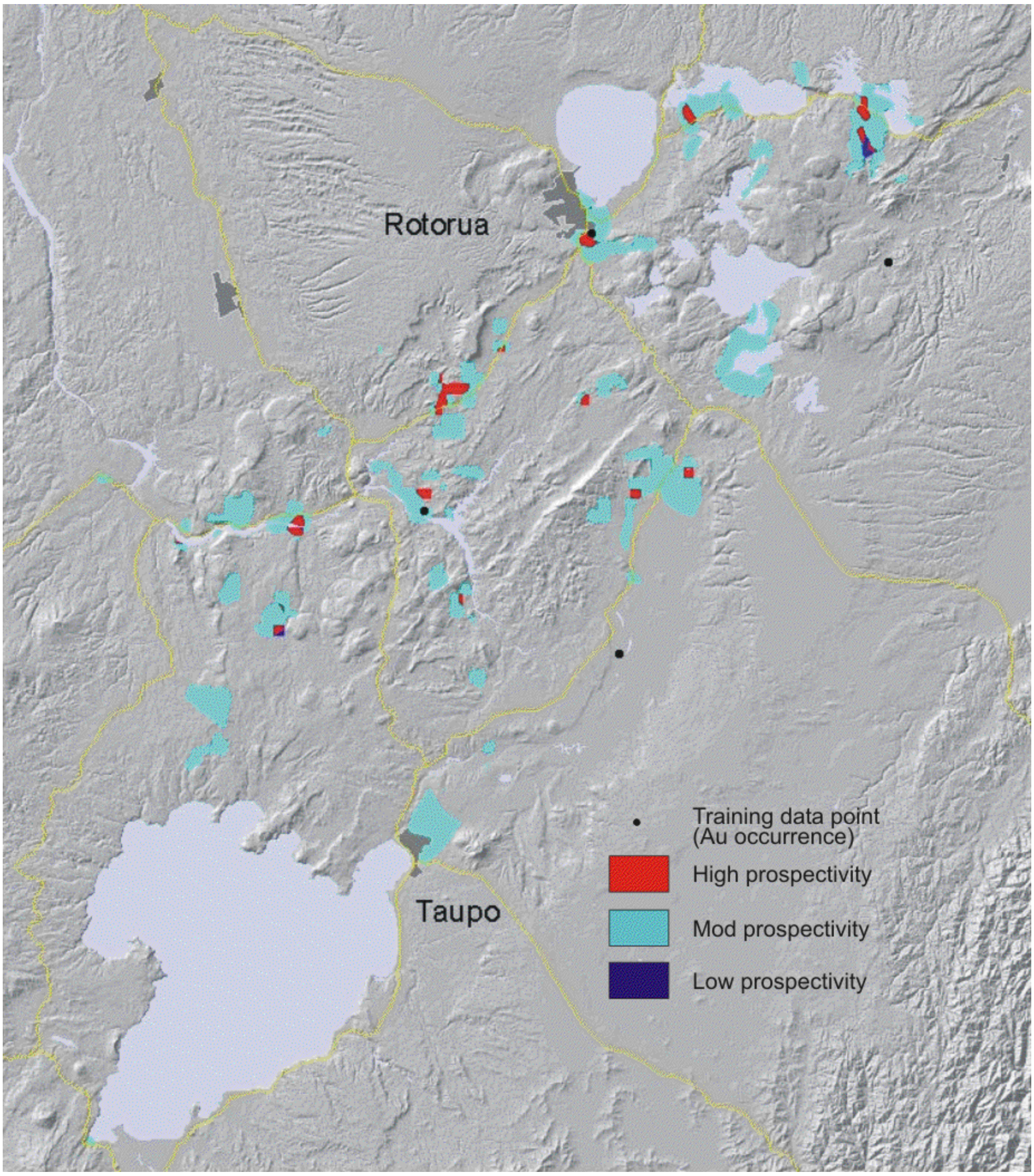

Figure 4: Epithermal gold prospectivity map for the TVZ region.

The TVZ prospectivity model provides a basis, and encouragement for continuing exploration in the Taupo Volcanic Zone. It highlights the importance of geochemical and regional scale geophysical datasets for exploration. Fortunately, there are good geological datasets, which allow the focussing of exploration into areas of greater prospectivity (Fig. 4). These could be improved further by using aeromagnetics to interpret rock types and alteration zones that lie underneath thin covering tephras and ignimbrite deposits. Additional prospect scale geological information is required for follow-up prospect scale work.

Observations and future work

A large amount of detailed, prospect scale information such as drilling and soil sampling were not included in the digital data collation. The digital capture of these data combined with more detailed geoscientific information held by GNS (for example QMAP) will add extra value to the current spatial database.

The maps generated by the prospectivity modelling consistently highlight areas of known mineralisation and identify targets where follow-up investigations are warranted. It is clear from this study that the North Island of New Zealand remains highly prospective for epithermal gold mineralisation. Many of the highly prospective areas remain unpegged, especially in the Northland region. There are restrictions on access and exploration activities in lands under the administration of the Department of Conservation (DoC) which vary under legislation according to the category of DoC land. Lands administered by DoC are delineated on the CD.

The spatial analysis modelling also provides insights into the important geological variables that control mineralisation, and in turn, which exploration models and techniques should be used in the future for follow-up work. Tables 2, 3 and 4 define the most important controls on mineralisation for all regions studied. As predicted by the mineralisation model (Christie and Brathwaite 2003), geology and structure play an important role in any exploration model and more detailed geological and structural information should be collected at a prospect scale to improve the accuracy of the models. This study also highlights the importance of geochemistry in identifying areas prospective for mineralisation.

This study has utilised available data that emphasise outcropping host-rock to epithermal gold. There is considerable potential for exploration in areas where a veneer of cover sediments have obscured suitable host-rocks, and this study has not attempted to model these areas. Modern geophysical surveys, including airborne gravity, will be critical in advancing knowledge in areas of thin cover.

Valuable information and insights have been gained during the compilation and modelling phases of the project. This project has provided a focus on geological models and quantified the relative importance of various datasets used in exploration methodologies. Explorers should remember that all three models only use a small amount of available data in an attempt to follow accepted genetic models for epithermal gold mineralisation and to reduce conditional independence. Users are encouraged to experiment with different geological variables based on their own exploration models. The data on the CD are provided to let explorers test ideas and exploration strategies before having to invest time and significant money in acquiring tenement packages and collecting data in the field.

The project has successfully followed on from the mesothermal gold project and is well on the way to building a national scale database of the mineral resource potential of New Zealand. The epithermal and mesothermal gold studies have highlighted those areas prospective for gold mineralisation on both the North and South Islands. It

is clear that potential for new world class mines like Waihi and Macraes Flat is high. New mine developments have the potential to not only aid regional development and the national economy, but also to increase the prosperity of a large number of stakeholders, including Maori, in rural communities. Studies such as this should also be used as a tool for making more rational land management decisions.

In terms of research these spatial modelling techniques need to be further refined to overcome problems of spatial interdependence common in geological data-sets. Other techniques such as fuzzy logic and neural network analyses should be trialled. We intend to expand this type of analysis to other deposit types and to research better ways that the statistical information produced by prospectivity modelling can be used in exploration management.

Acknowledgements

The following people are thanked for the considerable time and effort they put into this project: Paul Stigley as the Project Sponsor, Rebecca Parish and Alan Sherwood from Crown Minerals; Phil Glassey managed the project and Bob Brathwaite, Tony Christie, Simon Cox, Richard Jongens, Dave Heron, Julie Lee, Graham Leonard, Biljana Lukovic, Simon Nathan, Dougal Townsend, Joe Prebble, and Stefanie Tille of GNS all contributed and compiled data. Thesis maps from the University of Auckland, University of Waikato, Victoria University, and University of Canterbury have been used in the compilation of the geological map, and access to these theses is gratefully acknowledged. Placer Dome are thanked for the supply of a Delta Gold database of exploration data from the Taupo Volcanic Zone. This report has benefited from reviews by Tony Christie and Bob Brathwaite. They are thanked for their time and constructive recommendations.

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List of Figures and Tables

Appendices

Appendix 1
Epithermal Gold Project Data Description

The epithermal gold GIS data are accessible through three different ESRI® GIS software packages. The software, in order of decreasing capability and functionality, are ArcMap, ArcView, and ArcExplorer. In addition, ArcView and ArcMap have additional software extensions to enhance their capabilities. For this combined project, the Spatial Analyst extension has been used and is recommended, though not essential for the use of these data. The contents of the ArcView - Spatial Analyst version of the epithermal gold GIS project are listed below. This version accesses all of the available data.

