A Report for Zinifex Rosebery Mine

A BRIEF REVIEW OF GEOLOGY, EXPLORATION AND VHMS POTENTIAL IN THE NORTH PINNACLES AREA

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INTRODUCTION

The North Pinnacles area forms part of EL 23/2000 'Silver Falls' currently held by Zinifex Ltd. The author was contracted by that company to summarise previous exploration, prepare fact and interpretive geological maps, and review the VHMS potential of the area. A review of the Burns Peak – Browns Tunnel area, just to the south on EL 49/2004, was undertaken concurrently.

The geology of the area is dominated by a long N-S 'finger' of semi-massive felsic lava, the Pinnacles Rhyolite, which is flanked by younger sediments (volcaniclastic sandstones, siltstones, shales) in synclinal basins to east and west. The sediments have been correlated with the Southwell Subgroup and White Spur Formation, but the correlation of the rhyolite body (i.e. whether part of the Central Volcanic Complex or some younger sequence) has not been clear. Correlates of the lower Tyndall Group, in the form of strongly magnetic volcaniclastic sandstones, occupy the core of the western syncline in the NW part of the area.

Most exploration activity has been focused on a northern section of the Pinnacles Rhyolite body and adjacent sediments, where a zone of silica-sericite-pyrite alteration with minor base metal and gold mineralisation occurs in the rhyolite. This area is the focus of this report. Some exploration has also been done in the 'Shale Basin' area in the southern part of the western syncline, where lead-zinc soil anomalies over shale-rich sediments appear to be related to manganese scavenging, but this has not been considered in this report.

PREVIOUS EXPLORATION

There are no known early prospects at North Pinnacles. Most of the exploration work in the area has been done by EZ Company/ Pasminco since the late 1970's, in part through a series of joint ventures. There have been three main periods of active exploration: (i) in 1978-80, when three short diamond holes were drilled for base metals; (ii) in 1986-88, when a fourth hole was drilled to evaluate gold potential in the rhyolite; and (iii) in 1993-94, when a deep hole (782m) was drilled targeting a possible VHMS position beneath the rhyolite.

EZ Company first became involved in the 1970's when they took up EL 12/72 following release of selected areas of Comstaff's very large EL 5/63. A large E-W grid was established (7 lines, 200 m spacing, 10.9 km total) across the rhyolite body, probably in response to observations of disseminated pyrite in the rhyolite and adjacent sediments. The grid was mapped, soil sampled (C horizon, 20 m spacing, Cu, Pb, Zn, Fe, Ag, Mn), and surveyed with 100m dipole-dipole IP (Mill, 1979). Soil sampling gave a number of Pb anomalies, to a maximum of 2500 ppm on Line 387300N, with Zn values being lower but broadly coincident. Most anomalies were over the rhyolite and in sediments near its eastern and western contacs. Leaf litter sampling showed much lower Pb and Zn levels and little or no correlation with the soils, so was discontinued.

The IP gave two anomalous zones: an eastern one ~600 m long straddling the eastern rhyolite contact and coincident with Pb-Zn soil anomalies in the northern part; and a 200 m long western zone over sediments about 200 m west of the contact.

The coincident IP and soil anomalies were followed up by further gridding, mapping, soil and rock chip sampling, IP surveys, stream sediment sampling, a small program of test pitting, and finally by drilling (Mollison, 1980). Additional soil sampling did not reveal any new anomalies, and stream sediment sampling gave surprisingly low values (mostly < 110 ppm Pb, 150 ppm Zn). Rock chip samples from drill tracks showed good correlation to soil data, with a highest assay of 1250 ppm Pb and 465 ppm Zn from a sample adjacent to the highest soil sample. Detailed IP over the known anomalies failed to produce any further anomalies 'of prime interest' but several low level ones which were coincident with soil geochemical anomalies. These were generally in bands near the eastern and western contacts, with some entirely within the rhyolite.

Hole NPP213 (130m) tested a coincident Pb soil anomaly and low-magnitude IP anomaly 300 m west of the rhyolite. The shale- siltstone- sandstone sequence intersected was little altered, with minor mineralisation consisting of fine pyrite, sphalerite and galena associated with carbonate veinlets, giving a best assay of 565 ppm Pb and 1350 ppm Zn from 85-90 m.

