Granite gold mineral systems in New Zealand

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Abstract

Recent research has highlighted the potential of a relatively new style of gold mineralisation related to granite intrusion. New discoveries in Alaska, Central Europe and Asia and Eastern Australia with total resources of 1,600t Au offer attractive targets for regional exploration in areas which may have been overlooked in the past. A spatial information system was developed to target granite-gold systems in eastern Australia and the West coast of New Zealand, using well constrained geological and exploration models derived from current research. Target areas were recognised in Queensland, New South Wales, Victoria, Tasmania and on the West Coast of the South Island of New Zealand that have similar spatial data relationships to known granite gold mineralisation elsewhere in the world. The second phase of the modelling better constrained the regional scale target areas by including more detailed geological, geochemical and geophysical data in the GIS to develop prospect-scale targets and to allow the acquisition of tenements over these areas. A geological review of each target area was carried out in the field to put the GIS models into context. The fieldwork has highlighted the potential for this style of mineralisation in New Zealand and will increase investment in mineral exploration and development in New Zealand in the near future.

Introduction

International research into Intrusion Related Gold Deposit has allowed new exploration concepts to be developed (e.g., Thompson et al., 1999; Lang et al., 2000; Braithwaite and Faure 2004; Mustard, 2004). New discoveries in Alaska, Central Europe and Asia and Eastern Australia with total resources of 1,600t Au offer attractive targets for regional exploration in areas which may have been overlooked in the past. This when combined with digital historic exploration data, (e.g., Nathan, 1998; Partington and Smillie, 2002; Rattenbury and Partington, 2003), now available over the internet has created new exploration opportunities in countries like Australia and New Zealand.

The West coast of the South Island of New Zealand has some of the oldest structural units in New Zealand, with strong similarities to terranes in eastern Australia. This area contains highly prospective geology with granites of a similar age and type to the Timbarra gold deposit in northern New South Wales (Mustard, 2004) or the Kidston gold deposit in north Queensland (Baker and Tullemans, 1990). Recent work by Braithwaite and Faure (2004) has confirmed similarities to Granite Gold style mineralisation at the Sams Creek gold deposit, which is currently being assessed by Oceana Gold. The current resource at Sams Creek is 10.7 Mt at 2.12 g/t Au, containing 729,000 oz at a 0.7 g/t Au cut-off and to a depth of 140 m (Braithwaite and Faure, 2004)

A regional prospectivity model was developed for the East Coast of Australia and the West Coast of New Zealand to assess the potential for new discoveries of this style of mineralisation. A total of 79,000 mineral occurrences, 9,324,000 rock geochemical data analyses, 21,912,000 stream sediment geochemical data analyses, 26,360,592 soil geochemical data analyses, 109,000 drill holes and 2,537,522 km^2 of geological information in eastern Australia and the West Coast of New Zealand were integrated to produce the prospectivity models. Tenements were acquired over the most prospective of these areas in Australia and New Zealand and a new company, Auzex Resources Limited, floated on the Australian stock Exchange to explore and develop these targets.

This paper presents the modelling results and the results of the follow-up work, which have important implications for a new style of mineralisation in New Zealand and it's future exploration potential.

Geology and mineralisation of the West Coast region of New Zealand

The geology of the New Zealand Project area comprises a fault-bounded core of Ordovician Greenland Group metasediments of the Buller terrane that is intruded by, or in fault contact with, granites and diorites of the Carboniferous Karamea or the Cretaceous Rahu and Separation Point Suites (Nathan et al., 2002). The Greenland Group forms part of the oldest structural units in New Zealand, with strong similarities to terranes in eastern Australia. The granites are predominantly S-type and I-type granites, similar to those found in the New England Fold Belt in Australia, and have related vein tungsten and tin deposits porphyry molybdenum, copper skarn and gold+silver-bearing base metal sulphide quartz veins (Tulloch, 1983; Tulloch and Braithwaite, 1986). The granites range from diorite, granodiorite, granite to leucogranite in composition. Limited whole-rock geochemistry suggest that the granites are fractionated, especially the Dunphy Leucogranite, Buckland Granite and Blackwater Granite. Where intruded by granitiods, contact metamorphic aureoles comprising biotite hornfels are developed over widths of up to two kilometres.