Project name: arcviewa.apr

There are 115 themes in this project (polygon, line and point shape files; GRID and raster images), some of which are portrayed in several different ways.

Themes:

- Number of shape(s) -> 52
- Number of raster(s) -> 63

View: Geology, geochemistry, geophysics, topography and cultural data

vector_data\auprodn.shp	Point	Recorded Gold Production
vector_data\au.shp	Point	Au Occurences
vector_data\au.shp	Point	Au Deposit Type
vector_data\bedding.shp	Point	Bedding
vector_data\minerals.shp	Point	Mineral occurences
vector_data\petl_maj.shp	Point	Whole rock major element geochemistry
vector_data\petl_key.shp	Point	Whole rock trace element geochemistry
vector_data\rockchip.shp	Point	Rock sample geochemistry (Au)
vector_data\streamsd.shp	Point	Stream sediment geochemistry (Au)
vector_data\blegbulk.shp	Point	BLEG/bulk leach geochemistry (Au)
vector_data\pancon.shp	Point	Pan concentrate geochemistry (Au)
vector_data\rockchip.shp	Point	Rock sample geochemistry (Ag)
vector_data\streamsd.shp	Point	Stream sediment geochemistry (Ag)
vector_data\rockchip.shp	Point	Rock sample geochemistry (As)
vector_data\streamsd.shp	Point	Stream sediment geochemistry (As)
vector_data\rockchip.shp	Point	Rock sample geochemistry (Cu)
vector_data\streamsd.shp	Point	Stream sediment geochemistry (Cu)
vector_data\rockchip.shp	Point	Rock sample geochemistry (Pb)
vector_data\streamsd.shp	Point	Stream sediment geochemistry (Pb)
vector_data\rockchip.shp	Point	Rock sample geochemistry (Sb)
vector_data\streamsd.shp	Point	Stream sediment geochemistry (Sb)
vector_data\rockchip.shp	Point	Rock sample geochemistry (Zn)
vector_data\streamsd.shp	Point	Stream sediment geochemistry (Zn)
vector_data\rockchip.shp	Point	Rock sample geochemistry (Hg)
vector_data\streamsd.shp	Point	Stream sediment geochemistry (Hg)
vector_data\regchem.shp	Point	Exploration geochemistry (all samples types)
vector_data\vents.shp	Point	Eruptive vents: active and extinct
vector_data\veins.shp	Arc	Quartz veins
vector_data\geolbnd.shp	Arc	Geological boundaries
vector_data\faults.shp	Arc	Faults
vector_data\aoi.shp	Polygon	Area of interest
vector_data\roads.shp	Arc	Roads
vector_data\rivers.shp	Arc	Rivers
vector_data\urbannz.shp	Polygon	Urban areas

vector_data\nzlakes.shp	Polygon	Lakes
vector_data\docland.shp	Polygon	Department of Conservation administered land
vector_data\maganoml.shp	Arc	Geophysical interpretation: linear features
vector_data\calderap.shp	Polygon	Calderas: geological & geophysical evidence
vector_data\calderas.shp	Polygon	Calderas: surface geology
vector_data\maganoms.shp	Polygon	Small magnetic anomalies
vector_data\maganomp.shp	Polygon	Large aeromagnetic anomalies
vector_data\resanomp.shp	Polygon	Resistivity anomalies
vector_data\hydrothm.shp	Polygon	Hydrothermal alteration: active
vector_data\altnpoly.shp	Polygon	Hydrothermal alteration: fossil
vector_data\geolpoly.shp	Polygon	Geology: QMAP 1:250k data
vector_data\geol1m.shp	Polygon	Geology: 1:1M map
vector_data\gtb_aeromag.jpg	Image	Aeromagnetic map, Great Barrier Island
vector_data\coro_aeromag.jpg	Image	Aeromagnetic map, Coromandel area
vector_data\tvz_aeromag.jpg	Image	Aeromagnetic map, Taupo Volcanic Zone
vector_data\tvz_resistivity.jpg	Image	Electrical resistivity map, Taupo Volcanic Zone
grid_data\gravityb	Image	Regional gravity map
grid_data\dtm100m	Grid	DTM (100 m)
grid_data\shade315	Grid	Hill-shaded relief model
vector_data\coast.shp	Polygon	Northern NZ land area
vector_data\aoi.shp	Polygon	Area of interest

View: Prospectivity modelling

vector_data\au.shp	Point	Au Occurences
vector_data\auprodn.shp	Point	Recorded Gold Production
vector_data\au.shp	Point	Au Deposit Type
vector_data\minerals.shp	Point	Mineral Occurences Ranked by Au Prospectivity
grid_data\nlpmap1grid	Grid	Northland Grid prospectivity model
grid_data\nlpmap1poly.shp	Polygon	Northland prospectivity model
grid_data\coropmap1grid	Grid	Coromandel Grid prospectivity model
grid_data\coropmap1poly.shp	Polygon	Coromandel prospectivity model
grid_data\tvzpmap1grid	Grid	Taupo Volcanic Zone Grid prospectivity model
grid_data\tvzpmap1poly.shp	Polygon	Taupo Volcanic Zone prospectivity model
vector_data\roads.shp	Arc	Roads
vector_data\permits_region.shp	Polygon	Exploration Permits as at 9/6/03
vector_data\basinpol.shp	Polygon	Modelled stream catchments
vector_data\combinedfaults.shp	Arc	Combined faults segments
vector_data\fltintnenw.shp	Point	NE-NW fault intersections
vector_data\fltintnee.shp	Point	NE-E fault intersections
vector_data\fltintnen.shp	Point	NE-N fault intersections
vector_data\fltintne.shp	Point	N-E fault intersections
vector_data\fltintnwn.shp	Point	N-NW fault intersections
vector_data\fltintnwe.shp	Point	E-NW fault intersections
vector_data\faultint.shp	Point	Fault intersections (all)
grid_data\rcanomag	Grid	Anomalous Ag in rock chip/samples
grid_data\rcanomas	Grid	Anomalous As in rock chip/samples
grid_data\rcanomau	Grid	Anomalous Au in rock chip/samples
grid_data\rcanompb	Grid	Anomalous Pb in rock chip/samples
grid_data\rcanomsb	Grid	Anomalous Sb in rock chip/samples
grid_data\rcanomzn	Grid	Anomalous Zn in rock chip/samples
grid_data\rcanomhg	Grid	Anomalous Hg in rock chip/samples
grid_data\ssbasinag	Grid	Anomalous Ag in stream sediment samples
grid_data\ssbasinas	Grid	Anomalous As in stream sediment samples
grid_data\ssbasinau	Grid	Anomalous Au in stream sediment samples
grid_data\ssbasincu	Grid	Anomalous Cu in stream sediment samples
grid_data\ssbasinpb	Grid	Anomalous Pb in stream sediment samples

grid_data\ssbasinsb	Grid	Anomalous Sb in stream sediment samples
grid_data\ssbasinzn	Grid	Anomalous Zn in stream sediment samples
grid_data\ssbasinhg	Grid	Anomalous Hg in stream sediment samples
vector_data\basinchem.shp	Polygon	Multi-element stream sediment geochemistry
vector_data\maginterpcalderaedge.shp	Polygon	Interpreted caldera margins
vector_data\lithchem.shp	Polygon	Major element geochemistry of QMAP rock units
vector_data\altnpoly.shp	Polygon	Alteration (reclassified)
vector_data\epiareas.shp	Polygon	Regional modelling areas
grid_data\nlandarea	Grid	Northland modelling area
grid_data\coroarea	Grid	Coromandel modelling area
grid_data\tvzarea	Grid	Taupo Volcanic Zone modelling area
vector_data\coast.shp	Polygon	Northern NZ land area
vector_data\aoi.shp	Polygon	Area of interest
grid_data\dtm100m	Grid	DTM (100 m)
grid_data\shade315	Grid	Hill-shaded relief model

View: Northland Prospectivity Map

vector_data\coast.shp	Polygon	Land area
vector_data\roads.shp	Arc	Roads
vector_data\nzlakes.shp	Polygon	Lakes
vector_data\urbannz.shp	Polygon	Urban areas
grid_data\nlandtrain.shp	Point	Training dataset
grid_data\nlpmap1	Grid	Prospectivity model
grid_data\nlfltage	Grid	Fault age buffer
grid_data\nlhganom600	Grid	Hg distance
grid_data\nlsio2buf600	Grid	Quartz-adularia-sericite alteration distance
grid_data\nlargbuf400	Grid	Argillic alteration distance
grid_data\nlerptbuf400	Grid	Eruptive feature distance
grid_data\nlsintbuf2000	Grid	Sinter distance
grid_data\nlqtzbuf2200	Grid	Quartz vein distance
grid_data\nllith	Grid	Reclassified lithologies
grid_data\nlfltlgth	Grid	Fault length
grid_data\nlstrat	Grid	Reclassified stratigraphy
grid_data\nlfltorient	Grid	Fault trends
grid_data\ssbasinau	Grid	Anomalous Au by catchment
grid_data\nlandarea	Grid	Northland modelling area
grid_data\dtm100m	Grid	Dtm100m
grid_data\shade315	Grid	Hill-shaded relief model

