The Sovereign, Jubilee, Scotia and Jasper Creek prospects, Waitekauri Valley, Hauraki Goldfield

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Abstract

The Sovereign, Jubilee, Scotia and Jasper Creek prospects occur in an area of ~3.0 km by 2.5 km (~7.5 km^2) in the Hauraki goldfield. The prospects are hosted by andesitic to dacitic flows, autoclastic breccias and localised pyroclastic and air fall deposits. Jubilee and Sovereign prospects lie along the northern and southern parts of the Waitekauri Fault, respectively, whereas Scotia is located ~1km to the E, and Jasper Creek a further ~1.2 km to the ENE. Wall rocks are typically intensely altered, although the degree of alteration becomes more variable east of Scotia and at Jasper Creek. Alteration minerals include quartz, adularia, albite, chlorite, pyrite, illite, interstratified illite-smectite, smectite and calcite. Several of these minerals have distributions that show distinct zonation with adularia most abundant at Sovereign and Jasper Creek, but restricted to shallow levels at Scotia. Illite occurs throughout Sovereign and Jubilee plus the western margin of Scotia where it grades into interstratified illite-smectite; smectite predominates at Jasper Creek. Veins are uncommon and typically narrow, but show distinct zonations. Quartz veins are more abundant at Sovereign and Jubilee, whereas calcite veins are more abundant at Scotia and Jasper Creek. Laumontite veins occur at Scotia, and rare clinoptilolite, mordenite and stilbite veinlets with calcite occur at Jasper Creek. Fluid inclusion in quartz and calcite homogenised between 141º to 272ºC and trapped a dilute solution with an apparent salinity of less than 2.6 weight percent NaCl equivalent. Homogenisation temperatures are hottest at Sovereign (ave. 241ºC) and Jubilee (ave. 239ºC), cooler at Scotia (ave. 204ºC) and coolest at Jasper Creek (ave. 162ºC). Calculated paleowater table elevations suggest the water table was 680 m to 750 m above sea level at Sovereign and Jubilee, 450 m at Scotia and 225 m at Jasper Creek. The current data suggest three scenarios that can explain why Sovereign and Jubilee are deep and hot, whereas Jasper Creek is cool, shallow and marginal; 1) Some or all of the prospects may represent separate overlapping hydrothermal system, 2) a high-relief hydrothermal system on the side of volcano with an inclined water table and outflow towards Jasper Creek, or 3) a low-relief hydrothermal system that has been either tilted or block faulted with greatest uplift and erosion to the west.

Keywords: *Sovereign, Jubilee, Scotia, Jasper Creek, epithermal Au-Ag, Hauraki goldfield*

Introduction

The Sovereign, Jubilee, Scotia and Jasper Creek prospects are located in the southern Waitekauri Valley, approximately 4 km west of Waihi, New Zealand (Fig. 1). Historic mining at Sovereign (formerly know as Maorilands), Jubilee, and Scotia collectively produced 392 kg of gold-silver bullion, with almost 60 percent mined from Sovereign (Brathwaite and Christie, 1996). Veins are comparably rare with the exception of the Jubilee vein, which has a strike length of 800 m, explored vertical extent of 215 m and is up to 2.5 m wide. Exploration and drilling of these prospects commenced in the 1980's and continued in the early 1990's by Cyprus Minerals and

Coeur Gold NZ Ltd, respectively (n = 87 drill holes, 10,605 m). The area is currently being explored and drill tested by Newmont. In this study, we examined hydrothermal alteration and veins from all four prospects along three overlapping cross sections that collectively span 3 km in length. We also present fluid inclusion results for quartz and calcite veins. These data are used to interpret the physical and chemical conditions prevailing during hydrothermal activity and are used to speculate on the hydrothermal system or systems that formed these prospects.