The main mineralisation in the area forms as gold bearing saddle-reef deposits associated with Greenland Group rocks that are mesothermal in nature and are controlled by north east trending faults (Christie and Braithwaite, 1999; Christie et al., 1999a; Christie et al., 1999b; Christie et al., 2000; Rattenbury and Stewart, 2000). The Reefton Gold Mines are examples of this style of mineralisation and are thought to be similar in genesis to the Victorian Gold Deposits in Australia (Christie and Braithwaite, 1999; Christie et al., 1999a; Christie et al., 1999b; Christie et al., 2000; Rattenbury and Stewart, 2000; Partington et al., 2001). Tin and tungsten mineralisation has been identified in the area, but only in sub-economic quantities. However, there appears to be a strong association of Au and Bi in several granite intrusions, with the granites hosting the mine at Mt Rangitoto and the Buckland Granite the best examples. Historic exploration to date has ignored this style of mineralisation. There are numerous small alluvial gold operations in the area and gold dredging is common along the coastal. One of the largest alluvial gold mines in New Zealand is currently operated at Ross.

Spatial data modelling methodologies

The discovery of mineral resources is based on probability and for any company to be successful at the exploration end of the value chain they have to be able to efficiently integrate and assess large volumes of data including mineral occurrence data, geology and geochemistry to increase their probability of success (e.g., Henley, 1977). Currently, most exploration targeting is performed by searching prospect information from mineral occurrence databases while focussing on a few prospects known to the explorers often in a confined area. While this type of analysis has been effective in the past, many areas have now been well explored and the limited prospect coverage means the probability of discovery is low. Effective targeting can only be done if all relevant data are compiled and integrated in a way that matches the mineral occurrence model being used and combined into a single mineral potential map (e.g., Partington et al., 2001; Partington and Smillie, 2002; Rattenbury and Partington, 2003; Partington and Sale, 2004). These data are not only diverse but voluminous, including regional geology, geochemistry, remote sensing and geophysical data, making the task of interpretation complex.

A variety of new tools are available for use in computer aided geographic data management systems or Geographic Information Systems (GIS) for evaluating the distribution of spatial data in a statistical framework (Atterberg et al.; 1993; Bonham-Carter, 1997; Boleneus et al., 2001; Kemp et al., 2001; Mihalasky, 2001; Raines, 1999). Weights of Evidence is a Bayesian statistical approach used in this study that allows the analysis and combination of data to predict the occurrence of events (Bonham-Carter, 1997). The technique was initially developed as a diagnostic tool in medicine, but has successfully been used for mineral exploration (Raines 1999; Milhalasky, 2001; Partington and Sale, 2004). The resulting model provides a map display of the probability of discovery of the minerals being sought within the area being assessed.

Prospectivity modelling

A national scale GIS database of known mineral occurrences, regional geology and geochemistry were compiled for both Eastern Australia and New Zealand for this study. The data in the GIS were modelled using Weights of Evidence software to produce a national scale probability map for Granite Hosted Metal Deposits in Eastern Australia and New Zealand (Figure 1).