Hole NPP 214 (142m), on the same line, targeted a Pb-Zn-Cu soil anomaly close to the rhyolite contact. It intersected a similar sedimentary sequence before penetrating 'rhyolitic volcaniclastics' – assumed to be part of the Pinnacles Rhyolite- near the contact, which was considered to dip west at 80°. Minor galena- sphalerite associated with fluorite veinlets at 35-50 m correlated with the soil anomaly.

Hole NPP215 (128m) targeted coincident IP and Pb soil anomalies in the rhyolite. It intersected feldspar-phyric rhyolite and breccia with minor pyrite-galena-sphalerite in small quartz-carbonate veinlets, with a maximum assay of 0.38%Pb and 1.1%Zn from 45-50 m. A zone of disseminated pyrite from 30-64 m in rhyolite breccia was probably responsible for the IP anomaly.

It was concluded that all three holes showed the mineralisation to be 'epigenetic' and vein-style in both sedimentary and volcanic host rocks, with the presence of fluorite possibly indicating a genetic association with an intrusive at depth. Exploration interest waned for a period.

Interest in the gold potential in the 1980's led to the holes being re-assayed for gold, with NPP215 returning anomalous levels averaging 0.2 g/t over 20.3 m of pyritic brecciated rhyolite (only reported in Taylor, 1988?). Pancontinental- Outukumpu ('Pancon') farmed into the joint venture in late 1986, and reviewed the previous exploration (Herrmann, 1987a; Taylor, 1987; Airas, 1987). It was suggested that the association in NPP 215 of weak Au-As-Pb-Zn mineralisation with a zone of 'unusual' brecciation and weak but pervasive quartz-sericite-carbonate alteration, coupled with Zinc Ratios which were similar to VHMS deposits, could indicate a peripheral part of a VHMS hydrothermal system. However, the limited area of volcanics, the absence of recognizable host horizon, and the possibility that it had been stripped away prior to deposition of the adjacent sediments, were negative factors.

Nevertheless, Pancon re-cut and extended the grid and carried out a 4-loop EM37 survey covering the anomalous area (18 lines of 600m) on the rhyolite. No anomalous responses related to massive sulfides were recorded (Wilson, 1987).

The gold potential was revitalized when rock chip sampling undertaken by Herrmann (1987b) during mapping highlighted an outcrop of brecciated rhyolite containing up to 2.2 g/t Au about 200m north of NPP215. This suggested that the zone of gold mineralisation was of greater extent and grade than previously recognized, and revived the possibility of a low grade – high tonnage gold deposit. Follow-up Wacker sampling on 6 lines at 10 m spacing indicated erratic Au, Ag, Pb values peaking at 3.1g/t Au and 33g/t Ag in brecciated quartz-veined quartz-sericite-altered rhyolite over 400 m strike length north from NPP215, with the highest Au anomaly located over the NPP215 intersection. Additional rock chip sampling was done along the access track to NPP215, but the vast majority of samples were below detection limit of .005g/t Au, with only 3 with .01g/t (Taylor, 1988; Airas, 1988). This confirmation of the highly erratic nature of the gold distribution prompted the withdrawal of Pancon from the joint venture.

The IP surveys were reviewed by Bishop (1988), who recommended drill testing of the strongest chargeability anomaly in the gold-anomalous zone on Line 5387300N. A 2-year extension of the licence was gained by EZ to enable this drilling to take place (Mathison, 1989). Hole NPD004 (199m) was drilled on the IP-gold anomaly 200m north of NPP215. It intersected rhyolitic lava and breccia with patchy silica-sericite-pyrite alteration, minor pyrite-sphalerite-galena in quartz-carbonate veinlets, and rare galena veins to 5cm. Base metal grades were generally low, with maximum assay of 3m @ 1.8%Pb. Gold grades were mostly <0.01g/t, with a maximum of 9m @ 0.05g/t at the bottom of the hole. The small amount of sulfide intersected did not explain the IP anomaly. Downhole EM showed no significant conductors close to the hole.

It was concluded that while an east-dipping zone of weak mineralisation could exist east of and above NPD004, to explain the IP, the low grade and erratic gold distribution were not favourable indications of an economic deposit, and the area had been adequately tested. EL 12/72 was finally relinquished in 1989.