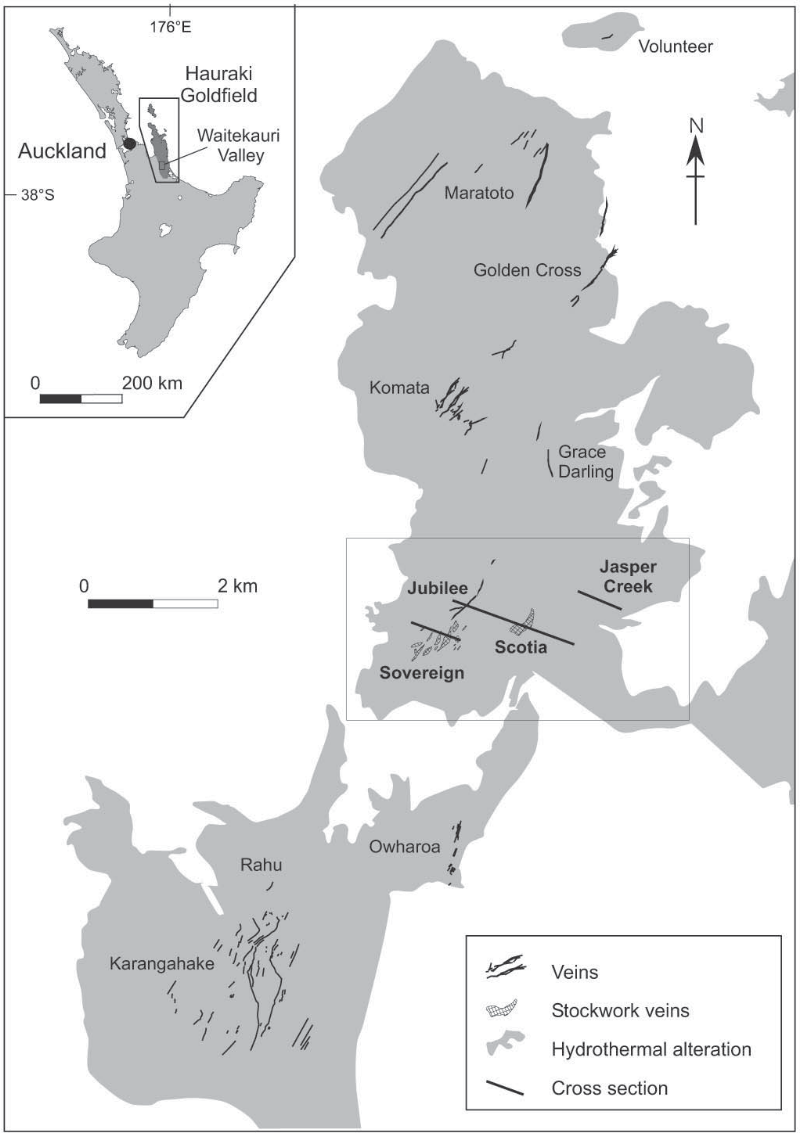

Fig. 1. The location of the Sovereign, Jubilee, Scotia and Jasper Creeks prospects in relation to other deposits of the Waitekauri Valley. The extent of alteration surrounding veins is also shown. Inset of North Island shows the location of the Hauraki Goldfield and Waitekauri Valley.

Geological setting

The Sovereign, Jubilee, Scotia and Jasper Creek prospects are located in the southern part of the Hauraki Goldfield (Fig. 1; inset), a 200 km long by 40 km wide metallogenic province that contains the greatest concentration of precious metal deposits in New Zealand (Brathwaite et al., 1989). Over 50 separate low-sulfidation epithermal gold-silver deposits comprise the Hauraki Goldfield and are hosted in a thick succession of Miocene to Pliocene andesites and rhyolites that overlie a block faulted basement of Jurassic greywacke (Skinner, 1986). Gold and silver predominantly occur in steeply dipping quartz veins mainly hosted in the andesite, with historic (1862 to 1952) and recent mining (since 1988) producing 1.73 million kg of Au-Ag bullion (Brathwaite et al., 1989). The Sovereign, Jubilee, Scotia and Jasper Creek prospects in the southern Waitekauri Valley (Fig. 1) are hosted in andesite flows, volcanic breccias and very local lithic-crystal tuffs. Sovereign is almost exclusively hosted in volcanic breccias and pyroclastics, whereas both Scotia and Jasper Creek are predominately hosted in andesite flows. Structurally, the area is dissected by northeast striking faults, with the Jubilee vein and Sovereign prospect developed along the northern and southern parts of the Waitekauri Fault, respectively. However, the amount of displacement and timing of these faults is poorly constrained. The extent of hydrothermal alteration surrounding the four prospects is difficult to define since they all occur within an irregular elongated magnetic "quiet" zone that covers 34 km^2 of the Waitekauri Valley (Fig. 1) and includes the Maratoto, Golden Cross, Komata, Owharoa and Karangahake deposits (Morrell et al., 2003). Argon-argon age determination for two wall rock adularia samples from Sovereign that show weak illite alteration gave plateau ages of 6.5 to 6.8 Ma (Ward et al., 2005). These differ from the Ar-Ar plateau ages for Maratoto (~6.4 Ma), Komata (~6.0 Ma), Golden Cross (~6.9 Ma) and Karangahake (Mauk and Hall, 2004; Ward et al., 2005), and suggest that the single magnetic quiet zone contains several spatially overlapping but temporally distinct paleo-geothermal systems.