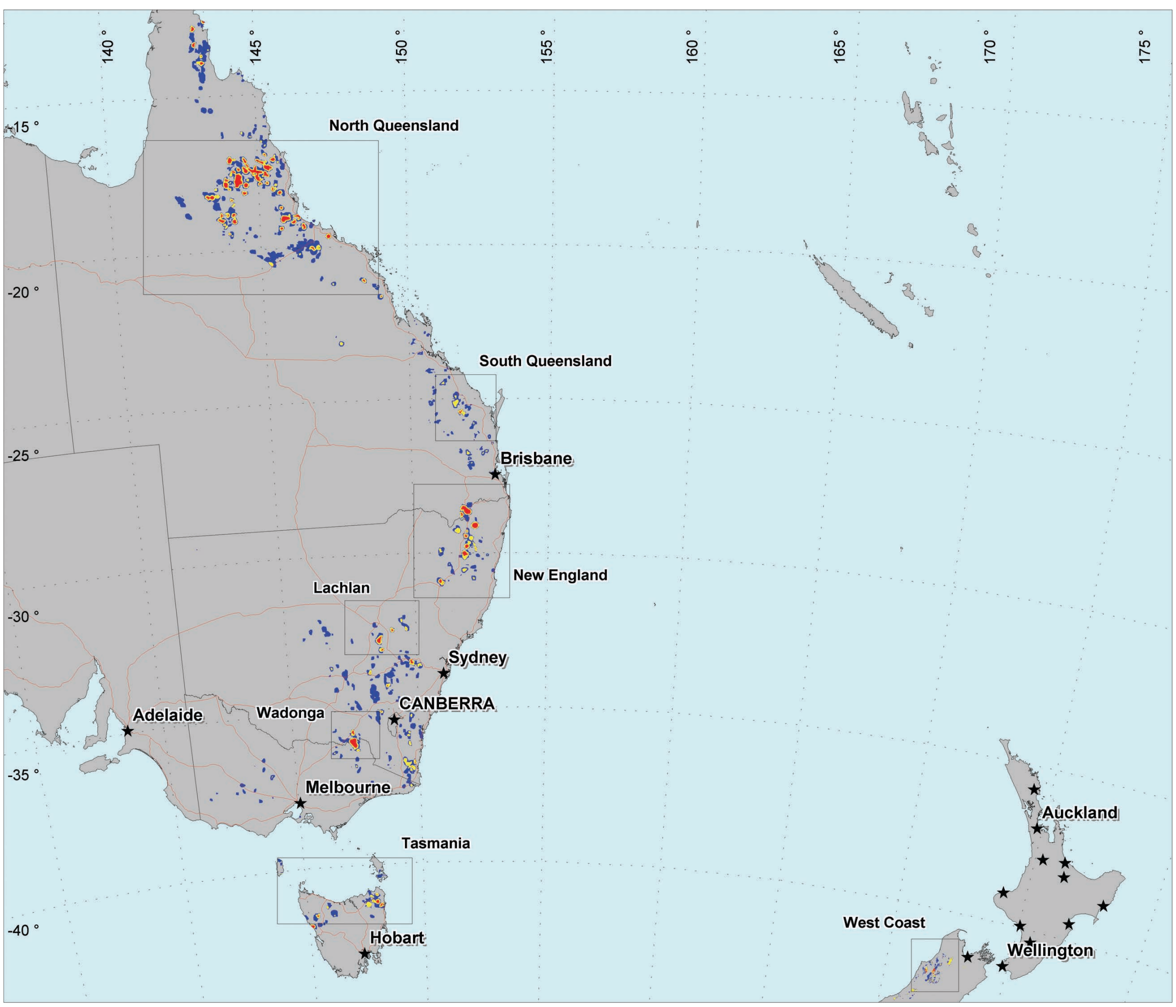

Figure 1 National scale prospectivity map.

As a first step in the spatial correlation calculation, a 200 by 200 metre grid was generated over eastern Australia and New Zealand. The size of the grid was chosen to represent the minimum probable extent that would be covered by an economically viable mineral deposit. Mineral deposit locations for hard rock mineralisation were extracted from the various Geological Survey mineral resource databases and a training data set of Bi-W-Mo-U-Au mineral occurrences was selected.

Spatial correlations were calculated using the Weights of Evidence technique (Bonham-Carter et al., 1988; Bonham-Carter, 1997; 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. The accepted genetic model for the formation of granite related mineralisation was used to constrain the input data themes for the analysis along with their spatial correlation to known mineralisation.

The granite prospectivity model was created, highlighting three districts where project acquisition was concentrated. These were in New South Wales, Queensland and on the west coast of the South Island of New Zealand. The three districts have similar spatial data relationships to known mineralisation as at Kidston in North Queensland and Timbarra in New South Wales (c.f., Baker and Tullemans, 1990; Mustard 2001; Mustard 2004).

The regional targets were then better constrained by including more detailed geological, geochemical and geophysical data in the GIS to develop prospect-scale targets using a 40 by 40 metre grid to allow tenement acquisition. Eight high priority prospect areas were identified by this work including Lynbrook, Khartoum and West Tinaroo in North Queensland, Glen Innes, Stanthorpe and Boorolong in New South Wales and southern Queensland, and Ross and Buller in New Zealand. All prospect areas have similar characteristics with unexplained occurrences of alluvial gold, historic Mo-Bi-W or Sn workings and little or no modern exploration.

Field data checking

Follow-up field work, including geological mapping, rock sampling and laser ablation analysis has been completed and focussed on the Mt Rangitoto and Buckland Granite areas (Figs 2 and 3). Results confirmed anomalous gold grades with a bismuth association in both areas. Laser ablation work further confirmed that a fine-grained granite located downstream from Mt Rangitoto contained primary gold within miarolitic cavities, indicating for the first time that granites in New Zealand are capable of producing gold from a fractionating magma. A direct link between gold mineralisation and fractionated granites has been clearly demonstrated in Australia (Mustard et al, 2005).

