HYDROGEOLOGICAL ASPECTS OF EPITHERMAL GOLD DEPOSITS IN THE COROMANDEL PENNINSULA, NEW ZEALAND

Photo: View from the Tui Mine

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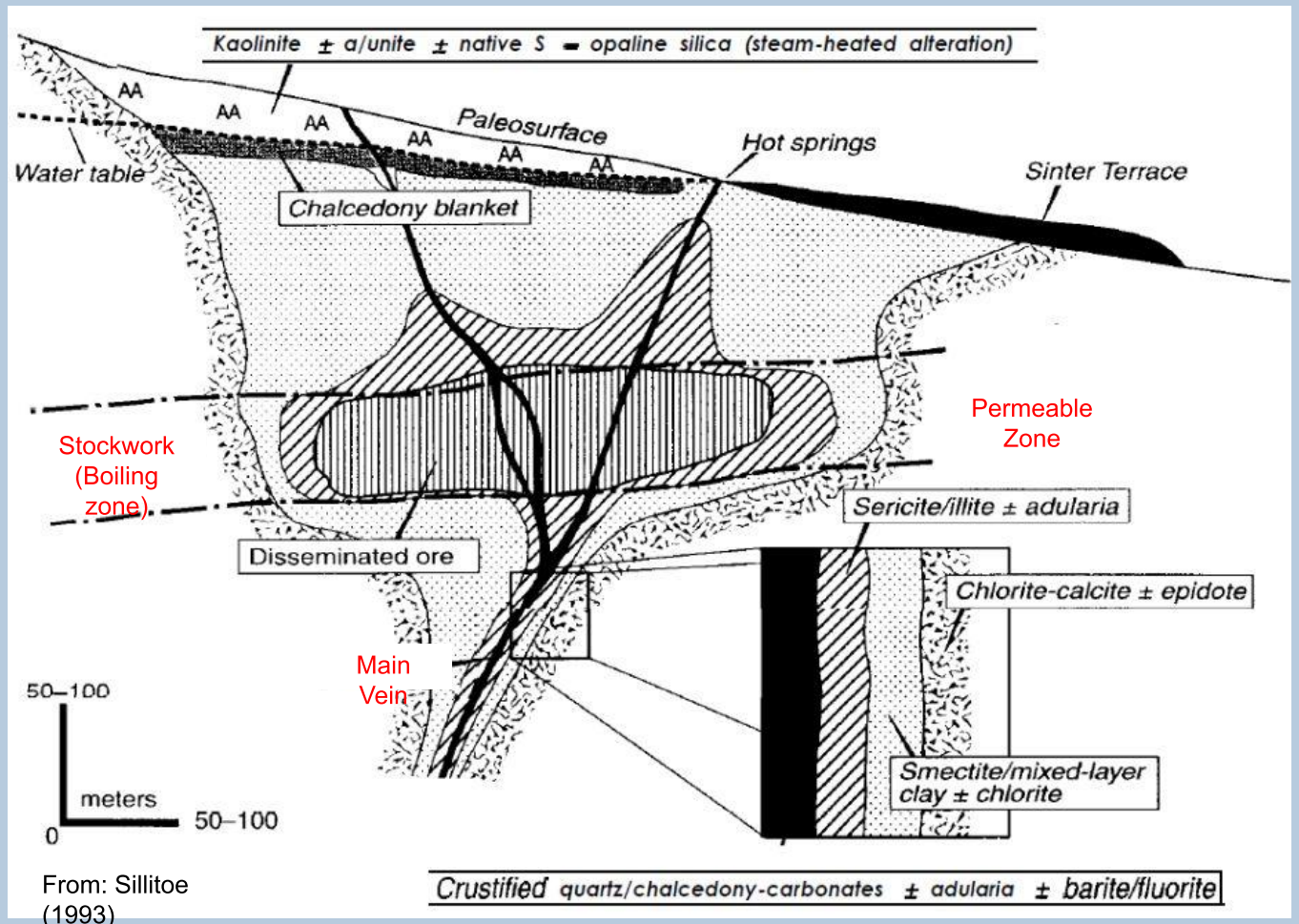
INTRODUCTION

- There is a distinct absence of information available in the public domain related to the hydrogeology in the Coromandel or of epithermal gold deposits in New Zealand.
- Over the past 30 years working as a geologist and hydrogeologist I have had the fortune to have been involved with several epithermal deposits.
- This presentation summarises some key aspects of the hydrogeology of epithermal gold deposits based on my work and observations during my career to date.
- This presentation is focused on mine dewatering and potential effects.
- There is a paper in preparation.