Hydrothermal alteration

Hydrothermal alteration was examined along three drill line cross sections orientated west-northwest, that collectively span 3 km in length and transect the Sovereign, Jubilee, Scotia and Jasper Creek prospects (Figs. 1 and 2). Wall rock alteration of the lava flows, volcanic breccias and pyroclastics is typically intense (>98 to 100 % altered), although the degree of alteration on the eastern margin of Scotia and at Jasper Creek is more variable. A breccia occurs at Jasper Creek at shallow levels that may be hydrothermal in origin. Oxidation in the form of iron oxyhydroxides occurs mainly at shallow levels and extends 20 to 50 m below the surface, although oxidation locally extends up to 300 m below the ground surface along fracture zones. Hydrothermal alteration minerals have been studied for 172 samples by whole rock and clay separate X-ray diffraction (XRD), supplemented by preliminary petrography. A variety of alteration minerals occur at the prospects with the occurrence, spatial distribution and temporal relationships of selected minerals described below.

Quartz

Quartz is a ubiquitous alteration mineral that forms 50 to 60 percent of the rocks by volume. Quartz predominantly replaces the groundmass as microscopic interlocking anhedral grains inter-grown with adularia, chlorite, illite or illite-smectite and disseminated pyrite. Lesser amounts of quartz replace augite, hypersthene and rare plagioclase phenocrysts. By comparison, quartz veins are rare.

Adularia and albite

The occurrence of hydrothermal adularia and hydrothermal albite is mainly based on XRD; however it is not possible to distinguish hydrothermal albite versus igneous plagioclase using this technique. Distinction between the two has been made visually by determining the degree of alteration in the wall rocks supplemented by preliminary petrography. Hydrothermal adularia is a common alteration mineral that is found in over 70 percent of samples studied from Sovereign and Jasper Creek, but is found in 40 percent of samples from Jubilee and Scotia (Fig. 2A). Adularia occurs at all depths although is generally restricted to shallow levels at Scotia. Hydrothermal albite is less common than adularia. It locally coexists with adularia at Jubilee, Scotia, and Jasper Creek, but also forms a discrete zone below and on the eastern margin of Scotia. Both hydrothermal adularia and albite replace phenocrystic and groundmass plagioclase and have subsequently been variably replaced by illite or interstratified illite-smectite and overprinted by late calcite.

Fig. 2. Alteration mineral distribution maps for cross sections that transect the Sovereign, Jubilee, Scotia and Jasper Creek prospects. A) Hydrothermal adularia and hydrothermal albite B) Illite, interstratified illite-smectite and smectite. Smectite that overprints illite or illite-smectite has been omitted for clarity. A number of drill holes project above the topographic surface and this is because they have been projected up to 150m on to the section.

Epidote

Preliminary petrography identified epidote in two deep samples from the Sovereign prospect. This epidote replaces phenocrystic plagioclase together with adularia, albite and is overprinted by late calcite. The extent of this mineral at Sovereign and possibly Jubilee is not known, but will be documented by future petrography.

Chlorite, chlorite-smectite and corrensite

Chlorite, interstratified chlorite-smectite and corrensite are found in over 75 percent of samples studied. Chlorite is the most common and widespread (70 % of samples), whereas both interstratified chlorite-smectite and corrensite are rare and sporadic in occurrence (6 % of samples). Chlorite is conspicuously absent from the deepest drill hole from Jasper Creek, although it is present in adjacent shallower holes to the east. Chlorite replaces mafic phenocrysts and the groundmass of volcanic rocks.

Illite, interstratified illite-smectite and smectite

Illite, interstratified illite-smectite and smectite are common clay minerals. Illite predominates at the Sovereign, Jubilee and western margin of Scotia prospects (Fig. 2B). The illite at Scotia grades eastward into interstratified illite-smectite that contains 10 to 50 percent smectite with the percentage of smectite increasing towards the east. By contrast, smectite is the most abundant clay mineral at Jasper Creek with rare localised occurrences of interstratified illite-smectite that contain 10 percent or less illite. In addition, smectite sporadically coexists with illite or interstratified illite-smectite at the Jubilee and Scotia prospects where it is interpreted to overprint these minerals. All three clay minerals replace plagioclase, hydrothermal adularia and hydrothermal albite. They also flood the groundmass and are overprinted by late calcite.