Several mineralisation styles were observed at Mt Rangitoto including disseminated sulphides in muscovite-tourmaline leucogranite, early quartz-tourmaline±sulphide veins, late sulphide-rich quartz veins and massive sulphide-poor quartz veins. Rock chip sampling of a range of mineralisation styles from Mt Rangitoto returned values of up to 9.13 ppm Au, 85.3 ppm Ag and >500 ppm Bi. Laser ablation of sulphides located within miarolitic cavities of fine-grained granite detected primary gold. Four main geochemical associations were highlighted from the LA-ICPMS studies of the disseminated mineralisation including: (1) Pb-Bi-Au-Te+/-Ag-U-Mo (pyrite), (2) Sb-As (arsenopyrite), (3) Cu-Ag-(Sn) (chalcopyrite) and (4) W-Ta (quartz). Reflected light petrography revealed early pyrite locally contains inclusions of, or is mantled by chalcopyrite, bismuth tellurides and gold.

Two mineralisation styles within the Buckland granite area include sulphide-bearing chalcedonic quartz veins hosted in medium to coarse-grained two-mica granite and disseminated sulphide-bearing altered medium to fine-grained two-mica granite. The chalcedonic quartz veins returned assays up to 2.32 ppm Au and the disseminated fine-grained sulphide bearing granite assayed up to 1.51 ppm Au. Disseminated granite hosted. Three main geochemical associations were highlighted from the LA-ICPMS studies of the disseminated mineralisation including: (1) Cu-Ag-Sn- (Sb), (2) Bi-Pb +/- Au-Te and (3) Sn-W-Ta (in quartz). No significant As, Sb or Mo were detected. The chalcedonic quartz veins revealed a strong Au-As-Sb±Sb-Pb geochemical association, with coarse arsenopyrite containing low gold and fine arsenopyrite containing very high Au. Trace Bi was detected in arsenopyrite from veins.