EPITHERMAL DEPOSITS



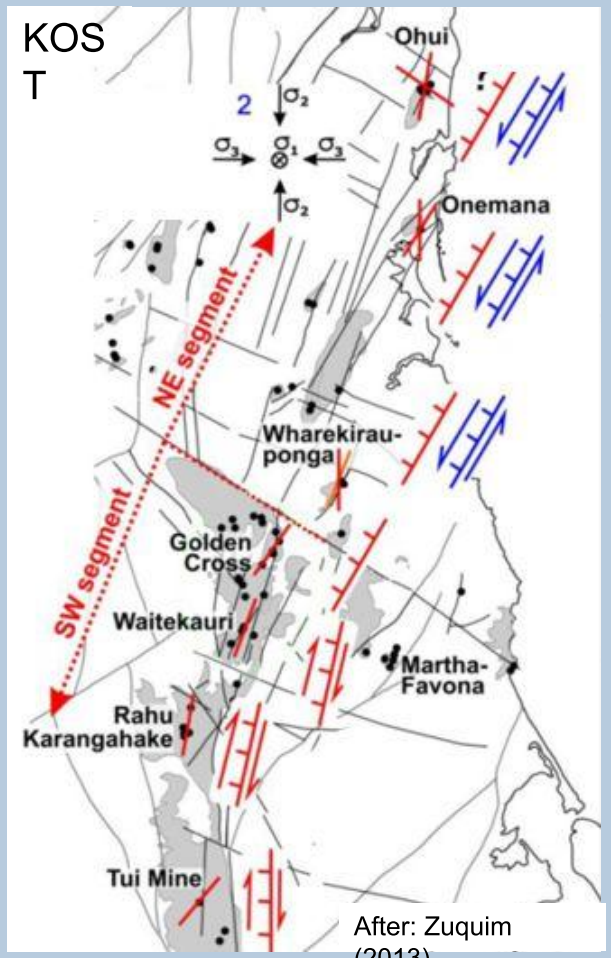
From: Sillitoe (1993)

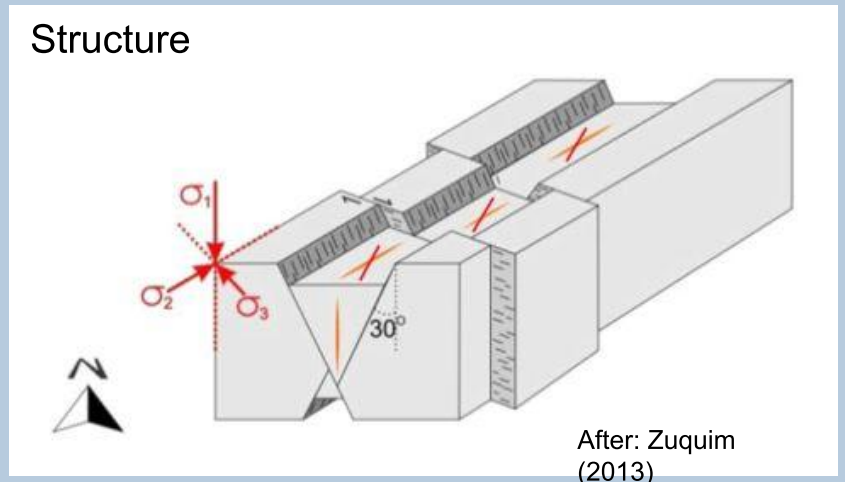
Epithermal deposits are ancient hydrothermal deposits.

