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THE KARANGAHAKE FOSSIL GEOTHERMAL FIELD: *AN EPITHERMAL GOLD-SILVER MINERALISED SYSTEM*

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ABSTRACT

A subsurface investigation of the Maria Lode and associated hydrothermal alteration of andesites facilitated reconstruction of the local evolutionary sequence in the once active Karangahake geothermal field.

The evolutionary sequence involved two main phases of activity: Phase A (dominant) - initial development of the Maria fissure by a progressive fault related hydrofracturing mechanism forming a breccia complex comprised of hydrothermally altered and hydrofractured andesite in a quartz matrix. Contemporaneous with this development was almost all the hydrothermal alteration of the host andesites forming three lateral zones around the Lode. The mineralogy in these zones was directly related to their distance from the Lode because with decreasing distance the increasing fluid/andesite ratio permitted greater attainment of equilibrium of the fluids with the thermodynamically stable secondary mineralogy (decreased buffering by andesite). The progressive mixing at ≈250°C of initial alkali-chloride fluids with the basal zone of the near surface acid-sulphate fluids during Phase A caused a change in fluid composition resulting in deposition of gold and silver (as electrum) within the quartz matrix of the breccia complex. Phase B (waning) - silicification and self-sealing of the near surface during Phase A culminated in a hydrothermal eruption and onset of local waning. Throughout Phase B there was minimal fluid/andesite interaction, fluids remained at ≈250°C but *of* slightly different mixed composition than that at the end of Phase A. The hydrothermal eruption ejected Phase A breccia complex material forming a lensoid conduit in the Maria Lode up which there were fast flowing fluids. These fluids deposited hematitic potassium aluminosilicates on the walls of the conduit until the flow rate dropped due to re-silicification and re-selfsealing in the near surface. This was followed by a second hydrothermal eruption which caused an implosion in the conduit brecciating and milling the hematitic potassium aluminosilicates. A fine immature lensoid shaped breccia was formed containing a small irregular conduit up which there were fast-flowing fluids (last locally) depositing pyritic potassium aluminosilicates until the fluid flow in the Maria Lode ceased altogether due to total silicification with temperatures beginning to fall.

The Karangahake geothermal field later became extinct, eroded down 150-200 m near the summit of Mt Karangahake and mined as a gold-silver deposit.

While much data from New Zealand active geothermal fields can be applied to the Karangahake fossil geothermal field the greater accessibility of the latter permits further investigation of some features.

INTRODUCTION

The Karangahake fossil geothermal field is located in the Hauraki Goldfield on the Coromandel Peninsula of New Zealand (Fig 1).

The field began activity in the Pliocene at the earliest and deposited epithermal gold-silver type mineralisation (Barker and Merchant, 1984; Christie, 1984; The field is now extinct, eroded down 150-200 m near the summit of Mt Karanqahake and mined as a gold-silver deposit. The mine produced 125 million grams of gold-silver bullion between 1375 and the 1930's, and was the first [illegible] the world to use the cyanide process commercially parallel steeply dipping lodes striking between north and northeast which dissect hydrothermally altered host rocks composed of Miocene Coromandel group andesites overlain by Plio-Pleistocene Whitianga group rhyolites (Christie, 1982; Henderson and Bartrum, 1913; Williams, 1974).

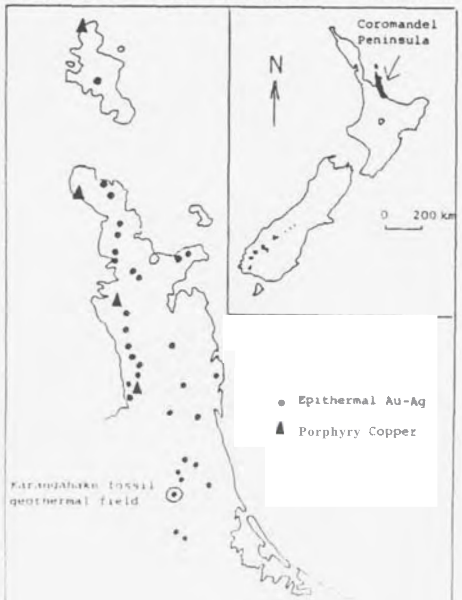
A subsurface investigation was carried out in the Talisman mine on a portion which when the field was active was ≈500 m below the surface and at ≈250°C. It includes some of the Maria Lode and hydrothermally altered homogeneous andesites which it dissects (Fig 2).