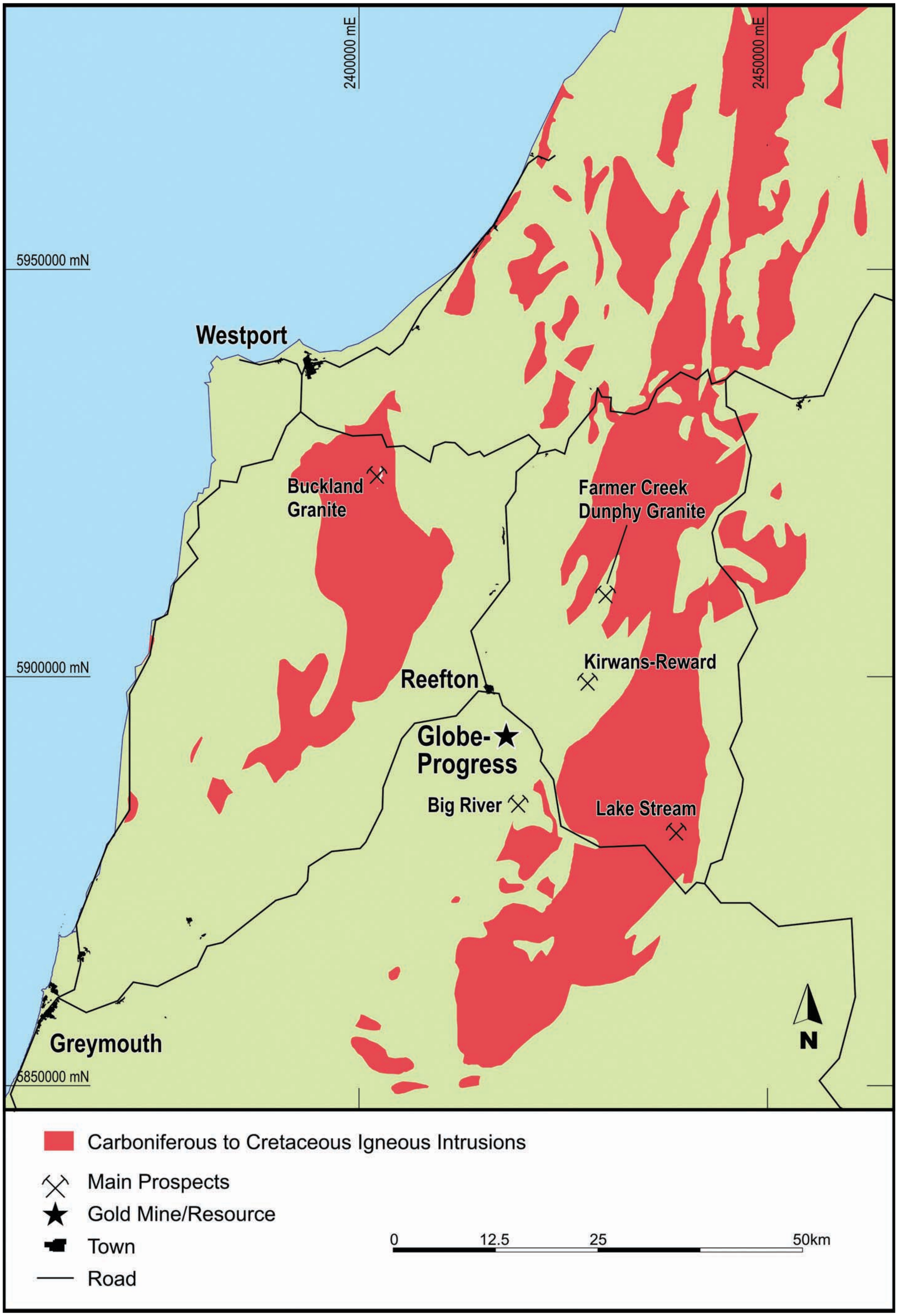

Figure 2. Location of the Buckland Granite in relation to generalised geology.