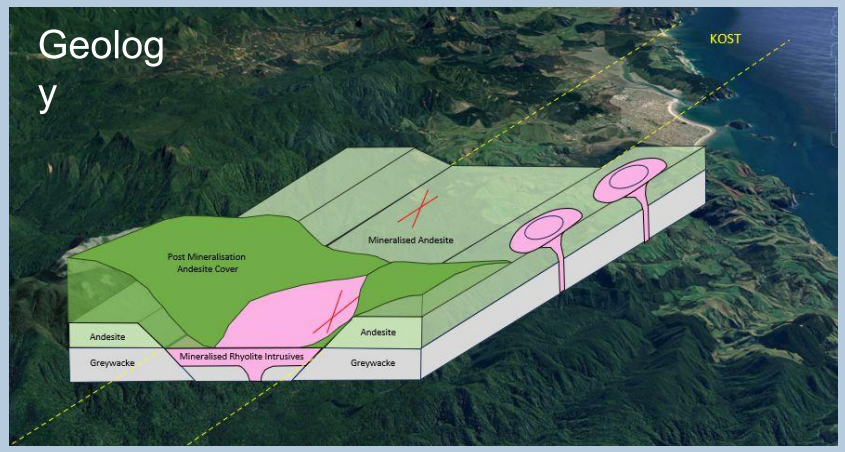
The structure is complex and vertical zonation dominates.

The primary structure and zonation affects the hydrogeological characteristics of the resultant aquifer system.

GEOLOGICAL CONSIDERATIONS







Hydrogeology

- Setting
- Structure
- Geology
- Alteration
- Weathering

GEOLOGIC IMPLICATIONS TO HYDROGEOLOGY

- **Setting** – Mineral deposits occupy dilatational structures. Determines the nature and extents of the vein system.

  Hydrogeologic domain - Size and extent of the vein system(s). Stockwork and/or main vein. e.g. caldera.

- **Structure** – Geological history and stress field. e.g. faulting and post mineralisation conjugate structures.

  Creates localised permeability and connectivity between aquifers and the near surface. Can result in high storage and groundwater inflows.

- **Geology** – The composition of the host rock and post mineralisation geologic history.

  Andesite host rocks have low and consistent permeability.

  Rhyolite host rock permeability ranges from high to low.

  Post mineralisation volcanic and alluvial deposits separates aquifers.

GEOLOGIC IMPLICATIONS TO HYDROGEOLOGY

- **Alteration** – Hydrothermal alteration changes the permeability of the host rock locally.

  Clay alteration results in lower rockmass permeability.

  Silicification results in higher rockmass permeability (from fracturing).

- **Weathering** and erosional surface.

  Erosion affects the "paleo-elevation" encountered within the hydrothermal system (above or below boiling zone).

  That affects the vein width, stockwork, and therefore permeability.

  Weathering of surface prior to post mineralisation deposits results in a low aquitard.

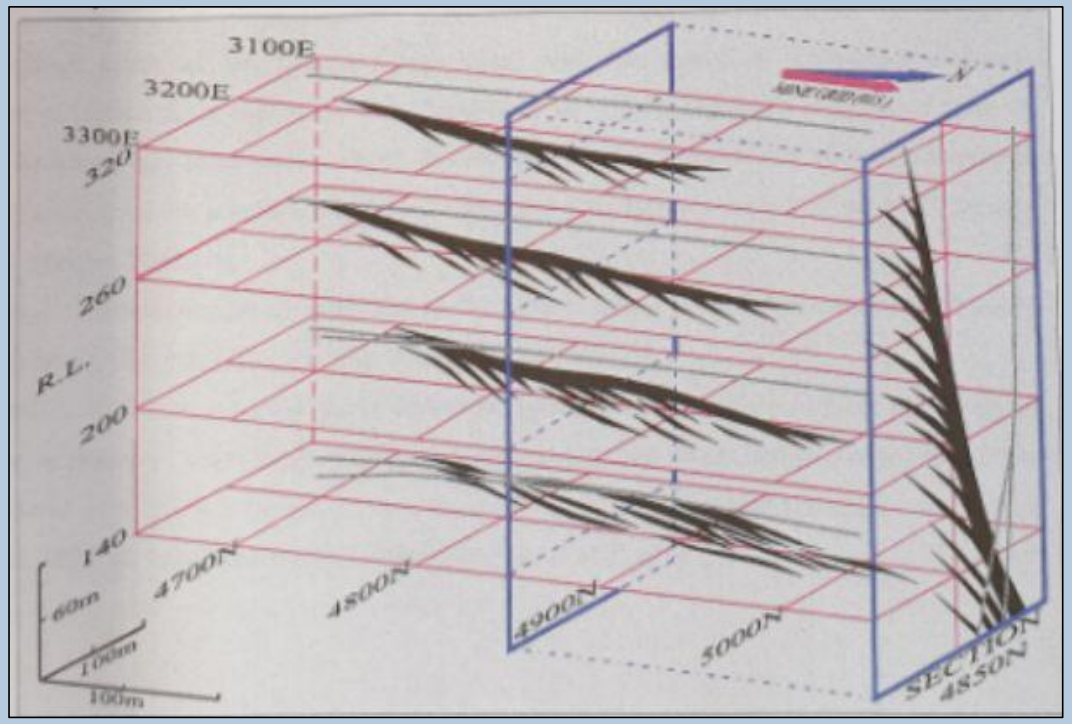
The geologic setting affects aquifer permeability, storage and heads that drive the movement of the groundwater system.