The area was taken up in 1990 by Billiton as part of EL 8/90 (Randell, 1991) for its VHMS potential based on several geological assumptions. Apart from taking 3 lithogeochemical samples, however, which were purported to show a favourable geochemical boundary near the western contact of the rhyolite, and suggesting the need for a deep hole beneath the rhyolite, no ground work was done. Pasminco farmed in to a joint venture with Billiton in 1991 (Kirsner, 1992), and the area was included in several regional surveys, including aeromagnetics and regional gravity (appendices by Leaman in Kirsner, 1992), and a regional mapping program by Lorrigan. A review of exploration data for North Pinnacles, and an initial phase of prospect-scale mapping and drill core re-examination, was begun. The nature of the western rhyolite contact was questioned, and the possibility of it being a fault, was raised, since it appeared that drill hole NPP214 had not actually reached it.

An Honours study of the Pinnacles Rhyolite was completed in 1993 by McKibben, giving a good account of the geology of the area and suggesting that the rhyolite could be a correlate of lavas in the Southwell Subgroup rather than of the CVC.

The review and consideration of regional structures was continued by Poltock (1993), noting that a major gravity ‘step’ more or less coinciding with the western margin of the rhyolite could indicate a major basement feature which had focused mineralizing fluids.

After further consideration (Poltock, 1994), including a review of the electrical geophysics at North Pinnacles (Hughes, appendix in Poltock, ibid), it was decided that the prospects for shallow mineralisation had been tested but that potential remained for a deep VHMS body beneath the 'hangingwall' alteration zone seen in the rhyolite. The target was the Browns Tunnel host sequence, which was known to plunge at a low angle beneath the rhyolite some 2 km to the south. The target depth was estimated (hoped?) to be between 350 and 650m, in the core of a broad anticlinal structure, but factors which might adversely influence this depth were admitted.

Hole NPD5 (782m) was collared about 100 m east of the rhyolite contact, and drilled through 44m of sediments, with a basal conglomerate, before penetrating 740m of rhyolite to EOH. The upper 200m of the rhyolite was rich in breccias and showed pervasive moderate to intense silicification, with a best gold assay of 0.02g/t. Scattered veins of galena and fluorite in more massive rhyolite from 280-460m gave a best assay of 1m @ 2.11%Pb. A pyritic fault zone at 360-362m gave 2m @ 0.38%Pb and 0.14%Zn, and a possible debris flow with blebs of sphalerite at 670-680m gave a best assay of 2.2m @ 0.23%Pb, 0.95%Zn. Alteration appeared to be decreasing in intensity down the hole, with no indication of proximity to the target host sequence.

Billiton departed the joint venture in the 1994-95 year, leaving Pasminco as managers. A downhole EM survey of NPD5 (Saxon, 1995) indicated a conductor more than 300 from the hole, possibly to the east, which was attributed to shales in the White Spur Formation. No more work was done at North Pinnacles except for a review by Morris (in Dibben, 1996a) which noted the difficulty of determining the extent and orientation of the alteration system in the rhyolite. The area was relinquished in 1996 (Dibben, 1996b).

RGC Exploration took up EL 47/96 over Boco Siding/North Pinnacles (Elliston, 1998), and once again had Herrmann (1998) review the area. Chemical data from the Pinnacles Rhyolite was assessed to indicate that the general nature of the mapped alteration (K2O and SiO2 gain, Na2O depletion, anomalous Pb-Zn-Au) had similarities to VHMS **footwall** alteration, with the possibility of a host horizon at the rhyolite-sediments contact …somewhere. The association of the rhyolite with a possible large basement structure, and the presence in the area of the base of the Tyndall Group, with possible analogies to the Henty-Comstock-Mt Lyell position, were also mooted as points for possible follow up. RGC reviewed its priorities and directions soon afterwards, however, and relinquished the licence in 1998.

Pasminco took out EL 23/2000 over the Silver Falls – North Pinnacles area in 2000, but no significant ground work has been done at North Pinnacles.

REGIONAL GEOLOGY

General Stratigraphy

Understanding of the regional stratigraphy of the Pinnacles – Burns Peak area has grown steadily since the publication of MRVP Map 2 in 1986 (Corbett and McNeill, 1986). The stratigraphic sequence from the Que-Hellyer area has been mapped to the Boco Road (McNeill, 2002; Reid, 1990; Coutts, 1990), and correlates of the Tyndall group have been identified just to the NW of the Pinnacles Ridge (McKibben, 1993; Poltock, 1994a.b). The major stratigraphic units are summarized below:

Top: (1) ***Tyndall Group sandstone sequence***: volcaniclastic sandstone with detrital pyroxene and magnetite; strongly magnetic. Not examined in present study.