Calcite

Replacement calcite is found at all four prospects, although its abundance at each is variable. Calcite is most abundant at Scotia and Jasper Creek where it is found in 57 and 49 percent of samples, respectively. Calcite is less common at Jubilee (32 %) and Sovereign (22 %). Replacement calcite is late stage overprinting hydrothermal adularia, albite and illite or illite-smectite altered plagioclase. Calcite also replaces mafic phenocrysts and locally floods the groundmass.

Pyrite and hematite

Disseminated pyrite is a common and widespread alteration mineral found at the Sovereign, Jubilee, Scotia and Jasper Creek prospects. By contrast, disseminated hydrothermal hematite is an uncommon mineral generally restricted to drill core from Jasper Creek and the eastern margin of Scotia. The strongest development of hematite alteration appears over a 60 m interval mid-way down the deepest drill hole at Jasper Creek; between 233 to 293 m down hole. Hematite typically occurs as sub-microscopic finely disseminated grains throughout the groundmass and locally replaces plagioclase phenocrysts. This mineral also forms rare veins (see below).

Veins and veinlets

The Jubilee vein is the largest vein in the area and is 800 m in strike, up to 2.5 m wide and was mined to a depth of 215 m. Apart from this, veins are sparse and typically narrow, seldom exceed 10 cm in width and are more common in competent lava flows than in volcanic breccias and pyroclastics rocks. Despite the lack of large veins, there is a range of different vein types that display distinct spatial and temporal zonation. Pyrite veinlets or stringers are less than 1 to

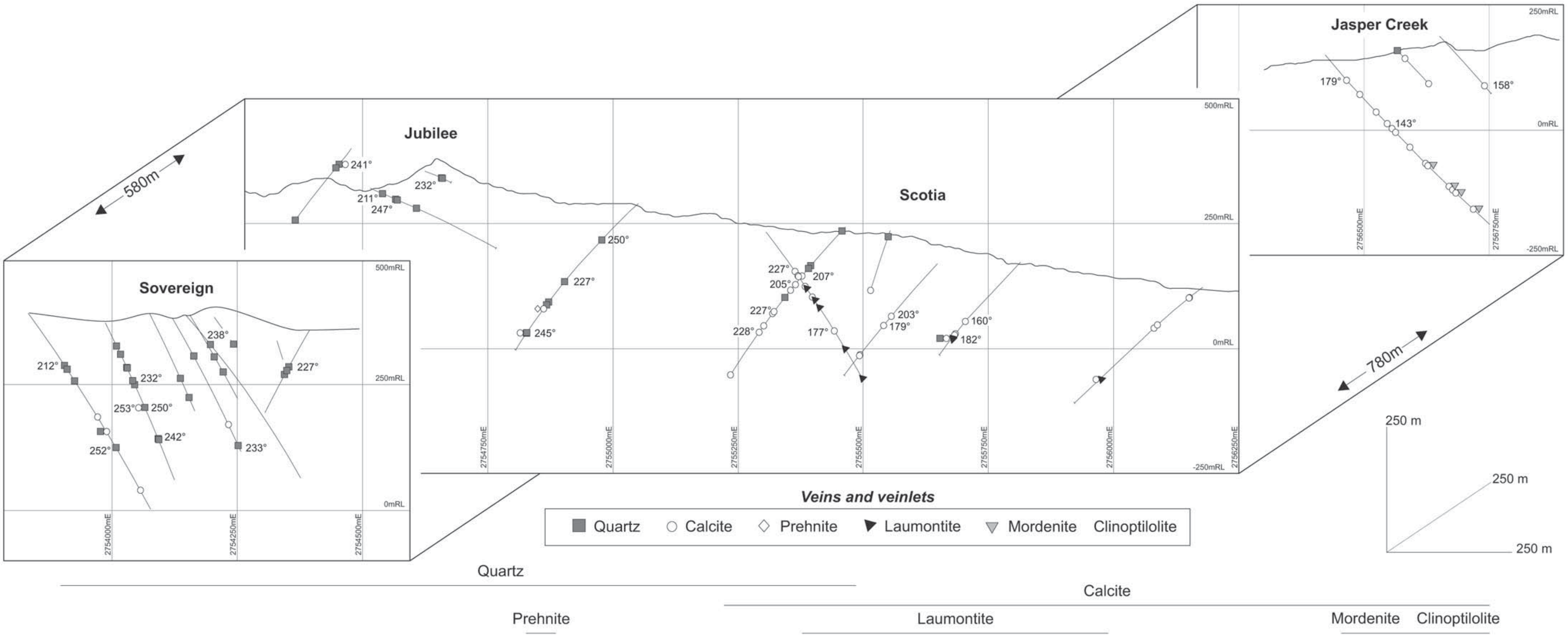

Fig.3. Distribution of quartz, calcite, and zeolites veins in cross section that transect the Sovereign, Jubilee, Scotia and Jasper Creek prospects. Fluid inclusion average Th values are also plotted.