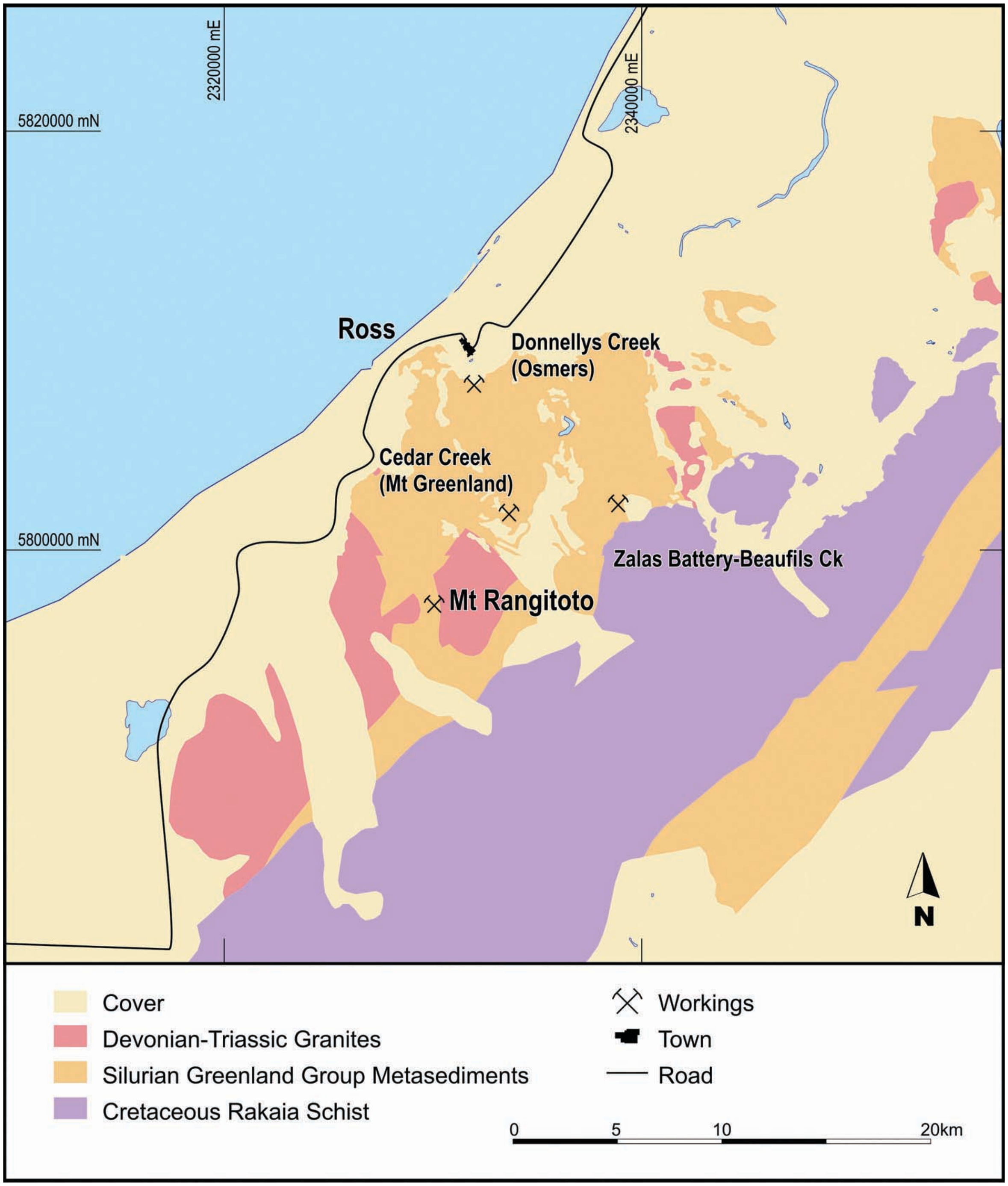

Figure 3. Location of Mt Rangitoto in relation to generalised geology.

Conclusions

The West Coast has excellent potential to host intrusion related granite mineralisation and Reefton style mesothermal gold mineralisation. The area has many of the geological features that contribute to the formation of these gold systems and there has been limited modern exploration, especially for gold within granite and Mo-Bi-Sn-W in the Greenland Group sediments. The most important conclusion arising from the geochemical sampling program is that the granites in the project area have similar metal associations to other Auzex prospects in Australia and a similar potential for new discoveries. The mineralised granite samples from the West Coast must be followed up to assess the potential for economic mineralisation.

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References

Atterberg, F. P., Bonham-Carter, G. F., Cheng, Q., Wright, D. F.1993. Weighs of evidence modelling and weighted logistic regression for mineral potential mapping. In: *Computers in Geology, 25 Years of Progress*, Davis J. C. and Herzfeld U. C. eds, pp 13-32, Oxford University Press, Oxford.

Baker, E.M, and Tullemans, F.J. 1990. Kidston Gold Deposit. In *Geology of the Mineral Deposits of Australia and Papua New Guinea*, Hughes F.E. ed, pp 1461-1465, The AusIMM, Australia.

Bonham-Carter, G. F. 1997. Geographic Information Systems for geoscientists: Modelling with GIS: p. 398, Pergamon, London.

Bonham-Carter, G. F., Agterberg, F. P., and Wright, D. F. 1988. Integration of geological data-sets for gold exploration in Nova Scotia. American Society for Photogrammetry and Remote Sensing 54: 171-183.

Boleneus, D. E., Raines, G. L., Causey, J. D., Bookstrom, A. A., Frost, T. P., and Hyndman, P. C. 2001. Assessment method for epithermal gold deposits in northeast Washington State using weights-of-evidence GIS modelling, USGS Open-File Report: 01-501.

Braithwaite, R. L. and Faure, K. 2004. The Sams Creek Peralkaline Granite Hosted Gold Deposit, Northwest Nelson, New Zealand - A New Variant on Alkaline Intrusion-related Gold Deposits. Australasian Institute of Mining and Metallurgy Pacrim 2004 Congress Volume, Adelaide: 239-250.

Christie, A. B. and Brathwaite, R. L. 1999. The mineral potential of New Zealand, Institute of Geological and Nuclear Sciences Science Report, 99/4.

Christie, A. B., Bierlein, F. P., Arne, D. C., Ramsay, W. R. H., Ryan, R. J., Smith, P. K. 1999a. Comparison of lode gold deposits of the Buller terrane, western South Island, to similar deposits in Victoria, Australia and Nova Scotia, Canada. New Zealand Mining 26: 43-55.

Christie, A. B., Smith, P. K., Ryan, R. J., Ramsay, W. R. H., Arne, D. C., Bierlein, F. P. 1999b. Quartz vein styles in turbidite-hosted mesothermal gold deposits of western South Island (New Zealand), Victoria (Australia) and Nova Scotia (Canada). Proceedings of the 32nd annual conference 1999, New Zealand Branch of the Australasian Institute of Mining and Metallurgy: 85-108.

