The association of low-sulphidation epithermal gold deposits with bimodal volcanism and rifting in New Zealand: implications for exploration

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Abstract

The worldwide association of low-sulphidation epithermal gold mineralisation, bimodal rhyolitic-basaltic volcanism and rifting is confirmed in New Zealand. In the currently productive Coromandel epithermal-gold province reported Ar-Ar dating of adularia from low sulphidation deposits falls into two groups at 6 and 7 Ma. Bimodal rhyolitic-basaltic volcanism has been reported to be K-Ar dated at 9 to 7 Ma and 6 to 5.5 Ma. Epithermal gold mineralisation in Northland is spatially associated with bimodal basaltic-rhyolitic volcanism, with rifting cogenetic with that in the CVZ. The Taupo Volcanic zone (TVZ) is sufficiently young that the presence of a segmented rift with recent bimodal rhyolitic-basaltic volcanism can be genetically associated with epithermal gold mineralisation, which occurs as both fossil occurrences and in active geothermal fields. This reinforces the known potential prospectiveness of the Coromandel area and increases that of Northland and the Taupo Volcanic Zone.

Keywords: *gold, epithermal, low-sulphidation, bimodal, volcanism, rifting*

Introduction

This paper reviews the link between bimodal volcanism, rifting and epithermal gold mineralisation in New Zealand. Worldwide there are two styles of non high-sulphidation, epithermal gold deposits. One has the "classic" features of epithermal gold deposits that include rhythmically banded veins with chalcedony, quartz pseudomorphs after platy calcite, adularia as a vein and alteration mineral and generally low base metal sulphide contents. The other style generally lacks chalcedony and adularia, has simpler crustiform textures and can contain significant amounts of base metal sulphides and barite. This difference in style was recognised by Bogie and Lawless (1987, 1997 and 1999), where it was attributed to the "classic" style occurring in rhyolitic basinal settings and the other style of deposit being hosted in andesitic stratovolcanoes. John (1999, 2000, and 2001) in his study of non high-sulphidation epithermal gold deposits in Nevada also established that epithermal gold deposits of two separate styles are found within two separate geological environments. He found that deposits associated with bimodal volcanism formed under relatively low oxygen and sulphur fugacities and have generally low total base metal contents, low Ag/Au ratios, and notably high selenide mineral contents and have the "classic" features described above. Temporally equivalent deposits lacking these features are associated with andesitic volcanism. Hedenquist et al. (2000) introduced the term intermediate-sulphidation for the non-"classic" type of deposit, with the "classic" style being regarded as true low sulphidation epithermal gold deposits. Sillitoe (2002) established that a similar association occurred world wide, although the selenide mineral occurrences are district specific. Sillitoe and Hedenquist (2003) expanded on this idea and made a brief mention of the

Waihi deposit in the Coromandel Volcanic Zone (CVZ) as "forming at the change from andesitic to rhyolitic volcanism" and that "the Taupo Volcanic Zone (TVZ) has many active geothermal fields, dominantly rhyolitic volcanism and traces of low-sulphidation epithermal mineralisation". This paper reviews these areas in more detail and the third bimodal volcanic field of Northland.

Coromandel Volcanic Zone (CVZ)

Rhyolitic and basaltic eruptive centres of the CVZ have no clear spatial association. The rhyolitic calderas have a distribution semi-parallel to the axis of the peninsula. The basalts mainly lie on an NE trend along the Kuaotunu peninsula and the Mercury Islands across the axis of the Coromandel peninsula, with a few minor more southerly occurrences (Adams et al., 1995) and as in the TVZ (Wilson et al., 1995) basalts may be under represented due to poor preservation. The submarine stratigraphic record of rhyolitic eruptions (Carter et al., 2004) is also more extensive than the terrestrial one. Therefore it is uncertain how much weight showed be placed upon their current outcrop pattern.