(2) ***Southwell Subgroup*** (=White Spur Formation): sedimentary sequence of interbedded volcaniclastic sandstone, siltstone, shale and minor conglomerate occupying large synclinal structures east and west of Pinnacles Ridge; graded-bedded; marine fossils in places.

(3) ***Que River Shale correlate*** with associated quartz-feldspar porphyry intrusive/extrusive sills: black shale; only recognized to SE of Pinnacles Ridge, but could be present to SW also.

(4) '***Burns Peak Subgroup***' (informal name); this new term is suggested to encompass the complex of interfingering lithologies between the Southwell Subgroup and Que River Shale above, and the Central Volcanic Complex and Animal Creek Greywacke below. Major lithologies within the subgroup are: volcaniclastic sandstone, siltstone, shale and minor conglomerate; pumice breccia and pumiceous sandstone; dacitic to rhyolitic lava and lava breccia; andesitic lava, breccia and sandstone; and quartz-feldspar porphyry intrusive/extrusive bodies. The subgroup contains the Hollway Andesite, Pinnacles Rhyolite, and Browns Tunnel Host Sequence, as described below.

(5) ***Animal Creek Greywacke correlate***: a thin unit of sandstone, siltstone and shale, in part micaceous and Precambrian-derived, which lies at the base of the Hollway Andesite but is not seen in the present area.

(6) ***Central Volcanic Complex***: felsic lavas and breccias, including pumice breccias, with locally abundant mafic dykes; not seen in present area.

Southwell Subgroup

This sequence is exposed along the Boco Road east and west of Burns Peak, and along the Silver Falls Track and several other tracks west of the Pinnacles Ridge. It has been intersected by holes NPP213 and 214. The thickness between the base of the Tyndall Group and the Pinnacles Rhyolite on the Silver Falls Track is of the order of 650-700 m, but the fairly clear onlap of units against the Pinnacles Rhyolite to the south of this suggests a significantly greater thickness in the core region of the syncline through the Shale Basin area.

The three major lithological types present are: (i) well-bedded sandstone-siltstone, typically in beds from a few cm to a m or so thick, with common graded bedding; (ii) sandstone-dominated units, typically with 20-40% interbedded siltstone; and (iii) siltstone-shale-dominated units, ranging from grey-green siltstone to black-grey shale, typically with interbedded thin sandstone layers.

The sandstones are typically volcaniclastic and felsic in composition, with the major components being feldspar crystals, quartz crystals (ranging from sparse to abundant, and up to 5-8mm across as 'quartz eyes'), felsic volcanic clasts (typically feldspar +/- quartz-phyric lavas and lesser quartz-feldspar-phyric lavas), pumice clasts (typically tube pumice clasts 5-50mm across), shards (typically partially to completely altered to sericite or silica-sericite), and sedimentary clasts (mostly shale-siltstone or ashy-cherty types). Coasely graded mass-flow sandstone units up to 10m or so thick, with lithic-rich bases and fine-grained tops, are common.

Two varieties of the sandstones are distinctive: (i) a coarse crystal-rich quartz-feldspar-phyric variety which may resemble (and be difficult to distinguish from) quartz-feldspar porphyry, and which is commonly described as ‘arkosic’ or even ‘granitic’; and (ii) a pumice-rich variety, with feldspar and sometimes quartz crystals, which may resemble fine-grained versions of the pumice breccias of the CVC elsewhere. Examples of the former are common along the eastern margin of the rhyolite, and several units of the latter type are present along the western margin, possibly extending into the Silver Falls area.

A unit of volcaniclastic conglomerate, 10-50m thick, with abundant subrounded to subangular clasts of felsic lava up to 30 cm across, in a quartz-feldspar crystal-rich matrix, is seen at the eastern contact of the Pinnacles Rhyolite on Boco Road and in DH NPD5 at North Pinnacles. The conglomerate appears locally derived, and indicates that the contact is an erosional-sedimentary one. Such conglomerates have not been seen on the poorly exposed western contact, although coarse pumice-rich sandstones with some lava clasts are present.

Burns Peak Subgroup

Mapping and compilation work associated with the author’s study of the Burns Peak area shows that there is complex interfingering between pumice breccias, sediments, felsic (dacitic and rhyolitic) lavas and breccias and andesitic lavas and breccias in the zone which wraps around Burns Peak from the Hollway Andesite in the east to the Browns Tunnel sequence in the west.