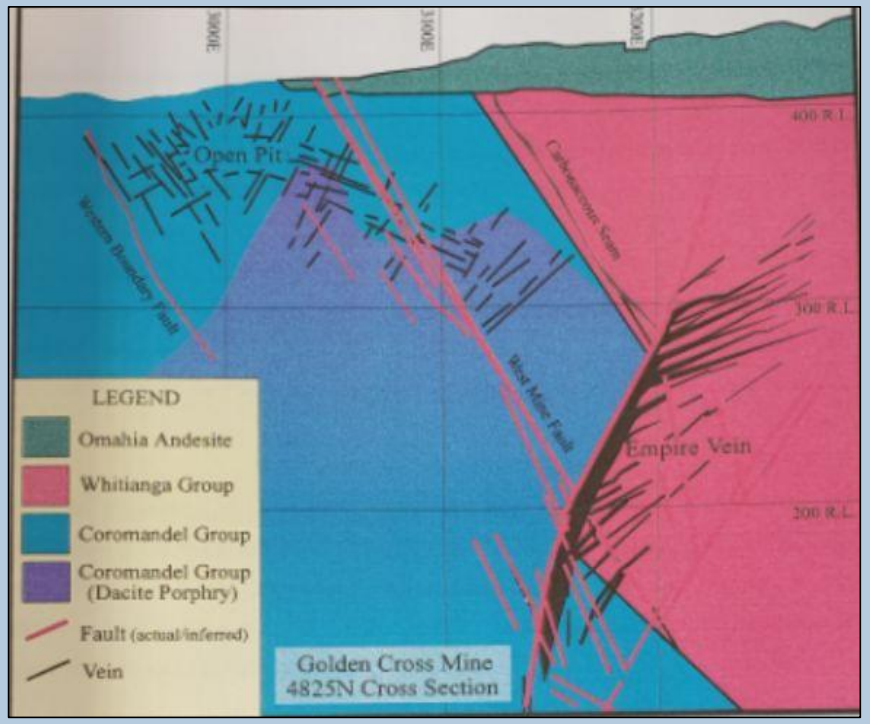
GOLDEN CROSS

- Historically mined from 1895 to 1920 for gold.
- Prospected and developed in the 1980s
- Operated from 1991 to 1998
- Closed and remediated in the early 2000’s.