The most obvious example of rifting in the area, the Hauraki Graben, post dates CVZ volcanism (Kear, 1994) and associated mineralisation. Kamp (1984) considers that steepening of the subduction zone due to changes in the relative movement of the Pacific plate provided 1 km of uplift in the Late Neogene in Northland and Coromandel resulting in NNE to NE rifting (Skinner, 1995), that may be the major control on the development of auriferous veins as well as providing conduits for the basaltic volcanism, as both appear related to structures with these trends. Another aspect to consider is that at the time of known major gold mineralisation in the CVZ (6-7 Ma, see below) Kear's (2004) tectonic reconstruction, shows that continental crust is no longer interposed between the CVZ and the subduction zone. This should result in a major reorganisation of the subduction zone geometry. This may have led to the down going slab tearing, which would have allowed diaparic movement of underlying hotter mantle material into and through the slab. This will have two consequences. The first is that adiabatic melting will occur in the mantle diapar to produce basaltic melts that should be distributed at right angles to the strike of the subduction zone, thus explaining the northeast lineation of the Mercury Bay basalts. The second consequence is that the down going slab will be heated by the diapar to possibly produce adakitic melts (Defant and Drummond, 1990) which have been linked with major gold deposits in several locations (Sonja and Maury, 1998). Such a link has not been established in the CVZ, but trace element data from fresh rocks of the CVZ is limited in availability (D.N.B. Skinner pers.com) and this concept has yet to be adequately tested.

The CVZ is mainly an andesitic arc and intermediate sulphidation epithermal gold mineralisation is present. An example is that at Thames (Bogie and Lawless, 1997 and 1999), but the majority of gold production from the CVZ has been from one low-sulphidation deposit of Waihi. Dating studies of both the volcanic rocks (Skinner, 1986; Adams et al., 1994; Braithwaite and Christie, 1996) and of epithermal deposits (Adams et al, 1974; Mauk and Hall, 2003, 2004) are available, although the most comprehensive of the rock dating studies (Adams et al., 1974) is limited to north of Thames. The volcanic rocks have been dated by a combination of K-Ar and fission track dating of which the K-Ar results are the most reliable. Both K-Ar and Ar-Ar dating has been undertaken on hydrothermal minerals from epithermal gold deposits of which Ar-Ar step heat dating of adularia has been demonstrated to be the most reliable (Mauk and Hall, 2003, 2004).

The majority of the andesitic volcanism north of Thames took place between 18 and 9 Ma. Rhyolitic volcanism began at 12 Ma (Carter et al., 2004), with two phases of bimodal basalt to basaltic andesitic/rhyolitic volcanism with post-caldera formation andesitic volcanism taking place between 9 and 7 Ma, and 6 to 5.5 Ma, with entirely basaltic volcanism from 4.7 to 4.2 Ma (Adams et al., 1994). Dates for andesitic volcanism south of Thames range from 7.94 to 3 Ma (Braithwaite and Christie, 1996; Kear, 2004), with rhyolites dated from 4.5 to 2.5 Ma. Adams et al. (1994) note a general younging to the east consistent with subduction roll back while Kear

(2004) shows a trend of younging to the south that he attributes to movement on a now abandoned extension of the Alpine fault into the North Island.

Available Ar-Ar dates of adularia from epithermal gold deposits fall into two groups. Golden Cross and Neavesville have ages close to 7 Ma, while Waihi/Favona and Komata have ages close to 6 Ma (Mauk and Hall, 2003 and 2004). These two events generally match the two separate periods of bimodal volcanism rather than the onset of rhyolitic volcanism, but other than Neavesville are much further south than the dated bimodal volcanic suites. These results are therefore strongly suggestive, rather than conclusive, of an association between low sulphidation epithermal gold mineralisation and bimodal volcanism.

Taupo Volcanic Zone (TVZ)

The TVZ is a segmented rift forming as a back arc basin (Rowland and Sibson, 2001). The northern and southern segments of the TVZ are dominated by andesitic volcanism. Rhyolitic ignimbrite overwhelmingly dominates volcanism in central segments of the TVZ, with some evidence for an early stage of andesitic volcanism. The reasons for these temporal and spatial variations in the nature of volcanism of the TVZ (Graham et al., 1995; Reyners et al, 2004; Price et al., 2005), has not been fully resolved. There is minor high-Al basaltic volcanism in the central portion of the TVZ occurring along NE structures, in response to thinned crust (Graham et al., 1995). Basaltic rocks elsewhere in the TVZ can be regarded as less siliceous counterparts to associated andesites and are distinct from the high-Al basalts (Graham et al., 1995). Wilson et al. (1995) note that all the known occurrences of high Al-basalt post date the Whakamaru Ignimbrites and thus are younger than 0.32 Ma, but attribute this to poor preservation of older occurrences as there are basalt lithic clasts in earlier ignimbrites. While some authors (eg Cole et al., 1995) divide the TVZ into an eastern andesite dacite arc and a western marginal basin with bimodal rhyolite-basalt volcanism, Wilson et al. (1995) find no simple spatial separation of basalts and andesites.