View: Coromandel Prospectivity Map

vector_data\coast.shp	Polygon	Land area
vector_data\roads.shp	Arc	Roads
vector_data\nzlakes.shp	Polygon	Lakes
vector_data\urbannz.shp	Polygon	Urban areas
grid_data\corotrain.shp	Point	Training dataset
grid_data\coropmap1	Grid	Prospectivity model
grid_data\corostrdenrc	Grid	Deformation intensity
grid_data\coroqvbuf600	Grid	Quartz veins buffered
grid_data\coroqvtrend	Grid	Quartz vein trends
grid_data\coroqvdenrcl	Grid	Quartz vein density
grid_data\corofltdenrc	Grid	Fault density
grid_data\coroflt1400	Grid	Faults buffered
grid_data\corolith	Grid	Lithology reclassified
grid_data\corostrat	Grid	Stratigraphy reclassified
grid_data\corofltint	Grid	Fault intersections

grid_data\ssbasinag	Grid	Anomalous Ag by catchment
grid_data\ssbasinas	Grid	Anomalous As by catchment
grid_data\ssbasinau	Grid	Anomalous Au by catchment
grid_data\coromagalt	Grid	Alteration from aeromagnetics
grid_data\coroalt	Grid	Alteration from geology
grid_data\corofltrend	Grid	Fault trends
grid_data\corofltname	Grid	Faults buffered by name
grid_data\coroarea	Grid	Coromandel modelling area
grid_data\dtm100m	Grid	DTM (100 m)
grid_data\shade315	Grid	Hill-shaded relief model

View: Taupo Volcanic Zone Prospectivity Map

vector_data\coast.shp	Polygon	Land area
vector_data\roads.shp	Arc	Roads
vector_data\nzlakes.shp	Polygon	Lakes
vector_data\urbannz.shp	Polygon	Urban areas
grid_data\tvztrain.shp	Point	Training dataset
grid_data\tvzpmap1	Grid	Prospectivity model
grid_data\tvzfltname	Grid	Faults buffered by name
grid_data\tvzresanom	Grid	Resistivity anomalies
grid_data\tvzmagalt	Grid	Alteration from geophysics
grid_data\tvzcalderas	Grid	Calderas from geology and geophysics
grid_data\tvzflttrend	Grid	Fault trends
grid_data\rcanomag	Grid	Anomalous Ag
grid_data\rcanomas	Grid	Anomalous As
grid_data\ssbasinag	Grid	Anomalous Ag by catchment
grid_data\tvzcaldedge	Grid	Buffered caldera edge
grid_data\tvzfltbuf	Grid	Faults buffered to 1.4 km
grid_data\tvzlith	Grid	Lithology reclassified
grid_data\tvzarea	Grid	TVZ modelling area
grid_data\dtm100m	Grid	Dtm100m
grid_data\shade315	Grid	Hill-shaded relief model

Missing Data

There are more than 115 themes provided on this CD. However, New Zealand still lacks good regional coverage of some digital data that are taken for granted in other countries, states and territories. Additional datasets that either needs to be acquired or converted from paper form into digital form include:

- High resolution gravity
- High resolution EM
- High resolution DTMs
- High resolution radiometric data
- High resolution magnetic data
- Prospect-scale soil sample geochemistry
- Prospect-scale rock chip sample data.
- Prospect scale drill geochemistry from all drilling methods (RAB, RC and Diamond)

Appendix 2
Summary Results from the Spatial Correlation Analysis

Northland Summary Spatial Correlation Results

Spatial Variable	Measure	Type	Variable	Area (km²)	Units	No.	W+	Ws+	W-	Ws-	C	Cs	Stud C	Comment
Internal Structure														
Structural Intensity	Intensity of deformation	Free	No Spatial Association											No Spatial Association, possibly relating to lack of prospect scale structural mapping data.
Bedding Strike Variance	Moving average of variability of bedding data, Measure of structural disruption													No Data
Bedding Dip Variance	Moving average of variability of bedding data, Measure of structural disruption													No Data
External Regional Structure														
Proximity to calderas	Spatial association with volcanic centres of any age.	ordered	No calderas identified in the area.											No calderas identified in the area.
Ring faults	Association with volcanic structures	Free	Feature not present.											Feature not present.
Rifts			No Rifts Identified											No Rifts Identified
All Faults	Structural control at a local level.	ordered	3,000	4,164	5,948	5	0.5	0.4	-0.7	0.7	1.1	0.8	1.3	Weak regional correlation at 3,000m from any fault trend, with 5 of the 9 deposits located at least 3,000m from a fault.

Spatial Variable	Measure	Type	Variable	Area (km^2)	Units	No.	W+	Ws+	W-	Ws-	C	Cs	Stud C	Comment
Reverse, Normal and Strike-slip Faults	Structural control at a local level by normal, reverse and strike-slip faults.	ordered	4,800	4,267	6,095	6	0.5	0.4	-1.2	1.0	1.6	1.1	1.5	Good correlation with faults other than thrusts. The better correlation when thrusts are removed from the analysis suggests the thrusts mapped in the Northland area have no genetic link to epithermal mineralisation in the Northland area, especially at a regional scale. More prospect scale structural data are required.
Reverse, Normal and Strike-slip Faults	Structural control at a local level by normal, reverse and strike-slip faults.	ordered	800	915	1,307	2	0.9	0.7	-0.2	0.4	1.1	0.8	1.3	Weak local spatial correlation with faults other than thrusts at a local scale.
Fault Orientations	Preferred orientation of structure	Free	NE	3,020	4,314	5	0.9	0.4	-0.7	0.6	1.5	0.7	2.1	Good correlation with NE-trending faults at a regional scale. Similar spatial association as the Coromandel area once the influence of the Northland thrusts is taken out.
Individual Faults	Preferred mineralised structures	Free	PmapN745	74	106	5	4.6	0.5	-1.0	0.6	5.6	0.7	7.6	Very strong spatial correlation, probably influenced by better mapping around historic exploration.
Individual Faults	Preferred mineralised structures	Free	Upokorau Fault	111	158	1	2.6	1.0	-0.1	0.4	2.7	1.1	2.5	Strong spatial correlation.

Spatial Variable	Measure	Type	Variable	Area (km^2)	Units	No.	W+	Ws+	W-	Ws-	C	Cs	Stud C	Comment
Fault Sense	Dominant sense of movement	Free	normal	7,696	10,995	6	0.1	0.4	-0.3	0.7	0.4	0.8	0.4	There is a weak spatial association with the normal faults and mineralisation. However although the spatial association is not significant all mineralisation is associated with normal faults which may be significant if there was more detailed prospect scale data..
Reactivated Faults	Use only reactivated faults in fault buffer analysis													Not Enough Data
Fault Length	Association with length of fault, relating to order and possibly depth of penetration into the crust.	Free	Short	2,229	3,184	5	1.2	0.4	-0.8	0.6	1.9	0.7	2.6	Most mineralisation in the Northland area is associated with shorter length faults.
Fault Density	Structural control at a regional scale as determined by density of faulting	Free	No Spatial Association											No Spatial Association, possibly relating to lack of prospect scale structural mapping data.
Fault Intersections	Mineralisation controlled by intersecting faults.	Ordered	No Spatial Association											No spatial Association, possibly relating to lack of prospect scale structural mapping data.
Fault Dip														Not Enough Data
Temporal														
Fault Age	Age of Faults	Free	Pl	74	106	5	4.9	0.5	-1.0	0.6	5.9	0.7	8.0	Mineralisation correlates spatially with Pliocene age faults. There is no correlation with younger faults.