In the east, the complex includes the large Hollway Andesite body (itself probably composite), the large lens-shaped dacite body which crosses Boco Road and appears to be an along-strike correlate of dacites at Sock Creek and Que-Hellyer (McNeill, 2002), and a volcaniclastic sandstone unit which overlies both of these and underlies the Que River Shale correlate. In the vicinity of the Boco Road north of Burns Peak, this sequence appears to pass laterally into a sheared and faulted complex of pumice breccias, volcaniclastic sandstones, shales and minor conglomerates, and felsic lavas and lava breccias. The latter appear to be offshoots from the main Pinnacles Rhyolite body to the NW, which is also considered to part of the subgroup.

A major NE-trending shear zone, the ‘Burns Peak Shear Zone’, passes through the sequence in this area, and a broader zone of shearing of similar trend affects the sequence to the west of Burns Peak. Sedimentary facings indicate an anticlinal axis somewhere just west of Leos Find prospect, and the sedimentary sequence of sandstone, shale, pumice breccia and minor lavas extending through the Browns Tunnel area (Browns Tunnel Host Sequence = BTHS) is west-facing. The southwestern arm of the Pinnacles Rhyolite mass overlies and interfingers with the upper part of the BTHS. The lower part of the BTHS interfingers with, and is underlain by, a thick sequence of pumice breccias on the western flank of Burns Peak, passing downwards into felsic lavas which possibly represent the CVC in this area.

THE PINNACLES RHYOLITE

General nature and relationships

The Pinnacles Rhyolite is an elongate mass of felsic lavas and lava breccias about 4 km long. It narrows in width from a maximum of about 1.3 km just north of Boco Road to a poorly exposed 'nose' at the northern end. The body occupies an anticlinal position with respect to the off-dipping sediments on either side, but there is insufficient internal layering within the body to establish whether or not the rhyolite itself is anticlinally folded. The eastern margin is clearly a sedimentary-erosional contact,marked by locally derived conglomerates rich in lava clasts, and appears to dip east at about 45-55°. The western contact is much steeper (70-80°?) and is of uncertain character, as discussed below.

Two rock types occur in about equal abundance: massive to flow-banded grey to pink lava, and lava breccia, the latter with typically angular clasts ranging from less than a cm to 20 cm or more across. Thin units of ashy vitric shale and volcaniclastic sandstone are also present in places, particularly in the lower part of the sequence (e.g. DH BPD69, 78), but are rarely exposed, e.g. on Boco Road north of Browns Tunnel.

The lavas are almost universally feldspar-phyric, and also have small but visible quartz phenocrysts in some areas. The groundmass is spherulitic in some cases, and these varieties have a sandy texture on weathering. Some versions appear to have abundant quartz-cored spherulites and have a disconcerting resemblance to quartz-rich sandstone in weathered form (e.g. on Boco Road 500m west of the Browns Tunnel junction). The relative distribution of quartz-bearing as opposed to quartz-poor types has not been fully documented, although some observations suggest the quartz-rich type is more abundant in the upper levels.

The rhyolite sequence is at least 500 m thick in NPD5, and appears to consist of an upper zone, ~170m thick, of abundant breccias and thin flows, and a central zone dominated by more massive (and flow-banded) lava but with breccias still present. Several drill holes in the Browns Tunnel area indicate that the basal part of the sequence consists of flows interfingering with pumice breccias and sediments. Peperitic contacts of rhyolite flows with ashy/cherty mudstones are common in this area, suggesting that some of the flows may be shallow sill-like bodies emplaced into wet sediments. Several holes NE of Burns Peak (e.g. BPD72, 77) show breccias which seem to be intermediate between lava breccias and pumice breccias, with clasts which are both pumice-like and lava-like, suggesting an environment where highly-vesiculated fluidal flows were breaking up in-situ to produce pumiceous breccias. Re-sedimentation of this material could have produced the graded pumice breccias and pumiceous sandstones seen in the Browns Tunnel sequence.

The western margin of the Pinnacles Rhyolite

Although the western margin is crossed by four exploration tracks and by the Boco Road, it is nowhere fully exposed and its nature remains uncertain. Nearby bedding in the sedimentary sequence is steep – 70-80°- and minor folding is apparent near the contact on the Silver Falls Track. There is no real evidence for a major fault zone (such as the Rosebery or Henty Faults), with tens of m of disturbed rocks, where the two northern tracks cross, but a lesser structure could be present.