An economic low sulphidation epithermal gold deposit is yet to be found in the TVZ, but there are a number of prospects (eg Ohakuri, and Umikuri; Barker, 1993) that along with gold occurrences associated with active geothermal fields (eg Rotokawa, Krupp and Seward, 1987 and Ohaaki, Simmons and Browne, 2000) indicate that the TVZ has potential to host such a deposit. It is only with the advent of Ar-Ar dating that reliable radiometric dates have been obtained from rocks from the TVZ, unfortunately these are limited to the products of major ignimbrite eruptions (eg Pringle et al., 1992) and there is no data available for basalts or epithermal mineralisation. Nevertheless, since the TVZ is comparatively young the geographical association of bimodal volcanism, rifting and epithermal mineralisation is clearly apparent in the central segments of the TVZ.

There is also no simple relationship between gold occurrences and particular lithologies other than that the vast majority of occurrences are within the central segments of the TVZ (Figure 1) where rhyolitic volcanism is predominant and basaltic volcanism most common. Insufficient information is available to establish if the gold occurrences are low or intermediate sulphidation in nature to determine if there is any zonation in relation to the location of the active arc, particularly since the gold occurrence at Ohaaki (Simmons and Browne, 2000) which lies directly on the active arc has low-sulphidation characteristics.

Northland

Two main volcanic fields can be recognised, that of Kaikohe-Bay of Islands and Puhipuhi-Whangarei. The majority of basalts from the Kaikohe-Bay of Islands field have been dated at 5-2 Ma with some older dates of 9-7 Ma and some much younger volcanism. Dated rhyolitic material ranges in age from 8.13 - 2.84 Ma, with the undated Putahi rhyolite near Kaikohe, possibly being much younger (Letelier, 1979). The Puhipuhi-Whangarei field basalts have