Spatial Variable	Measure	Type	Variable	Area (km^2)	Units	No.	W+	Ws+	W-	Ws-	C	Cs	Stud C	Comment
Stratigraphic Unit	Association of mineralisation with sequences of rocks of a particular age.	Free	Western Bay of Islands facies	585	836	4	1.2	0.5	-0.4	0.4	1.6	0.7	2.4	There is a better correlation with basement rocks.
Stratigraphic Unit	Association of mineralisation with sequences of rocks of a particular age.	Free	Wairakau Volcanics	68	97	1	2.0	1.0	-0.1	0.4	2.1	1.1	1.9	Good correlation with volcanics similar to the Coromandel area.
Geology														
Host Rock Type	Rock composition.	Free	andesite	29	41	1	2.8	1.0	-0.1	0.4	2.9	1.1	2.7	Strong spatial correlation, like the Coromandel area.
Host Rock Type	Rock composition.	Free	greywacke	702	1,003	4	1.0	0.5	-0.4	0.4	1.4	0.7	2.1	Weaker association with greywacke as this rock type is more common in the Northland area.
Quartz Veins	Association with distance from mapped veins systems	ordered	2,200	33	47	4	2.3	0.5	-1.5	1.0	3.8	1.1	3.4	There is a strong spatial association with quartz veining at a regional scale. However there is a lack of data in other areas. The veins trend mainly NW and NE with one vein trending E. There is not enough data to carry out a spatial analysis on the correlation of mineralisation with vein trends.
Qtz Vein Density	Density of quartz veining representing possible centres of fluid flow.	Free	Not enough data											Not Enough Data. More prospect scale mapping required.
Clay Alteration	Spatial association with different types of hydrothermal and volcanic features.	ordered	1,000	61	87	3	2.5	0.6	-0.5	0.5	3.0	0.8	3.9	Good medium range spatial correlation. Confirms importance of alteration mapping in Northland area.

Spatial Variable	Measure	Type	Variable	Area (km^2)	Units	No.	W+	Ws+	W-	Ws-	C	Cs	Stud C	Comment
Eruption Breccia	Spatial association with different types of hydrothermal and volcanic features.	ordered	400	20	28	2	3.3	0.7	-0.4	0.5	3.7	0.9	4.1	Strong spatial association at a short range.
Sinter	Spatial association with different types of hydrothermal and volcanic features.	ordered	2,000	55	78	4	2.3	0.5	-0.8	0.6	3.1	0.8	4.0	Strong regional spatial correlation, which agrees with the model of Au mineralisation occurring distal to hydrothermal outflow zones.
Argillic Alteration	Spatial association with different types of hydrothermal and volcanic features.	ordered	400	14	20	4	3.6	0.6	-1.6	1.0	5.2	1.1	4.5	Strong short spatial correlation with both silicic and argillic alteration. Agrees with epithermal model of Au associated with areas of more intense alteration compared to propylitic alteration.
Silicic Alteration	Spatial association with different types of hydrothermal and volcanic features.	ordered	600	45	64	4	3.0	0.5	-0.8	0.6	3.8	0.8	5.0	Strong short spatial correlation with both silicic and argillic alteration. Agrees with epithermal model of Au associated with areas of more intense alteration compared to propylitic alteration.
Pyrite Alteration	Spatial association with different types of hydrothermal and volcanic features.	ordered	No Spatial Association											No Spatial Association
SiO2 and Pyrite Alteration	Spatial association with different types of hydrothermal and volcanic features.	ordered	No Spatial Association											No Spatial Association
Propylitic Alteration	Spatial association with different types of hydrothermal and volcanic features.	ordered	800	17	25	3	2.9	0.6	-0.9	0.7	3.8	0.9	4.0	Strong longer spatial correlation with propylitic alteration. Agrees with epithermal model of Au associated closely with

Spatial Variable	Measure	Type	Variable	Area (km^2)	Units	No.	W+	Ws+	W-	Ws-	C	Cs	Stud C	Comment
														areas of more intense alteration and more distally with areas of less intense alteration..
Hg Mineralisation.	Spatial association with other mineralisation associated with volcanic processes.	ordered	600	7	10	3	4.7	0.7	-0.6	0.5	5.3	0.9	6.2	Very strong spatial association at a short range with Hg mineralisation. Agrees with mineralisation model.
Basemetal Mineralisation	Spatial association with other mineralisation associated with volcanic processes. Areas of high basemetals should have a lower potential for Au and Ag mineralisation.	ordered	No Spatial Association											No Spatial Association, which agrees with mineralisation model.
Geochemistry														
Rock Ag	Geochemical pathfinder for gold, which has a larger geochemical signature within alteration halos around gold deposits.	Free	Not Enough Data											Not Enough Data. There are six Ag anomalous areas in the region that require further investigation in relation to epithermal Au mineralisation.
SS Ag	Geochemical pathfinder for gold, which has a larger geochemical signature within alteration halos around gold deposits, especially with dispersion down rivers and streams.	Free	No Spatial Association											No spatial association, which relates to a lack of data. The data may be useful in expert driven modelling or to highlight areas of Ag geochemical anomalism at a regional scale. Additional regional scale Ag data needs to be collected as there are regional level anomalies of

Spatial Variable	Measure	Type	Variable	Area (km^2)	Units	No.	W+	Ws+	W-	Ws-	C	Cs	Stud C	Comment
														interest in the area.
Rock As	Geochemical pathfinder for gold, which has a larger geochemical signature within alteration halos around gold deposits.	Free	Not Enough Data											Not Enough Data. There are four As anomalous areas in the region that require further investigation in relation to epithermal Au mineralisation.
SS As	Geochemical pathfinder for gold, which has a larger geochemical signature within alteration halos around gold deposits, especially with dispersion down rivers and streams.	Free	No Spatial Association											No spatial association, which relates to a lack of data. The data may be useful in expert driven modelling or to highlight areas of As geochemical anomalism at a regional scale. Additional regional scale As data needs to be collected as there are regional level anomalies of interest in the area.
Rock Au	Geochemical pathfinder for gold, which has a larger geochemical signature within alteration halos around gold deposits.	Free	Not Enough Data											Not Enough Data. There are four Au anomalous areas in the region with corresponding Sb, Ag and As signatures that require further investigation in relation to epithermal Au mineralisation.

Spatial Variable	Measure	Type	Variable	Area (km^2)	Units	No.	W+	Ws+	W-	Ws-	C	Cs	Stud C	Comment
SS anomalous Au	Geochemical pathfinder for gold, which has a larger geochemical signature within alteration halos around gold deposits, especially with dispersion down rivers and streams.	Free	Anomalous Au	17	24	1	2.1	1.0	-0.2	0.5	2.3	1.1	2.0	Good spatial association even though there is a lack of data. Agrees with mineralisation model and confirms the usefulness of the technique in the area.
Rock Cu	Geochemical pathfinder for gold, which has a larger geochemical signature within alteration halos around gold deposits.	Free	Not Enough Data											Not enough data for a meaningful analysis.
SS Cu	Geochemical pathfinder for gold, which has a larger geochemical signature within alteration halos around gold deposits, especially with dispersion down rivers and streams.	Free	No Spatial Association											No spatial association, which in part relates to a lack of data and also no obvious relationship to porphyry mineralisation. This suggests that the Northland area may be exposed at a higher level than the Coromandel and porphyry mineralisation is mostly absent. The data may be useful in expert driven modelling or to highlight areas of Cu geochemical anomalism at a regional scale in two areas. Additional regional scale Cu data needs to be collected as there are

Spatial Variable	Measure	Type	Variable	Area (km^2)	Units	No.	W+	Ws+	W-	Ws-	C	Cs	Stud C	Comment
														regional level anomalies of interest in the area.
Rock Pb	Geochemical pathfinder for gold, which has a larger geochemical signature within alteration halos around gold deposits.	Free	Not Enough Data											Not enough data for a meaningful analysis.
SS Pb	Geochemical pathfinder for gold, which has a larger geochemical signature within alteration halos around gold deposits, especially with dispersion down rivers and streams.	Free	Not Enough Data											Not Enough Data
Rock Sb	Geochemical pathfinder for gold, which has a larger geochemical signature within alteration halos around gold deposits.	Free	Not Enough Data											Not Enough Data. There are four Sb anomalous areas in the region that require further investigation in relation to epithermal Au mineralisation.