Christie, A. B., Corner, N. G., Bierlein, F. P., Smith, P. K., Ryan, R. J., Arne, D. C. 2000. Disseminated gold at Reefton, South Island, New Zealand, compared with similar occurrences in Victoria, Australia and Nova Scotia, Canada. New Zealand Mining 28: 25-33

Henley R.W. 1997. Risky business: The essential blending of financial and scientific skills in the modern resource sector. Proceedings of the 1997 New Zealand Minerals and Mining Conference, Crown Minerals, Ministry of Commerce: 29-33.

Kemp, L. D., Bonham-Carter, G. F., Raines, G. L., Looney, C. G. 2001. Arc-SDM: Arcview extension for spatial data modelling using weights of evidence, logistic regression, fuzzy logic and neural network analysis, http://ntserv.gis.nrcan.gc.ca/sdm/.

Lang J. R., Baker, T., Hart, C. J. R., Mortensen, J. K. 2000. An exploration model for intrusion-related gold systems. SEG Newsletter 40: 1-11.

Mihalasky, M. J. 2001. Mineral potential modelling of gold and silver mineralisation in the Nevada Great Basin: A GIS-based analysis using weights of evidence. USGS Open-File Report: 01-291.

Mustard, R. 2001. Granite-hosted Gold Mineralisation at Timbarra, northern New South Wales, Australia. Min. Dep. 36: 542-562.

Mustard, R., 2004. Textural, Mineralogical and Geochemical Variation in the Zoned Timbarra Tablelands Pluton, New South Wales. Aust. J. Earth Sci. 51: 385-405.

Mustard, R., Ulrich, T., Kamenetsky, V. S. and Mernagh, T. 2005. Gold and metal enrichment in natural granitic melts during fractional crystallization. Geology, accepted.

Nathan, S. 1998. QMAP, national geological mapping programme, and the implications for mineral exploration. New Zealand Mining 23: 28-30.

Nathan, S., Rattenbury, M ., .Suggate, R. P. 2002. Geology of the Greymouth area, Institute of Geological and Nuclear Sciences 1:250,000 geological map 12: 1 sheet and 58 p.

Partington, G. A., Christie, A. B., and Cox, S. C. 2001. Mineral resources assessment for the West Coast of New Zealand using spatial analysis in a GIS: A new exploration management and land-use management tool, Australasian Institute of Mining and Metallurgy Conference Volume, 34th Annual Conference, Dunedin: 141-163.

Partington, G. A. and Smillie, R. W. 2002. A national-scale GIS and prospectivity models of mesothermal gold mineralisation in New Zealand, in *Mesothermal Gold in New Zealand GIS Data Package and Prospectivity Modelling*, 72 p. Crown Minerals, Ministry of Commerce, New Zealand.

Partington, G. A. and Sale, M. J. 2004. Prospectivity mapping using GIS with publicly available earth science data - a new targeting tool being successfully used for exploration in New Zealand. Australasian Institute of Mining and Metallurgy Pacrim 2004 Congress Volume, Adelaide: 239-250.

Raines, G. L. 1999. Evaluation of weights of evidence to predict epithermal deposits in the Great Basin of the Western United States. Natural Resources Research 8(4): 257-276.

Rattenbury, M. S. and Stewart, M. 2000. The structural setting of the Globe-Progress and Blackwater gold mines, Reefton Goldfield, New Zealand. New Zealand Journal of Geology and Geophysics 43: 435-445

Rattenbury, M. and Partington, G. A. 2003. Prospectivity models and GIS data for the exploration of epithermal gold mineralisation in New Zealand, in *Epithermal Gold in New Zealand GIS Data Package and Prospectivity Modelling*, 68 p, Crown Minerals, Ministry of Commerce, New Zealand.

Thompson, J.F. H., Sillitoe, R. H., Baker, T., Lang, J. R., Mortensen, J. K. 1999. Intrusion-related gold deposits associated with tungsten-tin provinces. Mineralium Deposita 34: 323-334.

Tulloch, A.J. 1983. Granitoid rocks of New Zealand a brief review. Geological Society of America Memoir 159: 5 20.

Tulloch, A. J. and Brathwaite, R. L. 1986. Granitoid rocks and associated mineralisation of Westland Nelson, New Zealand. Tourguides A3, C2 and C7. New Zealand Geological Survey record 13: 65 92.