2 mm wide and were the first to form. They exhibit planar and irregular geometries, are locally cut by quartz veinlets and mainly occur at Sovereign and Jubilee. Quartz veinlets are uncommon and mostly occur at the Sovereign and Jubilee prospects (Fig. 3). Quartz veinlets are typically less than 10 cm wide and are predominantly composed of medium- to coarse-grained massive quartz that typically lacks banding and has cavities rimmed by comb quartz. Rare veins contain sectors of quartz pseudomorphed platy calcite and a single narrow brecciated quartz vein at Sovereign contains disseminated grains of chalcopyrite, galena and pyrite. Quartz veins at Scotia and Jasper Creek are extremely rare and consist of finer-grained to chalcedonic quartz. Extremely rare jaspoidal quartz veins with pyrite occur at Scotia with rare hydrothermal hematite veins at Jasper Creek. Both are cut or centrally filled by later calcite. In a converse relationship to quartz, calcite is mostly restricted to the Scotia and Jasper Creek prospects (Fig. 3). Calcite veins are mineralogically diverse and formed after quartz as calcite is seen to overgrow quartz. The most prominent development of calcite veins occurs at Scotia where at shallow levels (above ~100 m above sea level, (asl)) there is a stockwork of 5 to 15 cm wide monomineralic massive calcite veins. Below the stockwork rare laumontite veins occur with or without calcite (Fig. 3). The timing of calcite and laumontite overlap; laumontite locally overgrows calcite, but elsewhere laumontite is cross cut by calcite. At Jasper Creek, nearly every calcite vein has a unique mineralogy. Those at shallow levels consist of calcite with either selvages of hematite or botryoidal smectite, with some calcite containing acicular mordenite (Fig. 3). A single vein is composed of calcite, ankerite and dolomite. Those at depth are comprised of massive and platy calcite together with mordenite, clinoptilolite or stilbite (Fig. 3). The timing between calcite and zeolites is complex and alternates. For example, one vein has tabular clinoptilolite selvages overgrown by platy calcite and interstices filled by massive calcite inter-grown with acicular mordenite. A single calcite vein at Jubilee is inter-grown with prehnite.

Fluid inclusions

Microthermometric measurements were made on rare primary and abundant secondary inclusions in quartz and calcite sampled over a 365 m vertical interval. Due to the zonation of vein types, quartz was the main host for inclusions at Sovereign and Jubilee, whereas calcite was the dominant host at Scotia and Jasper Creek. Both minerals host abundant two-phase liquid-rich and locally rare coexisting two-phase vapour-rich inclusions; the latter likely trapped under boiling conditions (Roedder, 1984). Homogenisation temperatures (Th) for inclusions in quartz from Sovereign and Jubilee closely overlap ranging from 196º to 273ºC and average 241º and 239º C, respectively (Fig. 4). Inclusions in calcite from Scotia are cooler ranging from 146º to 247º, and averaging 204ºC, whereas those from Jasper Creek are even cooler ranging from 132º to 204º and averaging 162ºC (Fig. 4). Final ice melting temperatures (Tm) for quartz range from 0.0º to -1.5ºC, and correspond to salinities up to 2.6 weight percent NaCl equivalent (Bodnar, 1993). By contrast, calcite has a narrower Tm range of 0.0º to -0.7ºC, which corresponds to 1.2 weight percent NaCl equivalent, although many have Tm values of 0.0ºC and have essentially trapped pure water.

Discussion

In the following, we consider the hydrothermal processes that formed the Sovereign, Jubilee, Scotia and Jasper Creek epithermal prospects based on their active analogues, modern geothermal systems (Henley and Ellis, 1983; Henley and Hedenquist, 1986; Simmons and Browne, 2000). In geothermal systems the mineral products of hydrothermal alteration and vein deposition can be directly related to coexisting fluids of known temperature, pressure, mass flow and chemical composition (e.g., Reyes, 1990; Simmons and Browne, 2000). Accordingly, this provides an interpretive framework for determining the significance of the different alteration and vein minerals at the four prospects as well as permits speculation on the relations among the areas during hydrothermal mineralisation.