GOLDEN CROSS

Geology and Structure



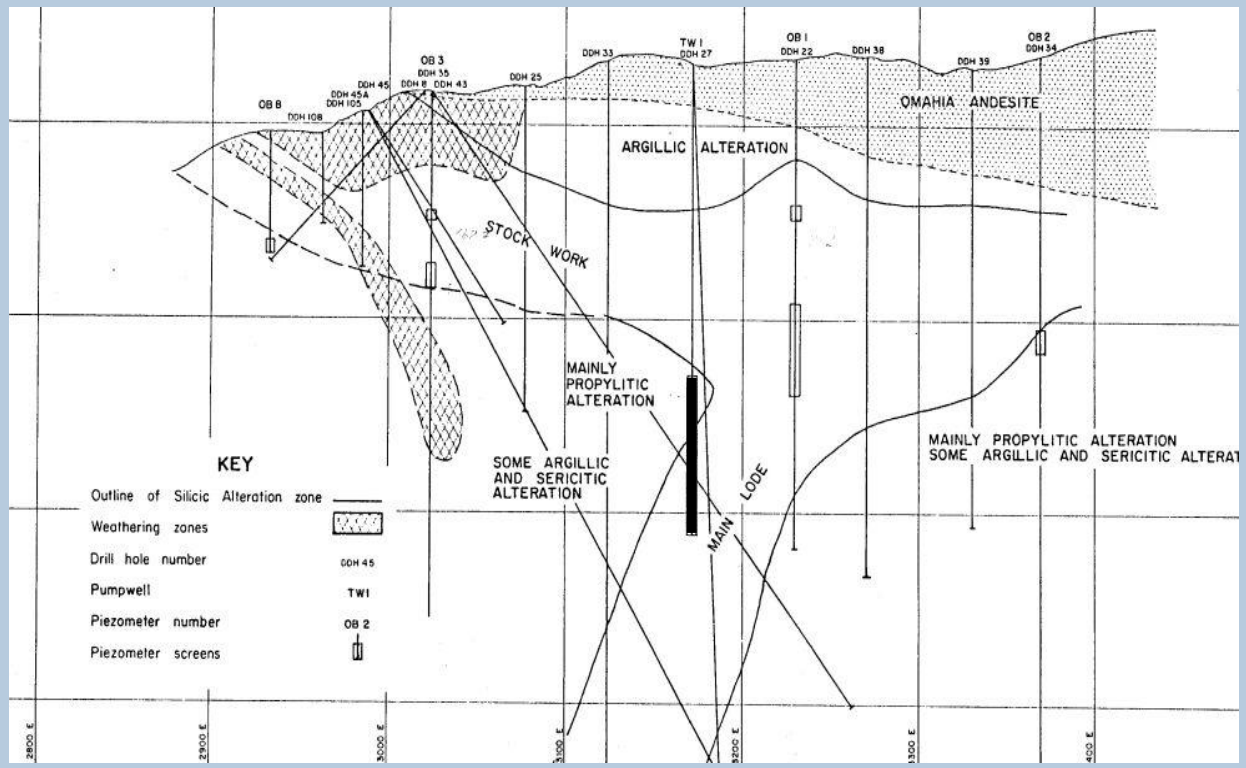


- Located near the top of a ridge.
- Andesite hosted deposit
- Approximately 550 m in

- Main vein and stockwork system
- Full system present
- Post mineralisation Andesite cover