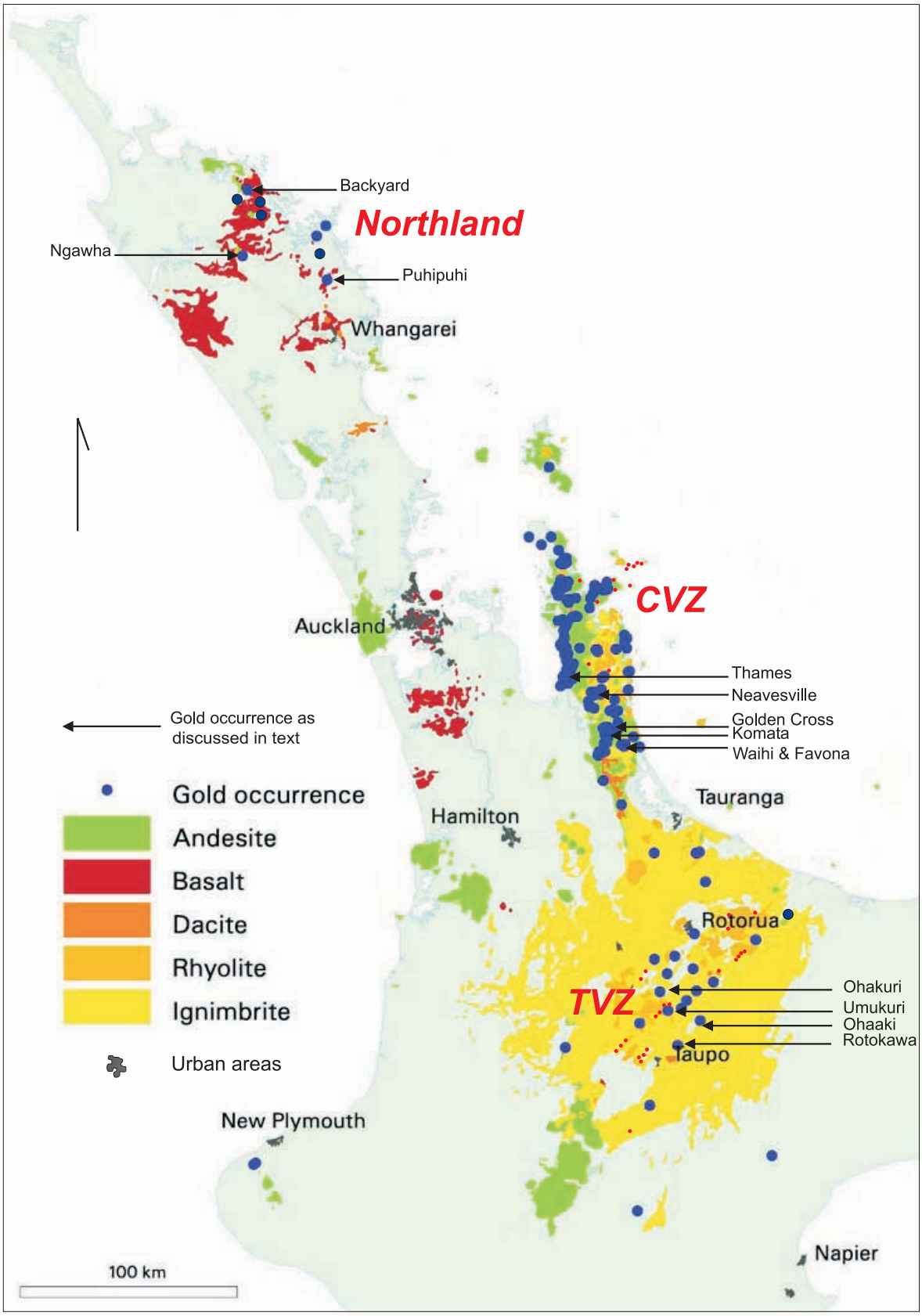

Figure 1: Gold occurences in relation to Cenozoic volcanism in the North Island of New Zealand. Base map from Ratlenbury and Partington (2003) with additions from Adams et al. (1994), Graham et al. (1995), and Taylor and O'Hara (2005).

been dated at 9.66 - 2.34 Ma, with a few much younger post mineralisation basalts, with the rhyolite at Puhipuhi dated at 4.08 Ma (Smith et al., 1993). No dating of Northland epithermal gold mineralisation is available, but since basalts are hydrothermally altered at Puhipuhi the hydrothermal activity must at least be younger than 9.66 Ma. It is of note that bimodal volcanism in Northland is penecontemporaneous with basaltic volcanism and mineralisation in the CVZ and that the basaltic volcanism in the CVZ has been correlated with the Northland bimodal volcanism (Skinner, 1995).

Smith et al. (1993) note that there is some structural control over the distribution of volcanism, most notably the presence of a NE trending graben formed by the Waipapa and Kawakawa faults controlling the distribution of basaltic volcanism in the Kaikohe-Bay of Islands volcanic field and that the eruptive centre distribution of the Puhipuhi-Whangarei field is fault controlled. Grieve et al. (1997) indicate NE bearing structures at Puhipuhi interpreted to be possible gold bearing structures, but this yet to be confirmed by drilling. Taylor and O'Hara (2005) report northeast striking auriferous veins in the Backyard prospect. As in the CVZ this NE rifting is likely to be related to changes in the relative movement of the Pacific plate (Kamp, 1984) particularly since the timing of these changes at 9 and 5 Ma give a good match to the timing of the basaltic volcanism.

As with the TVZ there are only epithermal gold prospects in Northland (eg Puhipuhi, Grieve et al. 1997 and Backyard, Taylor and O'Hara, 2005) with no economic deposits yet dtscovered. An active high temperature geothermal field is present at Ngawha, but Cox (1985) found only traces of gold associated with it. In contrast to both the CVZ and TVZ volcanism associated with epithermal mineralisation is non-subduction related and has been interpreted to be the result of back arc mantle diaparism (Smith et al., 1993). There has been protracted and relatively wide spread basaltic volcanism, with associated sporadic minor peralkaline rhyolitic volcanism, with rhyolitic intrusives reported in the immediate vicinity of gold mineralisation at the Backyard prospect (Taylor and O'Hara, 2005).

Summary and conclusions

Rifting and bimodal volcanism in both the CVZ and Northland is interpreted to be related to the result of changes in the relative motion of the Pacific plate, but with that in the CVZ combined with arc volcanism, with mineralisation related to magmatism triggered by subduction zone geometry changes due to movement of continental crust out of the CVZ fore arc. Rifting in the TVZ is occurring as a back arc basin and within its central segments there is a strong association with bimodal volcanism, rifting and epithermal gold mineralisation. Overall, the association of bimodal volcanism and epithermal mineralisation is present in New Zealand adding to the prospectivity of the CVZ, TVZ and Northland for these types of deposits.

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