Drill hole NPP214 was reported to have reached the contact by Mollison (1980), when it passed from shales and sandstones into relatively massive ‘rhyolitic pyroclastics’ (‘rhyolitic crystal vitric tuff’- - presumably pumiceous sandstone). However, later workers (e.g. Kirsner, 1992) have rightly questioned this and suggested that the hole did not reach the contact with the rhyolite proper. Mollison’s (1980) core log of NPP214 records the crystal-vitric tuff near the end of the hole as being partially silicified, with common quartz veins (5mm-2cm), some of which contained chlorite, suggesting that the actual contact was fairly close.

Regional considerations also raise questions about this contact. As noted by EZ Co geologists in the early 1990’s, drilling near Browns Tunnel (e.g. BPD82, 63; EAF2) shows the western rhyolite contact in this area south of Boco Road to be a major low-angle fault, dipping east at about 45°, sub-parallel to and almost certainly related to the main Rosebery Fault beneath it. This fault, referred to as the ‘Hangingwall Rosebery Fault’, juxtaposes the Pinnacles Rhyolite beside and partly over a volcano-sedimentary sequence similar to, and correlated with, the Southwell Subgroup (with the typical shales and porphyry-like sandstones). The continuation of this contact north of the Boco Road is covered by moraine, and it is not known if the major fault retains a northerly to NNW trend to cross the Marionoak River and head into the Silver Falls area, or swings north-easterly to follow the rhyolite contact. A third, and quite feasible, alternative is that the fault divides and does both, with a splay following the rhyolite. Some early EZ Co fact mapping (Mill, 1980) showing a ‘highly sheared’ zone along the contact in the Shale Basin area (around 5386,500N), lends some support to this.

Regional aeromagnetic and gravity surveys covered the Pinnacles – Silver Falls area in 1991, and were interpreted by Leaman (1992) and discussed by Kirsner (1992), Poltock (1993) and Lorrigan (in Kirsner, 1992). The aeromagnetics showed the Pinnacles Rhyolite straddling a broad zone of quiet magnetics grading towards a very large positive anomaly to the NE (later shown to be related to a deeply buried ultramafic mass), but no particular feature related to the contacts. The gravity, on the other hand, showed a distinct ‘step’ more or less coincident with the western margin of the rhyolite, which Leaman interpreted as a major basement feature possibly related to the edge of a rift-fill or something similar.

The writer’s conclusion about the western margin of the Pinnacles Rhyolite, pending further detailed mapping, is that it represents a splay from the upper Rosebery Fault, or even a separate fault in its own right, which is dying out to the north and may be relatively minor at the level of the Silver Falls Track.

Geochemistry of the Pinnacles Rhyolite

Some compilations of whole rock chemical analyses and comments on the geochemistry of the northern Pinnacles Rhyolite have been given by McKibben (1993) and Herrmann (1997), and some data from the southern part were compared with other units in the Browns Tunnel area by Poltock et al (1993). At North Pinnacle, nine analyses are available from rhyolitic rocks in NPD5 (Poltock, 1994), four from NPP215 (3 from Airas, 1987; 1 from McKibben, 1993) and one from NPD004 (McKibben, 1993). In addition, 5 analyses from BPD71 in the southern part of the area are given by McKibben (1993).

These 19 analyses give a range of SiO_2 values from 60.4-79.25, with an average of 73.05% SiO_2, suggesting that the sequence consists dominantly of rhyolites with minor rhyodacites and dacites. Plots of Zr/TiO_2 vs Nb/Y confirm the dominant rhyolitic nature of the unit (McKibben, 1993; Poltock et al, 1993). TiO_2 values range from 0.11-0.34, with an average of 0.21%TiO_2, and Ti/Zr ratios average 7.2. P_2O_5/TiO_2 values range from 0.09-0.52. Plots of such ratios against SiO_2 suggest that the Pinnacles Rhyolite is a Suite 1 type rock according to Crawford et al (1992), but the Rare Earth Elements seem to suggest otherwise.

Rare Earth Element analyses of two rhyolites are given by McKibben (1993), one from NPD004 (151m) and one from BPD71 (380m). There are distinct differences between the two. That from NPD004 shows very weak enrichment in LREE, with $(La/Yb)_N$ of 2.1 , while that from BPD71 shows strong enrichment, with $(La/Yb)_N$ of 26.2. The NPD004 sample is notably less enriched than typical Suite 1 CVC rhyolites, and the only possible match is with some Suite 3 andesitic-basaltic rocks from Sock Creek, some of which are also poorly enriched (Crawford et al, 1992). The BPD71 sample is notably *more* enriched than Northern CVC rhyolites (Suite 1), but shows some overlap with strongly enriched Suite 3 rocks from the Que-Hellyer and Queenstown areas.