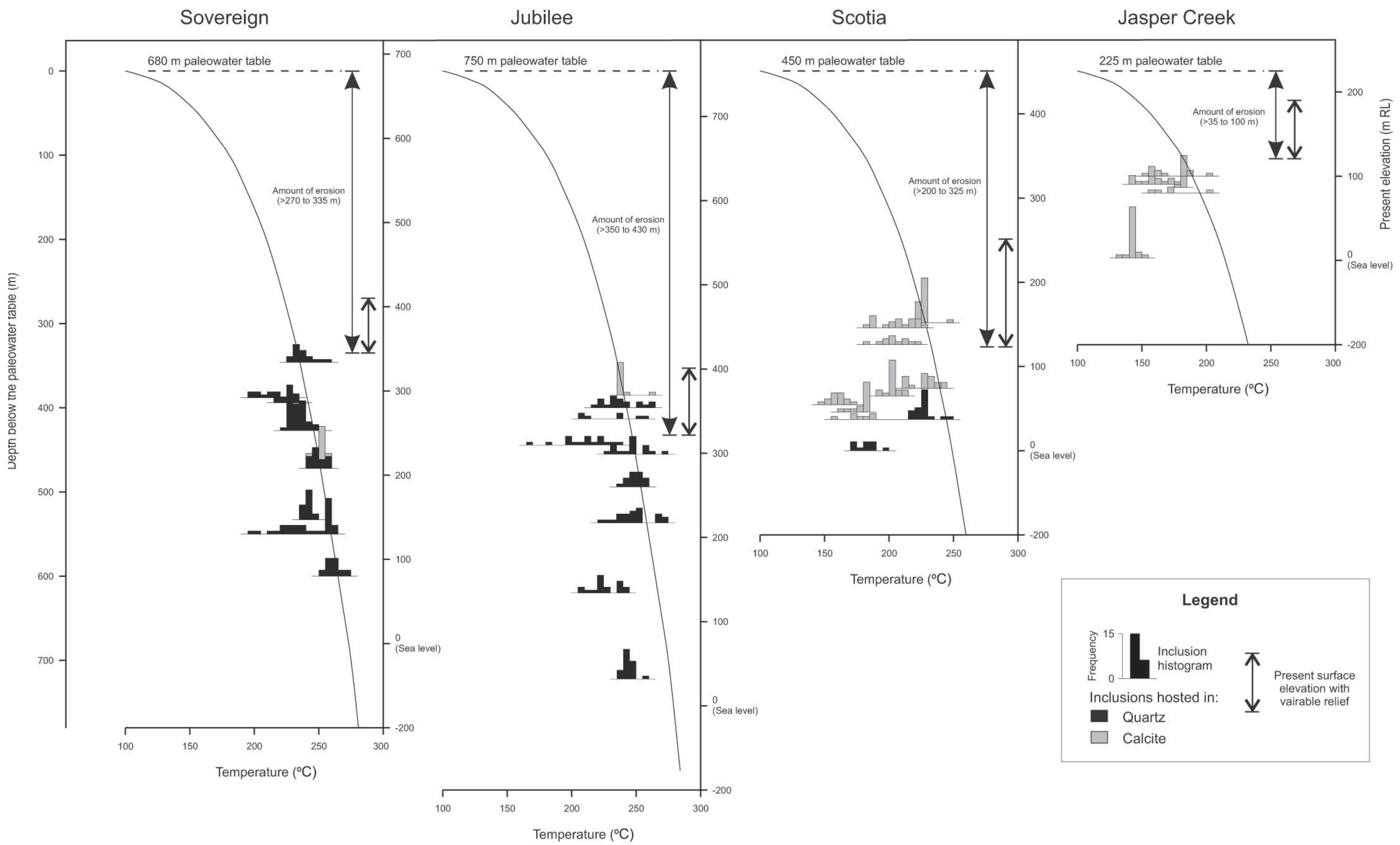

Fig. 4. Calculated paleowater table positions above the Sovereign, Jubilee, Scotia and Jasper Creek prospects. The boiling point for depth curve at Sovereign is constrained by fluid inclusions trapped under boiling condition. By contrast, the boiling point for depth curve for the Jubilee, Scotia and Jasper Creek prospects are positioned to encompass hotter Th values (excluding obvious outliers) and assumes that these inclusions were trapped under near boiling conditions.