The following is the local evolutionary sequence based on the subsurface investigation.

EVOLUTION OF THE LOCAL GEOTHERMAL FIELD

The initial development of the Maria fissure in the andesites was by a progressive fault related hydrofracturing mechanism (Grindley and Browne, 1976: Phillips, 1972) (possibly related to rhyolitic volcanism) which produced the Phase A breccia complex (Fig 2). This comprised of quartz invaded fractures in the hydrothermally altered andesitic wallrock of the hanging wall and detached hydrofractured wallrock blocks in a quartz matrix. These hydrofractured blocks were smaller towards the footwall where the proportion of quartz matrix increased. Most of the fluids flowed close to the footwall and the quartz deposited there became banded due *to* selective rejection of the finest andesitic fragments from the breccia (which were suspended in solution during the crystallisation). Occasional bladed calcite was deposited with the quartz due to boiling episodes (Browne, 1978).

Contemporaneous with the development of the Phase A breccia complex was almost all the hydrothermal alteration *of* the host andesites. The hydrothermal alteration mineralogy and thus rock chemistry, being directly related to distance from the Maria lade (Fig 3). The most distal zone 1 hydrothermal alteration mineralogy was controlled by the local mineral-fluid equilibria being highly buffered by the andesite (this zone had a



low fluid/andesite ratio). The intermediate zone 2 hydrothermal alteration mineralogy was controlled by local mineral-fluid equilibria (this zone had an average fluid/andesite ratio). Zone 3 hydrothermal alteration mineralogy (closest to the Maria Lode) was dominantly controlled by fluid pH (this zone had a high fluid/andesite ratio) (Browne and Ellis, 1970). The reason why the hydrothermal alteration mineralogy and thus rock chemistry were directly related to distance from the Maria Lode was that the physicochemical conditions which controlled them were a direct result of the increasing fluid/andesite ratio with decreasing distance from the Lode. The physicochemical conditions therefore caused increasing degrees of attainment of equilibrium of the fluids with the thermodynamically stable secondary mineralogy (Giggenbach, 1981) towards the Maria Lode.

The formation of the Phase A breccia complex in the Maria Lode and almost all of the hydrothermal alteration took place at approximately 250°C. Initially the fluids were alkali-chloride (pH ≈ 7), relatively unoxidised, undiluted and relatively low in CO_2 and H_2S. This fluid composition was located on the coexistence lines between illite-A-feldspar and chlorite-pyrite (position 1 on Figs 4 and 5). With increasing time these fluids mixed with the basal zone of the nearer surface fluids which were acid-sulphate, low pH, oxidised, dilute and rich in CO_2 and H_2S due to condensation of steam. (H_2S would only be partly oxidised in basal zone because of limited atmospheric exposure.)

The mixing of these acid-sulphate fluids with the initial alkali-chloride fluids (Barnes, 1979; Ellis and