There is clearly considerable diversity within the Pinnacles Rhyolite, but the available data seem to suggest affinities with the Que-Hellyer/ Sock Creek group of rocks rather than with the otherwise similar CVC rhyolites. Further study is needed to resolve the geochemical questions.

Correlation of the Pinnacles Rhyolite

Several lines of evidence seem to support a general correlation of the Pinnacles Rhyolite with the Que-Hellyer Volcanics – Sock Creek dacites, rather than with the CVC:

(1) The apparent interfingering of the rhyolites with pumice breccias and sandstones at the level of the upper part of the Hollway Andesite in the Boco Road area, in an equivalent position to the Boco Road dacite. Further detail on this stratigraphy is given in the report on the Burns Peak area (Corbett, 2005).

(2) The geochemical comparisons, which suggest affinities with the Que-Hellyer and Sock Creek dacites, as noted above;

(3) The apparent complete absence from the Pinnacles Rhyolite of any of the abundant mafic dykes which characterise the northern CVC, particularly in the Hollway – Boco area. Possibly related to this is the noisy magnetic signature of the northern part of the CVC, a feature also lacking from the Pinnacles Rhyolite.

Overall, the Pinnacles Rhyolite body is interpreted as a seafloor volcano or cryptodome which developed off the northern margin of the CVC in response to similar tensional tectonics to those which triggered the contemporaneous Que-Hellyer and Sock Creek andesitic-dacitic volcanism. The rhyolite complex was probably centred near its zone of maximum thickness just north of Boco Road, with a core zone which may be largely 'intrusive' and a carapace and marginal zones of multiple flows and breccias. Early flows interfingered southwards with sediments of the BTHS, and later flows with sandstones and pumice breccias just below the Que River Shale equivalent.

The considerable thickness involved suggests the lava pile of the Pinnacles Rhyolite was built up over a considerable period of time (i.e. from early post-CVC time to just before Que River Shale time), and should not be regarded as a single stratigraphic horizon.

MINERALISATION AND ALTERATION

The only known mineralisation/alteration of significance on the Pinnacles Ridge is the North Pinnacles Prospect located between 387000N and 387500N, originally discovered by EZ Company in the late 1970's. C-horizon soil sampling on a 200m-spaced grid produced a number of Pb anomalies (to 2500 ppm) on line 387300N, with Zn values broadly coincident. IP surveys gave an anomaly over the eastern part of the rhyolite and another over the sediments some 200m west of the contact. Drilling of the latter (NPP213) showed only minor fine pyrite, galena and sphalerite associated with carbonate and quartz-carbonate veinlets in the siltstones and sandstones. The IP response was attributed to shales. A second hole in the sediments closer to the rhyolite contact (NPP214) targeted a Pb-Zn-Cu soil anomaly, again showing minor fine galena-sphalerite in quartz-carbonate-fluorite veins (mainly in sandstone) and some disseminated to blebby pyrite in both sandstone and shale.

The more interesting mineralisation was in the eastern part of the rhyolite, where subsequent mapping and rock chip sampling showed a surface zone approximately 400 m long and 150 m wide (fig.) of silica-sericite-altered pyritic quartz-veined rhyolitic breccia with gold and low level Pb-Zn. The strongest mineralisation appeared to be in a NNE-trending band within this zone, in which the best rock chips assayed to 2.2g/t Au, 4.5g/tAg, 0.18%Pb, and best Wacker drill samples peaked at 3.1g/tAu and 33g/tAg (Airas, 1987). Initial drilling (NPP215) showed the zone extending to about 120m depth, with pyrite-galena-sphalerite again present in quartz-carbonate veinlets (best assay 0.38%Pb, 1.1%Zn from 45-50m), and gold averaging 0.2g/t over some 20m. Disseminated pyrite in the zone explained the IP anomaly.

The subsequent NPD004, located 200m to the north, was angled 50° east beneath a second IP anomaly, but gave poorer results (best assay 9m @ 0.05g/tAu, 3m @ 1.8%Pb). Again, the Pb-Zn was associated with quartz-carbonate veins. There did not seem to sufficient sulfide intersected to explain the IP anomaly.

While it was considered that an east-dipping and more sulfide-rich zone may have been located above and to the east of NPD004, the highly erratic and generally low tenor of the gold and base metal values were not suggestive of a viable near-surface deposit, and it was considered that the prospect had been adequately explored (Mathison, 1989).