Permeability of wall rocks

In general, wall rocks at Sovereign and Jubilee are intensely altered, whereas those on the eastern margin of Scotia and some at Jasper Creek show a mixture of intense to weak alteration. Widespread hydrothermal adularia at Sovereign, Jasper Creek and the shallow levels of Scotia is interpreted to reflect areas of high permeability and significant diffusive fluid flow based on this mineral's occurrence in geothermal systems (Browne and Ellis, 1970). Coexisting hydrothermal adularia and albite also reflect high permeability, although this association is uncommon. By contrast, hydrothermal albite that underlies adularia and occurs on the less altered eastern margin of Scotia represents an area of lower permeability (Browne and Ellis, 1970).

Temperature of vein formation and alteration

The formation temperature of alteration and vein minerals can be deduced from temperature sensitive minerals (clays, zeolites and calc-silicates) and fluid inclusions. In geothermal fields, illite, interstratified illite-smectite and smectite generally form at temperatures of >220°, 220° to 150° and less than 150°C, respectively (Steiner 1977; Reyes 1990). Both epidote and prehnite form at >240°, whereas laumontite, clinoptilolite, mordenite all typically formed at <220° to 120°, 200° to 110° and <200° to 55°, respectively (Steiner 1977; Reyes 1990). Accordingly, at Sovereign and Jubilee the occurrence of illite with local epidote and prehnite suggest formation temperatures >220° to >240°C; consistent with quartz fluid inclusion Th values that average 241°C for Sovereign and 239°C for Jubilee (Fig. 3). At Scotia, illite grades eastward into interstratified illite-smectite that encloses laumontite veins suggesting a temperature gradient of >220ºC in the west that cools to <220º to 150ºC to the west. This parallels eastward cooling calcite Th results that range from 146º to 247ºC (Fig. 3). Lastly, the predominance of smectite at Jasper Creek together with local mordenite and clinoptilolite indicate formation temperatures of less than 150º to 200ºC overlapping with the calcite Th range of 132º to 204º that averages 162ºC. Overall mineralogic and fluid inclusion temperatures are in excellent agreement and suggest both Sovereign and Jubilee generally formed at ~240ºC, Scotia between ~220º to 150ºC and cooling to the east, with Jasper Creek formed at ~170ºC or less.

Composition of hydrothermal waters

The alteration mineral association of quartz, adularia, albite, chlorite, illite, interstratified illite-smectite, smectite, calcite and pyrite presumably reflect formation from a near-neutral to weakly alkaline pH chloride water (Browne and Ellis, 1970; Simmons and Browne, 2000). The presence of zeolite veinlets coupled with the occurrence of calcite veins and significant replacement calcite suggest low to intermediate concentrations of dissolved CO_2 (0.01 to 0.05 molal) comparable to that at the Waiotapu geothermal field, which has both zeolites and calcite (Hedenquist and Browne, 1989). The zeolites (mordenite, laumontite and wairakite) and calcite at Waiotapu are usually mutually exclusive, expect in open spaces where they alternate in bands. Alternating zeolites and calcite at Scotia and Jasper Creek likely formed due to fluctuating CO_2 levels that varied as a function of boiling. Boiling results in the deposition of platy calcite near the point of boiling, partitioning of CO_2 into the steam phase and a more alkaline chloride water with significantly lower CO_2 content that would favour zeolite formation (Simmons and Christenson, 1994). Since zeolites and calcites alternate this suggests that the boiling front fluctuated in elevation causing variable CO_2 concentrations that at times favoured zeolite formation and at others calcite deposition. Uncommon hematite alteration and rare veins towards the eastern margin of Scotia and at Jasper Creek suggest changes in the redox state of the alkali chloride waters which shifted from reduced pyrite stability field to the more oxidised hematite field and could have resulted from the mixing of these waters with oxygenated groundwaters. Late-stage massive monomineralic calcite veins together with replacement calcite and overprinting smectite most likely formed from localized descending steam-heated CO_2-rich waters that originate by the condensation of CO_2 into marginal ground water (Hedenquist and Stewart, 1985; Simmons and Christenson, 1994).