Spatial Variable	Measure	Type	Variable	Area (km^2)	Units	No.	W+	Ws+	W-	Ws-	C	Cs	Stud C	Comment
SS Sb	Geochemical pathfinder for gold, which has a larger geochemical signature within alteration halos around gold deposits, especially with dispersion down rivers and streams.	Free	No Spatial Association											No spatial association, which like As relates to a lack of data. The data may be useful in expert driven modelling or to highlight areas of Sb geochemical anomalism at a regional scale in several areas. Additional regional scale Sb data needs to be collected as there are regional level anomalies of interest in the area.
Rock W	Geochemical pathfinder for gold, which has a larger geochemical signature within alteration halos around gold deposits.	Free	Not Enough Data											Not Enough Data
SS W	Geochemical pathfinder for gold, which has a larger geochemical signature within alteration halos around gold deposits, especially with dispersion down rivers and streams.	Free	Not Enough Data											Not Enough Data

Spatial Variable	Measure	Type	Variable	Area (km^2)	Units	No.	W+	Ws+	W-	Ws-	C	Cs	Stud C	Comment
Rock Zn	Geochemical pathfinder for gold, which has a larger geochemical signature within alteration halos around gold deposits.	Free	Not Enough Data											Not enough data for a meaningful analysis.
SS Zn	Geochemical pathfinder for gold, which has a larger geochemical signature within alteration halos around gold deposits, especially with dispersion down rivers and streams.	Free	No Spatial Association											No spatial association, which relates to a lack of data and also the high level of systems identified in Northland. The data may be useful in expert driven modelling or to highlight different basemetal mineralisation styles at a regional scale in several areas, which is outside the scope of this study.
Rock Hg	Geochemical pathfinder for gold, which has a larger geochemical signature within alteration halos around gold deposits.	Free	Not Enough Data											Not enough data as only two areas sampled. Both these contain significant Hg mineralisation at a regional scale that require further investigation.
SS Hg	Geochemical pathfinder for gold, which has a larger geochemical signature within alteration halos around gold deposits, especially with dispersion down rivers and streams.	Free	No Spatial Association											No spatial association, which like Hg relates to a lack of data. The data may be useful in expert driven modelling or to highlight areas of Hg geochemical anomalism at a regional scale in one area. Additional regional scale Hg

Spatial Variable	Measure	Type	Variable	Area (km^2)	Units	No.	W+	Ws+	W-	Ws-	C	Cs	Stud C	Comment
														data need to be collected as there is at least one regional level anomaly of interest in the area.
Geophysics														
Interpreted Calderas	Spatial association with interpreted volcanic centres of any age. Some of which may be buried.	ordered	No Data											No Data
Interpreted Major Faults	Spatial association with interpreted volcanic centres of any age. Some of which may be buried.	ordered	No Data											No Data
Magnetic Interpretation	Spatial association with interpreted regional magnetic features. Some of which may be buried.	Free	No Data											No Data

Coromandel Summary Spatial Correlation Results

Spatial Variable	Measure	Type	Variable	Area	Units	No	W+	Ws+	W-	Ws-	C	Cs	Stud C	Comment
Internal Structure														
Structural Density	Structural Intensity	Free	High Structural Density	225	321	73	3.0	0.1	-0.6	0.1	3.6	0.2	20.7	Strong correlation seems to relate to areas of intersection between fault systems.
Bedding Strike Variance	Moving average of variability of bedding azimuth data, Measure of structural disruption		Not done											Not enough data around areas hosting deposits. Therefore a data bias to areas with no mineralisation i.e. the areas with most variation have most measurements.
Bedding Dip Variance	Moving average of variability of bedding dip data, Measure of structural disruption		Not done											Not enough data around areas hosting deposits. Therefore a data bias to areas with no mineralisation i.e. the areas with most variation have most measurements.
External Regional Structure														
Proximity to calderas	Spatial association with volcanic centres of any age.	ordered	No Spatial Correlation											No correlation.
Ring faults	Association with volcanic structures	Free	No Spatial Correlation											No correlation. A better measure would be syn volcanic faults. Need to attribute fault database.
Rifts			Not Enough Data											Not Enough Data. Interpretation needs to be included with fault attribute data. This is not complete.
Faults	Structural control at a local level.	ordered	600	1,343	1,918	82	1.4	0.1	-0.6	0.1	1.9	0.2	12.1	Good correlation at 600m from any fault trend, with 82 of the 161 deposits located at least 600m from a fault.
Faults	Structural control at a local level.	ordered	1,400	2,760	3,943	132	1.1	0.1	-1.4	0.2	2.5	0.2	12.1	Better spatial correlation compared to 600m distance, with now 132 deposits found from 161. The 1400m buffer will be used for further spatial analysis of fault data.

Spatial Variable	Measure	Type	Variable	Area	Units	No	W+	Ws+	W-	Ws-	C	Cs	Stud C	Comment
N-S Fault Orientations	Preferred orientation of structure	Free	N	1,861	2,659	46	0.5	0.1	-0.1	0.1	0.6	0.2	3.5	Weak correlation with N-trending faults. 101 out 161 faults (62%) are associated with NE and N trending faults.
NE-SW Fault Orientations	Preferred orientation of structure	Free	NE	2,216	3,166	55	0.5	0.1	-0.2	0.1	0.7	0.2	3.9	Mineralisation correlates spatially best with NE-trending faults with 55 deposits spatially associated.
NW-SE Fault Orientations	Preferred orientation of structure	Free	NW	935	1,335	24	0.5	0.2	-0.1	0.1	0.6	0.2	2.6	NW faults have a weaker spatial association with only 24 deposits associated with faults of this trend.
E-W Fault Orientations	Preferred orientation of structure	Free	E	594	848	7	-0.3	0.4	0.0	0.1	-0.3	0.4	-0.8	No Spatial correlation.
Individual Faults	Preferred mineralised structures	Free	Settlers Fault	26	38	6	2.8	0.4	0.0	0.1	2.9	0.5	6.4	Only 37 of the faults in the Coromandel area have a spatial association with mineralisation.
Individual Faults	Preferred mineralised structures	Free	PmapN230	25	36	7	3.1	0.4	0.0	0.1	3.1	0.4	7.3	Only 37 of the faults in the Coromandel area have a spatial association with mineralisation.
Individual Faults	Preferred mineralised structures	Free	Moanataiari Fault	18	25	13	4.6	0.4	-0.1	0.1	4.7	0.4	11.4	Only 37 of the faults in the Coromandel area have a spatial association with mineralisation.
Fault Sense	Dominant sense of movement	Free	reverse	243	347	14	1.3	0.3	-0.1	0.1	1.4	0.3	4.9	There is a good spatial correlation of mineralisation with reverse faults, a weak correlation with normal faults and no correlation with strike-slip or thrust faults in the area.

Spatial Variable	Measure	Type	Variable	Area	Units	No	W+	Ws+	W-	Ws-	C	Cs	Stud C	Comment
Fault Sense	Dominant sense of movement	Free	normal	1,653	2,362	49	0.7	0.1	-0.2	0.1	0.8	0.2	4.9	There is a weak correlation of mineralisation with normal faults. Better with reverse faults (see above).
Reactivated Faults	Use only reactivated faults in fault buffer analysis													Not Enough Data
Fault Length	Association with length of fault, relating to order and possibly depth of penetration into the crust.	Free	No Faults	4,714	6,734	28	-1.0	0.2	0.4	0.1	-1.4	0.2	-6.7	No correlation.
Fault Length	Association with length of fault, relating to order and possibly depth of penetration into the crust.	Free	Short	934	1,334	20	0.3	0.2	0.0	0.1	0.4	0.2	1.5	Weak correlation.
Fault Length	Association with length of fault, relating to order and possibly depth of penetration into the crust.	Free	Moderate	1,388	1,982	41	0.7	0.2	-0.2	0.1	0.8	0.2	4.4	Weak correlation.
Fault Length	Association with length of fault, relating to order and possibly depth of penetration into the crust.	Free	Long	3,285	4,693	71	0.3	0.1	-0.2	0.1	0.5	0.2	3.4	Weak correlation.
Fault Density	Structural control at a regional scale as determined by density of faulting	Free	Moderate Density	377	538	53	2.0	0.1	-0.4	0.1	2.3	0.2	13.4	There is a strong correlation with areas where the density of faulting is greatest.
Fault Density	Structural control at a regional scale as determined by density of faulting	Free	High Density	61	87	5	1.4	0.5	0.0	0.1	1.4	0.5	3.0	There is a strong correlation with areas where the density of faulting is greatest.