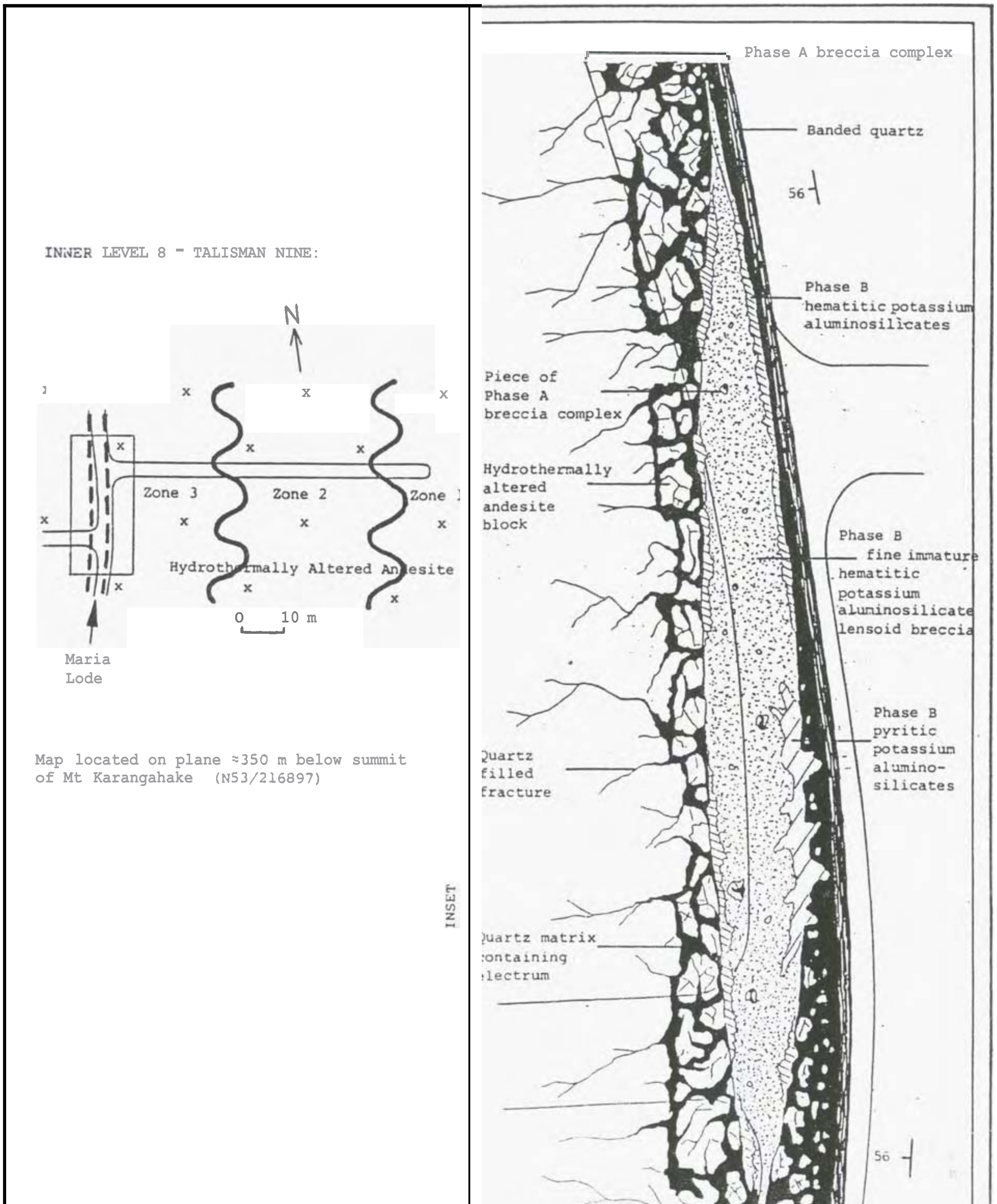


Fig 2 Maria Lode and associated hydrothermally

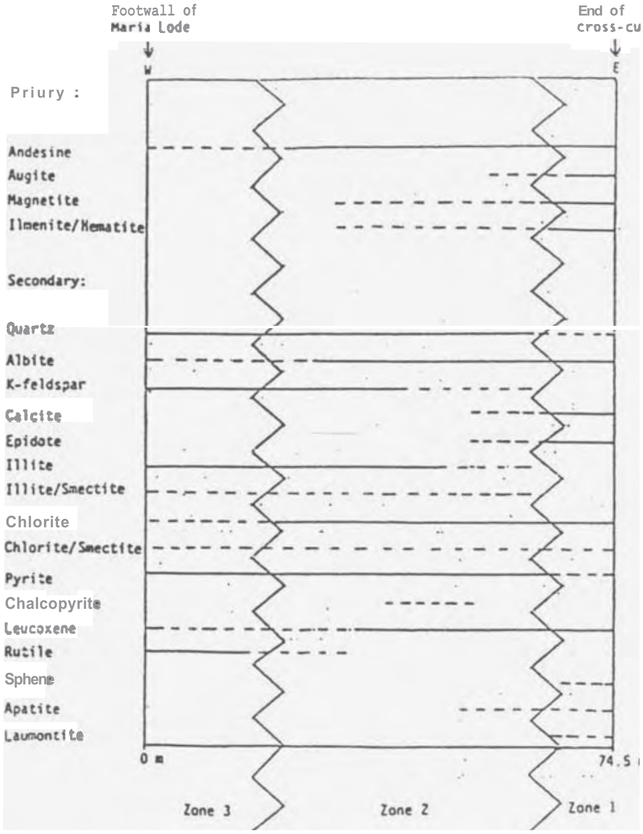


Fig 3 Hydrothermal alteration mineralogy

Mahon, 1977; Hedenquist, 1983) was very slow and progressive and did not cause any significant temperature drop. The initial fluid changed towards a composition (position 2 on Figs 4 and 5) which was neutral ($pH \approx 5.6$), sulphate dominant, relatively oxidised and diluted and richer in CO_2 and H_2S and which moved from the respective coexistance lines into the illite and pyrite stability fields. The main record of the change in fluid composition in the andesites was an overprinting by illite and pyrite in zone 3.