Formation depth below the paleowater table

The formation depth of veins below the paleowater table can be estimated from the trapping temperature and salinity of fluid inclusions that show evidence for boiling in the form of coexisting liquid- and vapour-rich inclusions (Roedder, 1984). Coexisting inclusions are seen in both quartz and calcite veins from Sovereign, and based on an average trapping temperature (T_T) of 253ºC and dilute salinity (<1 wt. % NaCl equiv.) the paleowater table occurred at 690 m relative to sea level (asl) (Fig. 4). Coexisting inclusions are also seen in a quartz vein located between the Jubilee and Scotia prospects and based on an average T_T of 227ºC indicate the paleowater table occurred at 690 m asl. The position of the paleowater table for the Jubilee, Scotia and Jasper Creek prospects can be calculated based on the hottest Th values for secondary inclusions, but assumes that they were trapped under boiling conditions. Accordingly, the paleowater table above the Jubilee, Scotia and Jasper Creek occurred at a minimum of 750, 450 and 225 m asl, corresponding to 350-430, 200-325 and 35-105 m of erosion, respectively (Fig. 4). However, because these calculations are based on secondary inclusions that were trapped at some time after vein formation these data need to be treated with caution. If the area was tectonically active during vein formation, secondary fluid inclusion temperatures may vary significantly from the original temperature during which the vein formed. Nonetheless, the available data suggest that the paleowater table existed at different elevations at each of the different prospects and is most elevated at Sovereign and Jubilee, at intermediate levels at Scotia and is shallowest at Jasper Creek.

Comparison with other deposits in the Waitekauri Valley

The Sovereign, Jubilee, Scotia and Jasper Creek prospects occur within a corridor of epithermal deposits that include Maratoto, Golden Cross, Komata, Owharoa, and Karangahake (Fig. 1). These deposits all occur within a single 34 km^2 area of hydrothermal alteration (Morrell et al., 2003). Argon-argon dates of vein and wall rock adularia from Golden Cross (6.9 Ma), Sovereign (6.8 to 6.5 Ma), Maratoto (~6.4 Ma), Komata (~6.0 Ma), and Karanagahake (6.6 to 5.6 Ma) indicate that some formed at different times, although some overlap (Mauk and Hall, 2004; Ward et al., 2005). Alteration at the prospects documented here are broadly similar with the major exception of zeolites, which are not found at Maratoto, Komata or Golden Cross. Massive calcite veins, extensive calcite alteration and lack of zeolites at Maratoto, Komata and Golden Cross (Main, 1979; Wayper, 1988, Simpson et al 2001) suggest relatively high concentrations of dissolved CO_2 that are comparable to high CO_2 (0.5 molal) geothermal fields in the Taupo Volcanic Zone that include Broadlands-Ohaaki and Rotokawa (Henley and Hedenquist, 1986). By contrast, the occurrence of zeolites with calcite at the Sovereign, Jubilee, Scotia and Jasper Creek prospects suggest lower dissolved CO_2 concentrations comparable to the Waiotapu intermediate CO_2 (0.05 molal) geothermal field (Hedenquist and Browne, 1989); Wairakei and Orakeikorako have low CO_2 (0.01 molal), common zeolites and lack calcite (Henley and Hedenquist, 1986).

The Sovereign, Jubilee, Scotia and Jasper Creek hydrothermal system(s)

The overall relationships between the Sovereign, Jubilee, Scotia and Jasper Creek prospects during and post mineral hydrothermal activity is difficult to constrain based on the current dataset. One of the biggest questions is that of temporal relations of each prospect. Because of this uncertainty there are three possible ways to explain why Sovereign and Jubilee are deep and hot, whereas Jasper Creek is cool, shallow and marginal. 1) Some or all of the prospects may represent separate independent geothermal fields. 2) All four formed in a single high-relief geothermal system on the flanks of a volcano with an inclined water table and cooler outflow. 3) Alternatively, all four formed in a low-relief geothermal field that was subsequently tilted or block faulted with the greatest uplift and erosion to the west.

Conclusions

Widespread intense hydrothermal alteration and veins at the Sovereign, Jubilee, Scotia and Jasper Creek prospects are typical of those seen in adularia-sericite epithermal deposits. Alteration minerals and fluid inclusion temperatures indicate that Sovereign and Jubilee are deep and hot, whereas Jasper Creek is shallow, cool and marginal. The complex relationships among calcite, zeolites and epidote suggest fluctuating low to intermediate CO_2 concentrations that vary as a function of boiling depth. Hematite alteration on the eastern margin of Scotia and hematite alteration and veins at Jasper Creek suggest mixing between alkali chloride waters and oxygenated groundwater. This mixing may have suppressed quartz deposition via dilution and could explain the general lack of quartz veins at both Scotia and Jasper Creek.

Acknowledgements

We thank Newmont Waihi Operations for providing access to the Waitekauri Valley prospects and permission to publish. We thank Rohan Worland, Ross McConnochie, Lorranace Torckler and Brain Arkell for geologic maps and for insightful discussions. This research has been funded by Newmont Waihi Operations and the New Zealand Foundation for Research Science and Technology (FRST).

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