Spatial Variable	Measure	Type	Variable	Area	Units	No	W+	Ws+	W-	Ws-	C	Cs	Stud C	Comment
NE-NW Fault Intersections	Mineralisation controlled by intersecting faults.	Ordered	2,600	416	595	57	1.1	0.1	-0.4	0.1	1.6	0.2	8.5	Good correlation at a short distance. Suggests a significant spatial association at a local and regional scale.
NE-E Fault Intersections	Mineralisation controlled by intersecting faults.	Ordered	800	11	16	4	1.8	0.6	0.0	0.1	1.8	0.6	3.1	Good correlation at a short distance, but for a small number of deposits. Suggests a possible local control, but not significant regionally.
NE-N Fault Intersections	Mineralisation controlled by intersecting faults.	Ordered	4,800	1,350	1,929	96	0.4	0.1	-0.5	0.2	0.9	0.2	4.8	Weaker correlation at a long distance finding largest number of deposits. Suggest an association at a regional scale.
N-E Fault Intersections	Mineralisation controlled by intersecting faults.	Ordered	4,600	545	778	59	0.6	0.1	-0.5	0.2	1.1	0.2	5.0	Correlation at a long distance finding fewer deposits. Suggest a possible association at a regional scale.
N-NW Fault Intersections	Mineralisation controlled by intersecting faults.	Ordered	2,000	172	246	32	1.0	0.2	-0.2	0.1	1.2	0.2	5.3	Correlation at a short distance, but for less deposits. Suggests a possible local and regional control. Not as significant as NE-NW
E-NW Fault Intersections	Mineralisation controlled by intersecting faults.	Ordered	8,800	754	1,078	75	0.1	0.1	-1.3	0.6	1.4	0.6	2.4	Correlation at a very long distance finding fewer deposits. Probably no spatial association.
Fault Intersections	Mineralisation controlled by intersecting faults.	Ordered	2,600	1,345	1,922	115	0.8	0.1	-0.9	0.2	1.8	0.2	9.8	Strong spatial association of epithermal mineralisation with fault intersections at a regional scale.

Spatial Variable	Measure	Type	Variable	Area	Units	No	W+	Ws+	W-	Ws-	C	Cs	Stud C	Comment
Fault Dip														Not Enough Data
Temporal														
Fault Age	Age of Faults	Free	IMi Pl	245	350	10	1.0	0.3	0.0	0.1	1.0	0.3	3.1	Mineralisation correlates spatially with Miocene to Pliocene faults. There is no correlation with younger faults
Fault Age	Age of Faults	Free	Mi	717	1,025	25	0.8	0.2	-0.1	0.1	0.9	0.2	4.2	Mineralisation correlates spatially with Miocene to Pliocene faults. There is no correlation with younger faults
Fault Age	Age of Faults	Free	Mi Pl	1,034	1,477	46	1.1	0.1	-0.2	0.1	1.3	0.2	7.4	Mineralisation correlates spatially with Miocene to Pliocene faults. There is no correlation with younger faults
Stratigraphic Unit	Association of mineralisation with sequences of rocks of a particular age.	Free	Kuaotunu Subgroup	962	1,375	73	1.2	0.1	-0.5	0.1	1.7	0.2	10.3	117 deposits are contained within three stratigraphic units. This unit has the highest spatial correlation and contains the greatest number of deposits.
Stratigraphic Unit	Association of mineralisation with sequences of rocks of a particular age.	Free	Waiwawa Subgroup	598	854	40	1.1	0.2	-0.2	0.1	1.3	0.2	6.8	117 deposits are contained within three stratigraphic units. This unit has a high spatial correlation and for a significant number of deposits.
Stratigraphic Unit	Association of mineralisation with sequences of rocks of a particular age.	Free	Omoho Formation	22	32	4	2.1	0.5	0.0	0.1	2.2	0.5	4.0	117 deposits are contained within three stratigraphic units. This unit has a high spatial correlation for a low number of deposits.
Geology														
Host Rock Type	Rock composition.	Free	andesite	1,917	2,738	115	1.0	0.1	-0.9	0.1	1.9	0.2	10.7	High spatial association containing the majority of the deposits.
Host Rock Type	Rock composition.	Free	tuff	22	32	4	2.1	0.5	0.0	0.1	2.2	0.5	4.0	High spatial association, but only locally, with a small number of deposits represented.
Host Rock Type	Rock composition.	Free	sand	2,557	3,653	6	-2.3	0.4	0.4	0.1	-2.8	0.4	-6.7	Strong negative spatial association.
Quartz Veins	Association with distance from mapped veins systems	ordered	600	150	214	84	3.0	0.1	-0.8	0.1	3.7	0.2	20.1	Highly significant spatial association with most of the deposits found within 600m of mapped vein systems. This has a very strong local spatial control.
Quartz Vein Orientation	Association with particular trend of mapped veins	Free	N	78	111	34	3.4	0.2	-0.2	0.1	3.6	0.2	16.1	Strong correlation with N trending veins.

Spatial Variable	Measure	Type	Variable	Area	Units	No	W+	Ws+	W-	Ws-	C	Cs	Stud C	Comment
	systems													
Quartz Vein Orientation	Association with particular trend of mapped veins systems	Free	NE	98	140	44	3.4	0.2	-0.3	0.1	3.7	0.2	18.2	Highest spatial correlation with NE trending veins.
Qtz Vein Density	Density of quartz veining representing possible centres of fluid flow.	Free	Medium	97	139	38	3.2	0.2	-0.3	0.1	3.5	0.2	16.5	The medium and high QV density categories cover a very small area and contain nearly half of the known deposits and have a very high spatial correlation with quartz veins.
Qtz Vein Density	Density of quartz veining representing possible centres of fluid flow.	Free	High	51	73	33	4.0	0.2	-0.2	0.1	4.2	0.3	16.8	The medium and high QV density categories should be combined.
Eruption Breccia	Spatial association with different types of hydrothermal and volcanic features.	Free	Not Mapped											Not Mapped
Sinter	Spatial association with different types of hydrothermal and volcanic features.	Free	Not Mapped											Not Mapped
Argillic Alteration	Spatial association with different types of hydrothermal and volcanic features.	Free	Argillic	281	401	80	0.2	0.1	-0.3	0.2	0.4	0.2	2.0	Weak regional correlation.
Silicic Alteration	Spatial association with different types of hydrothermal and volcanic features.	Free	SiO2	8	11	5	1.4	0.6	0.0	0.1	1.4	0.6	2.3	Good local correlation
Pyrite Alteration	Spatial association with different types of hydrothermal and volcanic features.	Free	Not Mapped											Not Mapped
Pyrite and Silicic Alteration	Spatial association with different types of hydrothermal and volcanic features.	Free	Not Mapped											Not Mapped

Spatial Variable	Measure	Type	Variable	Area	Units	No	W+	Ws+	W-	Ws-	C	Cs	Stud C	Comment
Propylitic Alteration	Spatial association with different types of hydrothermal and volcanic features.	Free	Propylitic	191	273	36	-0.3	0.2	0.2	0.1	-0.5	0.2	-2.4	Negative regional correlation
Hg Mineralisation.	Spatial association with other mineralisation associated with volcanic processes.	ordered	5,600	195	279	30	0.7	0.2	-0.7	0.3	1.5	0.3	4.5	Strong spatial association at a regional scale, which may not be significant at the scale of the modelling.
Basemetal Mineralisation	Spatial association with other mineralisation associated with volcanic processes. Areas of high basemetals should have a lower potential for Au and Ag mineralisation.	ordered	3,600	171	244	24	1.2	0.2	-0.6	0.2	1.8	0.3	5.8	24 deposits have a strong spatial regional association with basemetal mineralisation. Does not appear to be significant at the scale of the modelling.
Geochemistry														
Rock Ag	Geochemical pathfinder for gold, which has a larger geochemical signature within alteration halos around gold deposits.	Free	Not Enough Data											Not Enough Data
SS Ag	Geochemical pathfinder for gold, which has a larger geochemical signature within alteration halos around gold deposits, especially with dispersion down rivers and streams.	Free	Anomalous Ag	788	1,126	56	0.9	0.1	-0.5	0.1	1.4	0.2	7.0	Spatial association with epithermal mineralisation as suggested by mineralisation model.

Spatial Variable	Measure	Type	Variable	Area	Units	No	W+	Ws+	W-	Ws-	C	Cs	Stud C	Comment
Rock As	Geochemical pathfinder for gold, which has a larger geochemical signature within alteration halos around gold deposits.	Free	Not Enough Data											Not Enough Data
SS As	Geochemical pathfinder for gold, which has a larger geochemical signature within alteration halos around gold deposits, especially with dispersion down rivers and streams.	Free	Anomalous As	531	759	51	1.4	0.1	-1.1	0.2	2.5	0.3	9.2	Very strong spatial association with epithermal mineralisation as suggested by mineralisation model.
Rock Au	Geochemical pathfinder for gold, which has a larger geochemical signature within alteration halos around gold deposits.	Free	Not Enough Data											Not Enough Data
SS anomalous Au	Geochemical pathfinder for gold, which has a larger geochemical signature within alteration halos around gold deposits, especially with dispersion down rivers and streams.	Free	Anomalous Au	1,370	1,958	94	0.7	0.1	-1.0	0.2	1.7	0.2	7.9	Very strong spatial association with epithermal mineralisation as suggested by mineralisation model.