GOLDEN CROSS

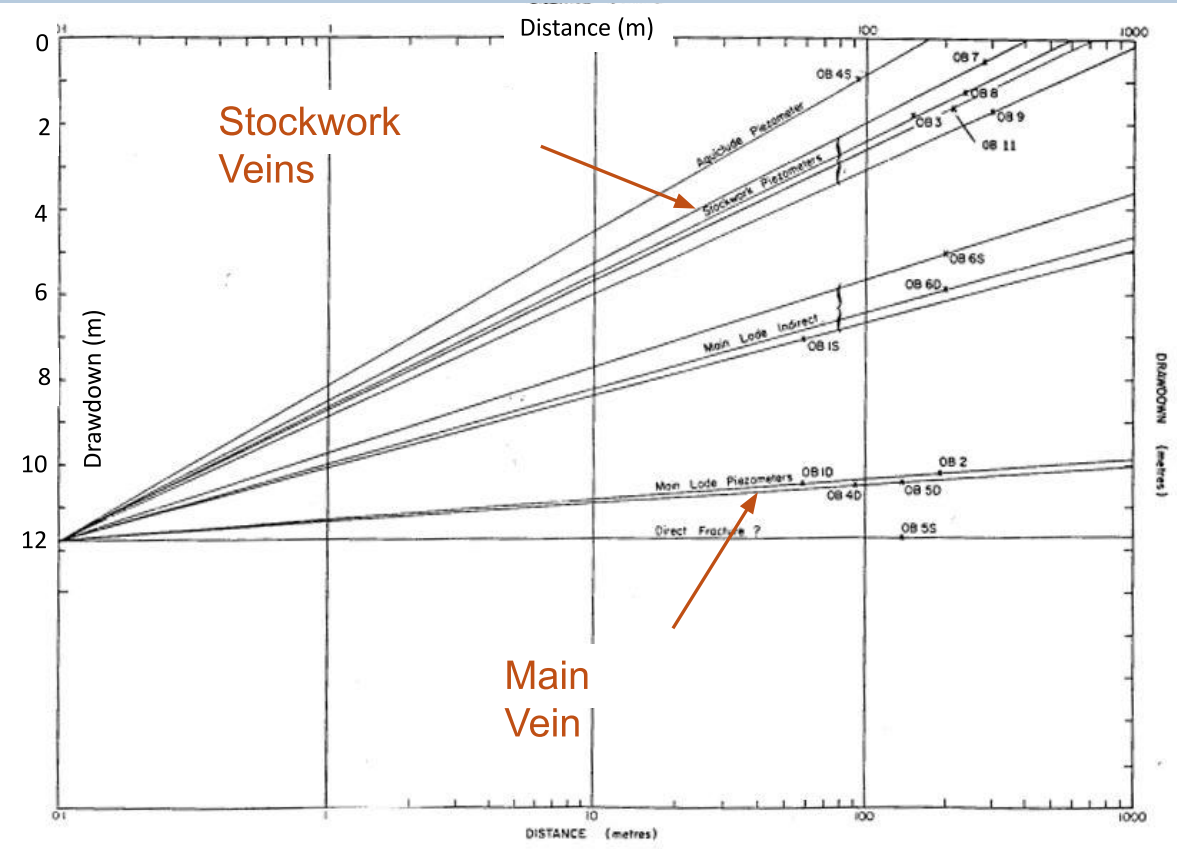
Hydrogeology



- A pumping bore was constructed in the main vein system.
- A pumping test was undertaken in May 1986.
- Pumping rates ranged from 900 to 2,000 m^3/day.
- The response to the test was observed through 18 piezometers (shallow and deep).