Assuming gold and silver occurred as $Au(HS)_2^-$ and $AgCl_2^-$ respectively because they were the most soluble complexes over the pH range (5.6 - 7) in question (Seward, 1973, 1976, 1982; Hedenquist, 1983) then the gold-silver mineralisation (electrum) in the quartz matrix of the Phase A breccia complex could be considered as being the product of co-precipitation of Au and Ag. The original fluid (1) may have deposited gold due to the decrease in pH (therefore decrease in $Au(HS)_2^-$ solubility) and the decrease in activity of reduced sulphur in the liquid caused by oxidation, dilution and the increase in precipitation of pyrite in the zone 3 wall-rock (Figs 4 and 5). At the s—— tine the original fluid (1) may have deposited silver due to the dilution of chloride (therefore decreasing in-Ag Cl_2^- solubility) dominating over increase in $AgCl_2$ solubility due to pH decrease (Fig 4).
The kinetics of the relative $Au(HS)_2^-$ and $AgCl_2^-$ solubility decreases may have effected the electrum composition.

The fact that during Phase A activity the electrum occurred in the .quartz of the Phase A breccia complex, was probably due to that location having the highest permeability, thus highest fluid content, therefore the processes causing the deposition would have had the most

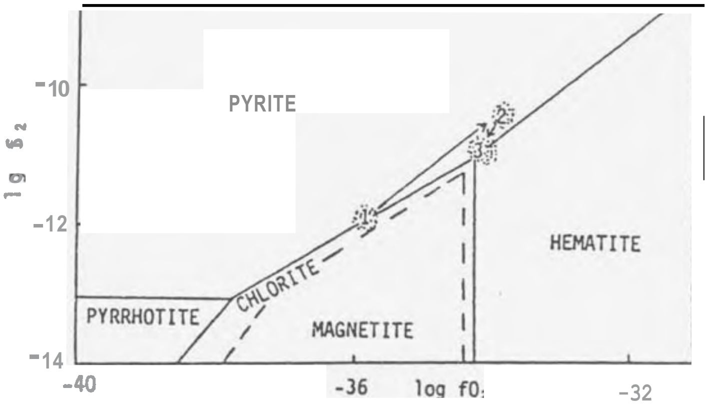
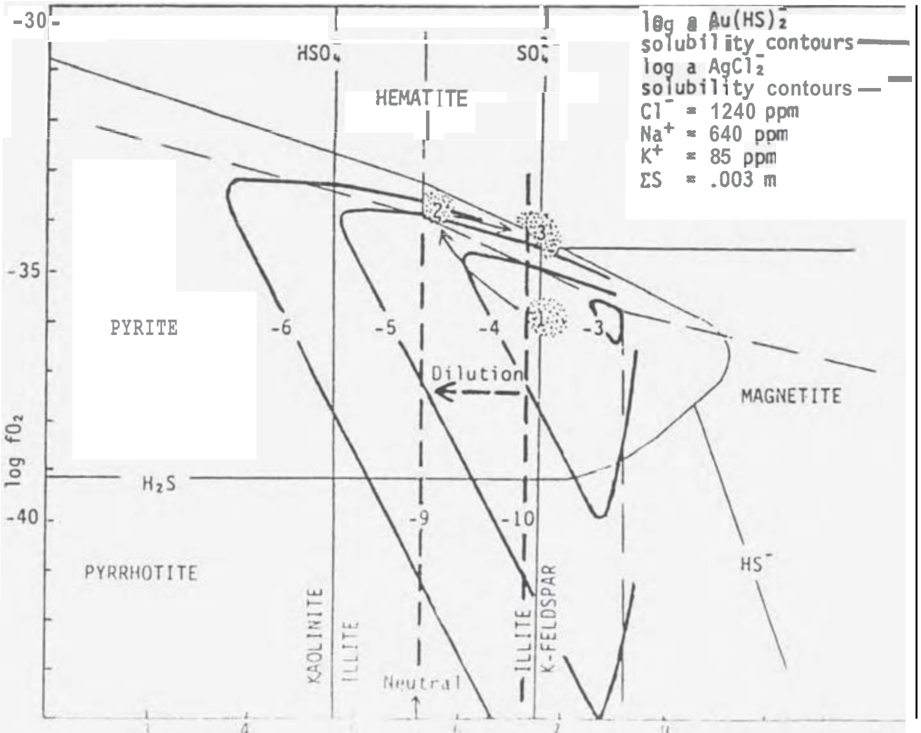