Spatial Variable	Measure	Type	Variable	Area	Units	No	W+	Ws+	W-	Ws-	C	Cs	Stud C	Comment
Rock Cu	Geochemical pathfinder for gold, which has a larger geochemical signature within alteration halos around gold deposits.	Free	Not Enough Data											Not Enough Data
SS Cu	Geochemical pathfinder for gold, which has a larger geochemical signature within alteration halos around gold deposits, especially with dispersion down rivers and streams.	Free	Anomalous Cu	438	626	45	1.3	0.2	-0.4	0.1	1.6	0.2	8.4	Very strong spatial association with epithermal mineralisation as suggested by mineralisation model. Confirms that there may be a link between Cu porphyry style mineralisation and epithermal mineralisation or there is greater potential for porphyry mineralisation than previously recognised.
Rock Pb	Geochemical pathfinder for gold, which has a larger geochemical signature within alteration halos around gold deposits.	Free	Not Enough Data											Not Enough Data
SS Pb	Geochemical pathfinder for gold, which has a larger geochemical signature within alteration halos around gold deposits, especially with dispersion down rivers and streams.	Free	Anomalous Pb	850	1,214	48	0.6	0.1	-0.3	0.1	0.9	0.2	4.5	Lower spatial correlation with base metals which is predicted by the mineralisation model. However, there is still a positive spatial correlation and therefore the presence of basemetals cannot be taken as significantly lowering the potential for gold mineralisation.

Spatial Variable	Measure	Type	Variable	Area	Units	No	W+	Ws+	W-	Ws-	C	Cs	Stud C	Comment
Rock Sb	Geochemical pathfinder for gold, which has a larger geochemical signature within alteration halos around gold deposits.	Free	Not Enough Data											Not Enough Data
SS Sb	Geochemical pathfinder for gold, which has a larger geochemical signature within alteration halos around gold deposits, especially with dispersion down rivers and streams.	Free	Anomalous Sb	271	387	33	1.5	0.2	-0.6	0.2	2.1	0.3	8.2	Strong spatial association with epithermal mineralisation as suggested by mineralisation model. Confirms that there may be a link between Cu porphyry style mineralisation and epithermal mineralisation or there is greater potential for porphyry mineralisation than previously recognised.
Rock W	Geochemical pathfinder for gold, which has a larger geochemical signature within alteration halos around gold deposits.	Free	Not Enough Data											Not Enough Data
SS W	Geochemical pathfinder for gold, which has a larger geochemical signature within alteration halos around gold deposits, especially with dispersion down rivers and streams.	Free	Not Enough Data											Not Enough Data

Spatial Variable	Measure	Type	Variable	Area	Units	No	W+	Ws+	W-	Ws-	C	Cs	Stud C	Comment
Rock Zn	Geochemical pathfinder for gold, which has a larger geochemical signature within alteration halos around gold deposits.	Free	Not Enough Data											Not Enough Data
SS Zn	Geochemical pathfinder for gold, which has a larger geochemical signature within alteration halos around gold deposits, especially with dispersion down rivers and streams.	Free	Anomalous Zn	1,477	2,110	79	0.5	0.1	-0.6	0.2	1.1	0.2	5.6	Lower spatial correlation with base metals which is predicted by the mineralisation model. However, there is still a positive spatial correlation and therefore the presence of basemetals cannot be taken as significantly lowering the potential for gold mineralisation.
Rock Hg	Geochemical pathfinder for gold, which has a larger geochemical signature within alteration halos around gold deposits.	Free	Not Enough Data											Not Enough Data
SS Hg	Geochemical pathfinder for gold, which has a larger geochemical signature within alteration halos around gold deposits, especially with dispersion down rivers and streams.	Free	Not Enough Data											Not Enough Data
Geophysics														
Interpreted Calderas	Spatial association with interpreted volcanic centres of any age. Some of which may be buried.	ordered	No Correlation											No Correlation

Spatial Variable	Measure	Type	Variable	Area	Units	No	W+	Ws+	W-	Ws-	C	Cs	Stud C	Comment
Interpreted Major Faults	Spatial association with interpreted volcanic centres of any age. Some of which may be buried.	ordered	1,800	2,332	3,332	140	0.3	0.1	-1.2	0.2	1.6	0.3	6.1	Strong spatial correlation at a similar distance from mapped fault theme. The mapped fault theme gave a stronger spatial correlation, but slightly fewer associated deposits.
Magnetic Interpretation	Spatial association with interpreted regional magnetic features. Some of which may be buried.	Free	Large scale hydrothermal demagnetisation	522	746	63	0.8	0.1	-0.3	0.1	1.1	0.2	6.6	Good spatial correlation with a magnetic feature. Provides a stronger regional association for alteration than the alteration mapping. Appears to be identifying areas of argillic alteration. The magnetic interpretation gives a better regional spatial coverage.

TVZ Summary Spatial Correlation Results

Spatial Variable	Measure	Type	Variable	Area	Units	Number	W+	Ws+	W-	Ws-	C	Cs	Stud C	Comment
Internal Structure														
Structural Intensity	Structural Intensity	Free	High Structural Density											No Correlation. Too few training data points. May have to use fuzzy model and Coromandel spatial correlations and expert weights.
Bedding Strike Variance	Moving average of variability of bedding data, Measure of structural disruption													No Data
Bedding Dip Variance	Moving average of variability of bedding data, Measure of structural disruption													No Data
External Regional Structure														
Proximity to calderas	Spatial association with volcanic centres of any age.	ordered	400m from caldera margin.	310	442	1	2.4	1.0	-0.4	0.7	2.8	1.2	2.3	Good correlation at 400m buffer. A secondary weaker correlation occurs at 3.6 km. There is a spatial association with quaternary Calderas in the TVZ.
Ring faults	Association with volcanic structures	Free	No ring structures identified.											No ring structures identified.
Rifts														Not Enough Data
Faults	Structural control at a local level.	ordered	800	1,775	2,536	2	1.4	0.7	-0.9	1.0	2.3	1.2	1.9	Good spatial correlation at a short distance, especially considering the limited training data set.

Spatial Variable	Measure	Type	Variable	Area	Units	Number	W+	Ws+	W-	Ws-	C	Cs	Stud C	Comment
E-W Fault Orientations	Preferred orientation of structure	Free	E	292	418	1	2.3	1.0	-0.3	0.6	2.6	1.2	2.2	Strong correlation with fault trend, which appears to relate to a bend in the regional NE trend.
Individual Faults	Preferred mineralised structures	Free	PmapN484	3	4	1	7.2	1.1	-0.3	0.6	7.5	1.3	5.8	Strong correlation with individual fault.
Individual Faults	Preferred mineralised structures	Free	PmapN295	76	108	1	3.7	1.0	-0.3	0.6	4.0	1.2	3.4	Strong correlation with individual fault.
Fault Sense	Dominant sense of movement	Free	normal	1,429	2,042	1	0.7	1.0	-0.2	0.6	0.9	1.2	0.8	Weak correlation. Not enough data.
Fault Length	Association with length of fault, relating to order and possibly depth of penetration into the crust.	Free	Long	874	1,249	1	1.2	1.0	-0.2	0.6	1.4	1.2	1.2	Good correlation, but not really enough data.
Fault Density	Structural control at a regional scale as determined by density of faulting	Free	No spatial association											No spatial association

Spatial Variable	Measure	Type	Variable	Area	Units	Number	W+	Ws+	W-	Ws-	C	Cs	Stud C	Comment
Fault Intersections	Mineralisation controlled by intersecting faults.	Ordered	No spatial association											No spatial association
Fault Dip			Not Enough Data											Not Enough Data
Temporal														
Rock Age	Association of mineralisation with sequences of rocks of a particular age.	Free	IQ	3,802	5,431	2	0.3	0.7	-0.3	0.7	0.6	1.0	0.6	Age too similar
Fault Age	Age of Faults	Free	All Quaternary.											All Quaternary. The attributes need refining to subdivide Quaternary.
Stratigraphic Unit	Association of mineralisation with sequences of rocks of a particular age.	Free	active-TVZ pyroclastics	2,336	3,337	2	0.8	0.7	-0.4	0.7	1.3	1.0	1.3	Age too similar
Stratigraphic Unit	Association of mineralisation with sequences of rocks of a particular age.	Free	Quaternary sediments	1,660	2,372	1	0.5	1.0	-0.1	0.6	0.6	1.2	0.5	Age too similar
Geology														
Host Rock Type	Rock composition.	Free	ignimbrite	6,015	8,592	3	0.3	0.6	-0.6	1.0	0.9	1.2	0.7	Weak correlation as mapping is of a regional nature.