GOLDEN CROSS MINE

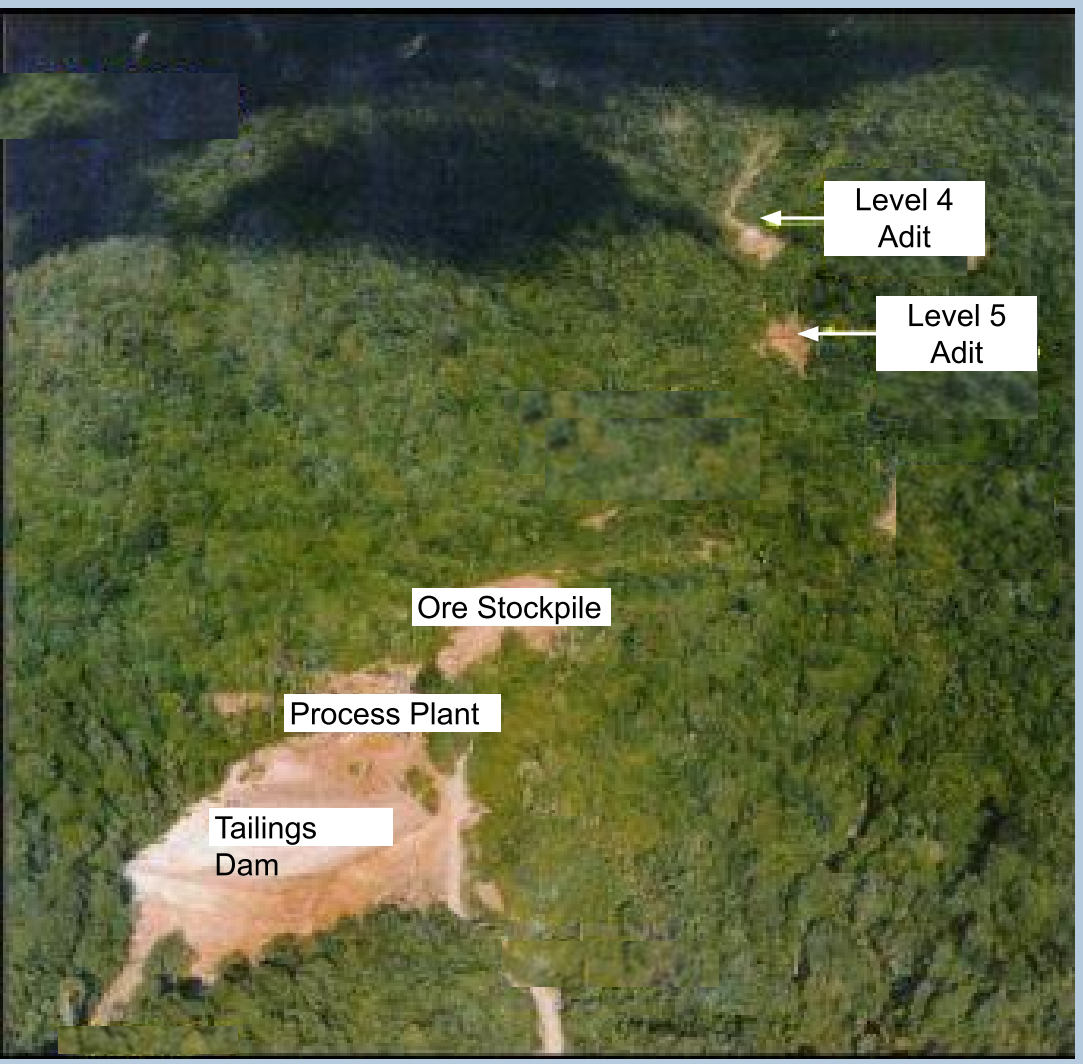
Hydrogeology



- The results showed that drawdown preferentially developed along the length of the main vein system.
- The stockwork system showed a similar but muted response to the main vein
- The drawdown then propagated perpendicular to the ore body
- The derived aquifer parameters from the test were:

  Vein Permeability = 1×10^{-5} m/s

  Host Permeability = 3×10^{-7} m/s
- The system is anisotropic with the <u>permeability along the length of the ore body being 3-12 time greater than across it.</u>

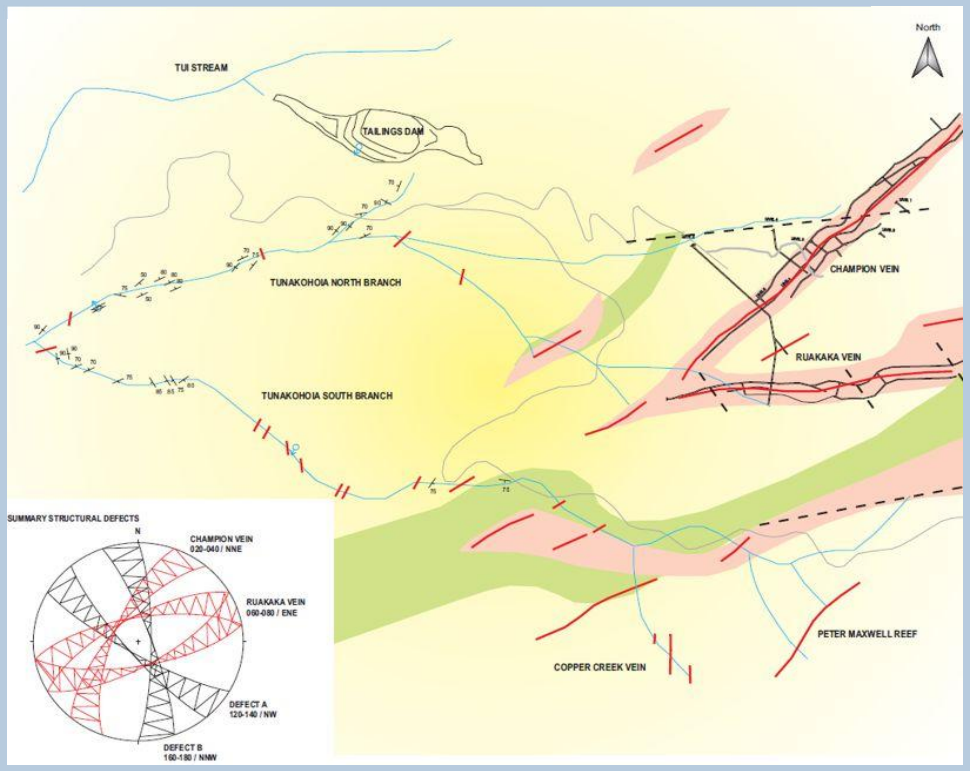


TUI MINE

- Historically mined from 1967 to 1975 for base metals (Cu, Pb, Zn).
- The owners went into liquidation and the mine was abandoned.
- The site was never formally closed and presented an environmental risk.
- Government funded investigations took place in the early 2000's.
- Mine remediation work commenced around 2010 and is complete.