Fig 5 $fS_2 - fO_2$ diagram at 250°C (from Barton et al, 1977)



effect and also that these processes became more effective towards the later stages of Phase A activity by which time many of the other minor fissures had been silicified.

There was an abrupt change to Phase B activity signifying the onset of waning of the local field and beyond which time no significant hydrothermal alteration of the surrounding andesites took place. The abrupt change was caused by a very large hydrothermal eruption in the near surface (Fig 6) due to gradual silicification, self-sealing and consequent pressure build up in the near surface during the preceeding Phase A activity (Fournier, 1983). During the period of pressure build up, the Maria Lode became gradually "sealed Off" from the andesites so no further significant fluid interactions took place between the two after about the time of the hydrothermal eruption. The consequence of such an eruption in the near surface was the ejection of Phase A breccia complex material forming a lensoid conduit confined to the Maria Lode up which there were fast flowing fluids (Figs 2 and 6). The eruption drew up large quantities of deep alkali-chloride fluids as well as drawing down and subsequently mixing with some acid-sulphate fluids. The resulting fluid composition thus changed from (2) to (3) (Figs 4 and 5). The quantities of near surface fluids drawn down and through the system were insufficient to cause the temperature to fall below 250°C.

The change in fluid composition from (2) to (3) may not have deposited electrum due to factors such as pH and chloride increase, kinetic effects and sealing off of the fluids from the andesite.

Fluid (3) was located at the intersection of the pyrite/hematite and illite/K-feldspar coexistance lines (Figs 4 and 5). The high flow rate of fluid (3) caused deposition of gel-like hematite banded potassium aluminosilicates on the walls of the conduit (Fig 2). These lined the lensoid conduit probably to a maximum thickness of less than .5 m leaving a cavity in the centre occupied by the fluids. When the flow rate eventually dropped continuously the potassium aluminosilicates recrystallised into a quartz + illite or K-feldspar (depending on pH) + rutile mosaic which overprinted the complex hematite banding. The decreased flow rate reflected the effects of rapid re-silicification and re-self-sealing in the near surface caused by the large volumes of fluids expelled after the large hydrothermal eruption.

Pressure gradually built up in the near surface again until another hydrothermal eruption occurred (Fig 6), the effect of which on the cavity inside the lensoid conduit was a violent implosion with high fluid turbulence brecciating and milling the wallrock of the lensoid conduit which was dominantly potassium aluminosilicates. The brecciation and milling progressed laterally until the relatively hard Phase A breccia complex material was reached. Thus the fine immature breccia produced approximates the shape of the oriqinal lensoid conduit and is comprised largely of the potassium aluminosilicates with minor amounts of Phase A breccia complex (Fig 2).

The escaping-depressurising fluids associated with the formation of the lensoid breccia were channelled into a small irregular conduit where they were fast flowing and deposited yel-like pyrite banded potassium aluminosilicates which filled the conduit (Fig 2) and occasionally detached and suspended within them pieces of conduit wallrock.

The fluid composition was still at position 3 (Figs 4 and 5) and at 250°C but was very slightly more alkaline and less oxidised due to the effects of the remaining deep fluids being drawn out of the local field - thus the potassium aluminosilicates had pyrite banding instead of hematite. Electrum was probably not deposited for the same reasons as in the earlier potassium aluminosilicates. The filling of the conduit marked the end of Phase B activity and the fluids dropped away causing the potassium aluminosilicates to recrystallise into a

The local geothermal field was now almost extinct and the cooler downward percolating solutions caused quartz pseudomorphing of most of the calcite in the Maria Lode. In the andesites there was minor overprinting by interlayered illite-smectite and chlorite-smectite and minor laumontite and quartz veining.