Spatial Variable	Measure	Type	Variable	Area	Units	Number	W+	Ws+	W-	Ws-	C	Cs	Stud C	Comment
Quartz Veins	Association with distance from mapped veins systems	ordered	No veins mapped.											No veins mapped.
Eruption Breccia	Spatial association with different types of hydrothermal and volcanic features.	Free	Not Enough Data											Not Enough Data
Sinter	Spatial association with different types of hydrothermal and volcanic features.	Free	Not Enough Data											Not Enough Data
Argillic Alteration	Spatial association with different types of hydrothermal and volcanic features.	Free	Not Enough Data											Not Enough Data
Silicic Alteration	Spatial association with different types of hydrothermal and volcanic features.	Free	Not Enough Data											Not Enough Data
Pyrite Alteration	Spatial association with different types of hydrothermal and volcanic features.	Free	Not Enough Data											Not Enough Data
Pyrite and Silicic Alteration	Spatial association with different types of hydrothermal and volcanic features.	Free	Not Enough Data											Not Enough Data
Propylitic Alteration	Spatial association with different types of hydrothermal and volcanic features.	Free	Not Enough Data											Not Enough Data

Geochemistry

Spatial Variable	Measure	Type	Variable	Area	Units	Number	W+	Ws+	W-	Ws-	C	Cs	Stud C	Comment
Rock Ag	Geochemical pathfinder for gold, which has a larger geochemical signature within alteration halos around gold deposits.	Free	Anomalous Ag	480	686	2	0.7	0.7	-0.7	1.0	1.5	1.2	1.2	Good spatial association. May not be enough training data to calculate a significant spatial association. The data may be useful in expert driven modelling or to highlight the three areas of Ag geochemical anomalism at a regional scale for additional work. Additional regional scale Ag data needs to be collected as there are regional level anomalies of interest in the area.
SS Ag	Geochemical pathfinder for gold, which has a larger geochemical signature within alteration halos around gold deposits, especially with dispersion down rivers and streams.	Free	Anomalous Ag	278	397	1	1.3	1.0	-0.5	1.0	1.8	1.4	1.3	Strong spatial association with mineralisation. The limited training dataset is possibly constraining the spatial analysis.
Rock As	Geochemical pathfinder for gold, which has a larger geochemical signature within alteration halos around gold deposits.	Free	Anomalous As	90	129	1	0.7	1.0	-0.4	1.0	1.1	1.4	0.8	Weak spatial association with mineralisation. The limited training dataset is possibly constraining the spatial analysis. Some interesting anomalies in the region.

Spatial Variable	Measure	Type	Variable	Area	Units	Number	W+	Ws+	W-	Ws-	C	Cs	Stud C	Comment
SS As	Geochemical pathfinder for gold, which has a larger geochemical signature within alteration halos around gold deposits, especially with dispersion down rivers and streams.	Free	No Spatial Association											No spatial association, which relates to a lack of data. The data may be useful in expert driven modelling or to highlight 2 areas of As geochemical anomalism at a regional scale. Additional regional scale As data needs to be collected as there are regional level anomalies of interest in the area.
Rock Au	Geochemical pathfinder for gold, which has a larger geochemical signature within alteration halos around gold deposits.	Free	Anomalous Au	146	209	1	0.3	1.0	-0.2	1.0	0.5	1.4	0.3	several anomalous areas and this is where the sampling has been focussed. There is not enough sampling in non prospective ground to highlight the spatial association at a regional scale.

Spatial Variable	Measure	Type	Variable	Area	Units	Number	W+	Ws+	W-	Ws-	C	Cs	Stud C	Comment
SS anomalous Au	Geochemical pathfinder for gold, which has a larger geochemical signature within alteration halos around gold deposits, especially with dispersion down rivers and streams.	Free	No spatial association											No spatial association with areas of known mineralisation. There are, however, five anomalous areas in the region worthy of follow-up, and the samples from the areas of known mineralisation checked.
Rock Cu	Geochemical pathfinder for gold, which has a larger geochemical signature within alteration halos around gold deposits.	Free	Not Enough Data											Not enough data. The systems are also probably too high for Cu to be a significant metal in the TVZ.

Spatial Variable	Measure	Type	Variable	Area	Units	Number	W+	Ws+	W-	Ws-	C	Cs	Stud C	Comment
SS Cu	Geochemical pathfinder for gold, which has a larger geochemical signature within alteration halos around gold deposits, especially with dispersion down rivers and streams.	Free	No Spatial Association											No spatial association, which in part relates to a lack of data and also no obvious relationship to porphyry mineralisation.
Rock Pb	Geochemical pathfinder for gold, which has a larger geochemical signature within alteration halos around gold deposits.	Free	Not Enough Data											Not enough data or training data. Although there are four regional Pb anomalies in the data worthy of follow-up.
SS Pb	Geochemical pathfinder for gold, which has a larger geochemical signature within alteration halos around gold deposits, especially with dispersion down rivers and streams.	Free	Not Enough Data											Not Enough Data

Spatial Variable	Measure	Type	Variable	Area	Units	Number	W+	Ws+	W-	Ws-	C	Cs	Stud C	Comment
Rock Sb	Geochemical pathfinder for gold, which has a larger geochemical signature within alteration halos around gold deposits.	Free	Not Enough Data											Not enough training data, even though there is a regional association of Sb and As with known mineralisation in the TVZ. There are six anomalous areas worthy of follow-up.
SS Sb	Geochemical pathfinder for gold, which has a larger geochemical signature within alteration halos around gold deposits, especially with dispersion down rivers and streams.	Free	No Spatial Association											No spatial association with known mineralisation, which relates to a lack of regional data. The data may be useful in expert driven modelling or to highlight 4 areas of Sb geochemical anomalism at a regional scale. The main areas of known mineralisation are not associated with anomalous Sb.
Rock W	Geochemical pathfinder for gold, which has a larger geochemical signature within alteration halos around gold deposits.	Free	Not Enough Data											Not Enough Data

Spatial Variable	Measure	Type	Variable	Area	Units	Number	W+	Ws+	W-	Ws-	C	Cs	Stud C	Comment
SS W	Geochemical pathfinder for gold, which has a larger geochemical signature within alteration halos around gold deposits, especially with dispersion down rivers and streams.	Free	Not Enough Data											Not Enough Data
Rock Zn	Geochemical pathfinder for gold, which has a larger geochemical signature within alteration halos around gold deposits.	Free	Not Enough Data											Not enough data or training data. Although there are several regional Zn anomalies in the data worthy of follow-up, including one area of known mineralisation.
SS Zn	Geochemical pathfinder for gold, which has a larger geochemical signature within alteration halos around gold deposits, especially with dispersion down rivers and streams.	Free	No Spatial Association											Not enough data. There is one area within the limited data set with anomalous Zn worthy of follow-up.

Spatial Variable	Measure	Type	Variable	Area	Units	Number	W+	Ws+	W-	Ws-	C	Cs	Stud C	Comment
Rock Hg	Geochemical pathfinder for gold, which has a larger geochemical signature within alteration halos around gold deposits.	Free	Not Enough Data											Not enough data. The main area of mineralisation has a significant association with Hg. There are several similar areas in the limited dataset worthy of follow-up.
SS Hg	Geochemical pathfinder for gold, which has a larger geochemical signature within alteration halos around gold deposits, especially with dispersion down rivers and streams.	Free	No Data											No Data
Geophysics														
Interpreted Calderas	Spatial association with interpreted volcanic centres of any age. Some of which may be buried.	Free	Caldera Edge	2,052	2,931	3	1.4	0.6	-1.2	1.0	2.6	1.2	2.2	Good correlation with the edges of interpreted caldera structures.
Interpreted Deep Faults	Spatial association with interpreted deep faults of any age.	ordered	1,600	3,662	5,231	3	0.5	0.6	-0.8	1.0	1.4	1.2	1.2	Weak association with deeper structures interpreted from magnetic data. The magnetic data is too coarse to interpret at a prospect scale. Better magnetic data are required.

Spatial Variable	Measure	Type	Variable	Area	Units	Number	W+	Ws+	W-	Ws-	C	Cs	Stud C	Comment
Interpreted Rift Axis	Spatial association with interpreted TVZ rift axis.	ordered	No spatial association											No spatial association
Magnetic Interpretation	Spatial association with interpreted regional magnetic features. Some of which may be buried.	Free	Hydrothermal demagnetisation	219	312	1	2.5	1.0	-0.3	0.6	2.8	1.2	2.4	Strong spatial association, similar to the Coromandel. Confirms the usefulness of magnetics for mapping hydrothermal alteration in the epithermal environment.
Resistivity Anomalies	Spatial association with resistivity low anomalies, which are interpreted to be active geothermal fields.	Free	Geothermal Field	494	706	2	2.4	0.7	-0.6	0.7	3.0	1.0	3.0	Strong spatial association with active geothermal areas. This agrees with current mineralisation model for epithermal mineralisation.