The next exploration phase was triggered by Billiton's speculation that the alteration might be representative of a hangingwall zone to a deep VHMS system (Randell, 1991). Underpinning this model, as further developed by Poltock (1994), was the knowledge that the Browns Tunnel Host Sequence, which was known to host VHMS-style mineralisation, plunged beneath the rhyolite from the south at a low angle, giving the possibility that the surface zone of silica-sericite-pyrite alteration in the rhyolite was located above a VHMS body in the BTHS at drillable depth (estimated between 350-650m). The deep hole NPD5 (782m) was drilled in 1994 from just east of the rhyolite contact, and penetrated 740m of rhyolite lavas and breccias without reaching the target. Disappointingly, the sequence intersected appeared to become more massive and less altered with depth, and there was nothing to indicate proximity to the base of the rhyolite complex. Minor galena, sphalerite and fluorite in veinlets through 250-400m, a pyritic fault zone at 360m, and some minor sphalerite blebs in a breccia at 677m, represented the mineralisation.

ASSESSMENT OF VHMS POTENTIAL

The possible potential for VHMS mineralisation at Pinnacles Ridge largely revolves around whether the silica-sericite-pyrite alteration seen at North Pinnacles represents the footwall or hangingwall environment of a VHMS system, or possibly neither. The possibility of it being a hangingwall phenomenon, such as that at Hellyer, related to an ore position in underlying Browns Tunnel host sediments, was tested by NPD5, which penetrated some 500m of essentially unaltered rhyolite below the alteration and gave no support for the model.

The possible analogy with footwall alteration was discussed in some detail by Herrmann (1997). His simple mass balance calculations on altered and unaltered samples from NPD5 and NPP215 indicated significant gain of K_2O, loss of Na_2O, and some gain (but less than expected in silicified-looking rocks) in SiO_2, and suggested possible comparison to the ‘gold rich distal part of the Que River footwall stringer zone’. However, some significant differences were also noted, such as the much higher sulfide contents at Que River (6-10% sulfur and anomalous Pb-Zn up to 2-3%) and the coarse permeable volcaniclastic nature of the host rocks there.

Interpretation of the North Pinnacles alteration as part of a VHMS footwall system would imply a host horizon most likely located at the rhyolite-sediment contact, but no indication of exhalative activity at this contact has ever been reported or indicated.

All the drilling to date at North Pinnacles has indicated that the Pb-Zn mineralisation is associated with quartz-carbonate +/- fluorite veins or fracture fillings, the largest recorded being 5 cm across in NPD004. This is the case in the sediments to the west, in the near-surface rhyolite, and in the rhyolite at depth (250-400m) in NPD5. Assays have only exceeded 1%Zn over small intervals where veins are abundant or bigger. Even within the most intense silica-sericite-pyrite alteration within the rhyolite breccias at North Pinnacles, the sphalerite and galena seem to have been essentially confined to veins and fractures (Mollison, 1980; Mathison, 1989).

The ‘epigenetic’ vein-related style of the mineralisation in both rhyolite and sediments, and the association with fluorite in many of the veins, led early workers to suggest a genetic association with an intrusive at depth (Mollison, 1980). It might be speculated that the mineralisation occurrences are to some extent centred around the steep western contact of the Pinnacles Rhyolite. The unresolved nature of this contact, and its possible association with a major basement structure of some kind – possibly the margin of deep rift (Poltock, 1993; Leaman, 1992), suggests it may represent a fluid leakage path from a large intrusive body (Cambrian or Devonian granite?) which has introduced small amounts of mineralisation into adjacent rocks, mainly via vein systems. Although some of the lead in this system has a Cambrian isotopic signature (2 of 3 samples analysed by McKibben, 1993, the third giving a Devonian signature), this could represent Devonian remobilization of Cambrian lead, as is the case for the Farrell lodes at the Henty Fault. It might be further speculated that the North Pinnacles silica-pyrite zone was developed in a relatively more permeable unit of breccias which intersected the fault zone above and west of the present erosion surface (fig. 3).

The above speculation does nothing to upgrade the potential for VHMS-type base metal mineralisation in the area, although it does suggest that questions related to mineralisation and the western margin of the Pinnacles Rhyolite remain to be resolved. The drilling and surface work done to date appear to have delimited the scope of the alteration/mineralisation at North Pinnacles, and no new VHMS-related targets can be suggested.

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