Up to the present the Karangahake geothermal field has become extinct, eroded down 150-200 m near the summit of Mt Karangahake (Fig 6) and mined for gold and silver.

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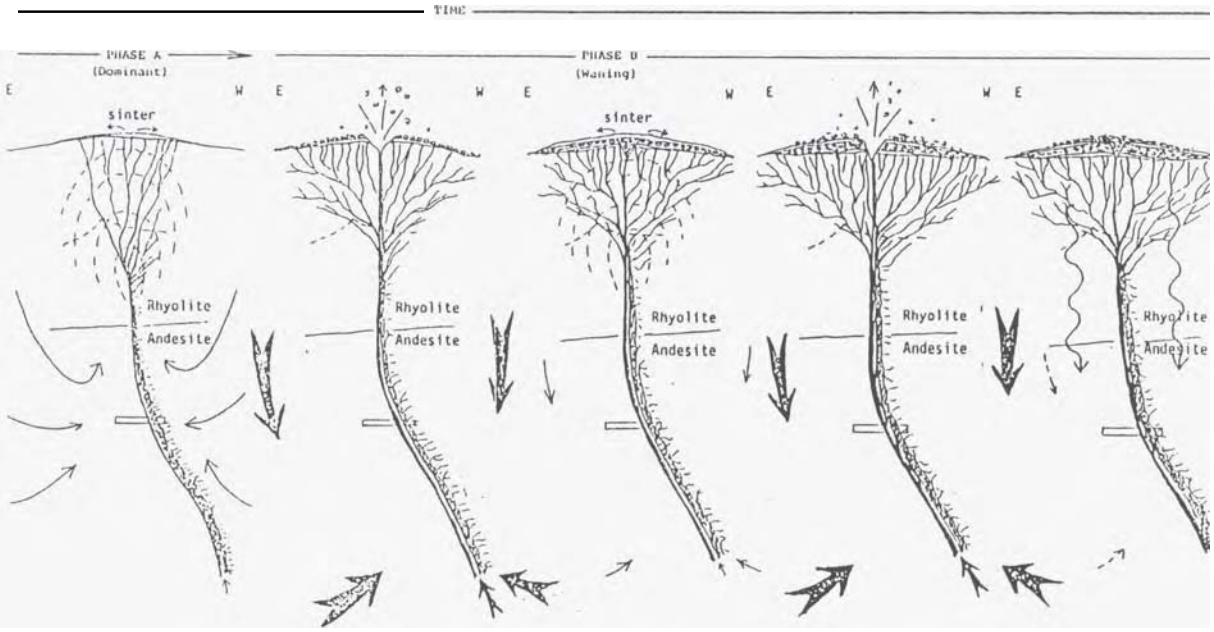

-Initial development of Maria fissure by a progressive fault related hydrofracturing mechanism forming Phase A breccia complex.
-Most of hydrothermal alteration in andesites.
-Progressive mixing of deep alkali-chloride fluids with basal zone of near surface acid sulphate fluids and consequent electrum deposition in breccia complex quartz.
-Gradual sealing off of Maria Lode from andesites and pressure build up in near surface due to silicification and self-sealing.

-Hydrothermal eruption in near surface ejecting Phase A breccia complex material forming a lensoid conduit in Maria Lode.
-Fast fluids flow in lensoid conduit.
-Drawing up of deep alkali-chloride fluids and drawing down of near surface acid-sulphate fluids.
-Hematitic potassium aluminosilicates deposited on walls of lensoid conduit.
-Fluid/andesite interaction is minimal.

-Re-silicification and re-self-sealing of near surface and consequent drop in fluid flow.
-Pressure again builds up in near surface.
-Hematitic potassium alumino-silicates recrystallise.

-Second hydrothermal eruption in near surface causing Implosion in lensoid conduit brecciating and milling the hematitic potassium alumino-silicates forming a fine Immature lensoid breccia.
-Drawing up of remaining deep alkali-chloride fluids and drawing down of remaining near surface acid-sulphate fluids.
-Escaping-depressurising fluids associated with breccia formation flow fast through small irregular conduit in breccia and deposit pyritic potassium aluminosilicates.

-Fluid flow in Maria Lod
stops due to total silic
cation,
-Pyritic potassium alumi
silicates recrystallise.
-Temperatures begin to f
as cold solutions percola
downwards.

Fig 6 Schematic evolution of local geothermal field