TUI MINE

Geology and Structure



- Located near the top of a ridge.
- Andesite hosted deposit
- Approximately 1000 m in length

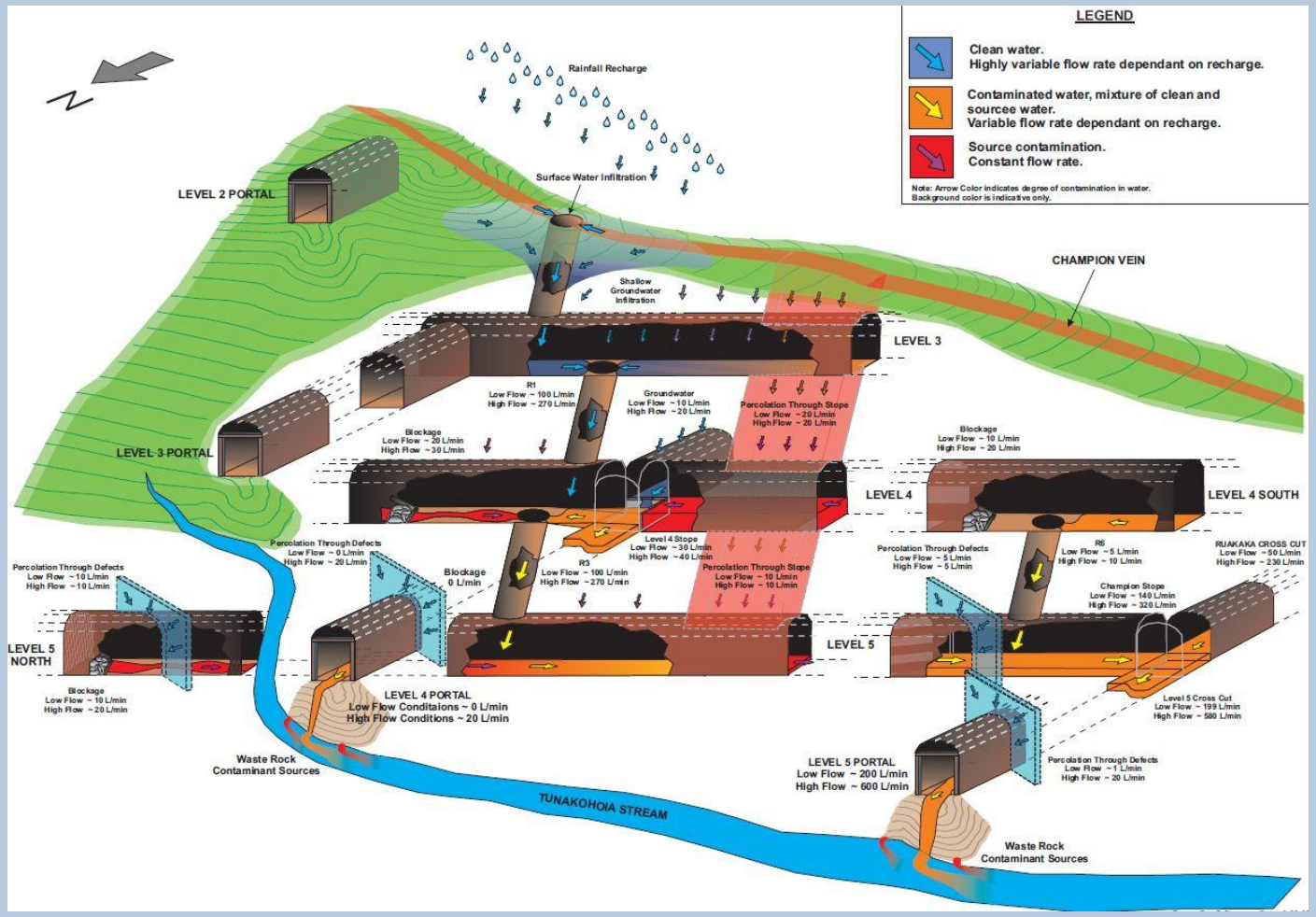
- Main veins only
- Only lower system present (base metals)
- No post mineralisation cover

TUI MINE

Hydrogeology

- As part of the works required to assess remedial options, the underground workings were investigated.
- That included determining the open extents, mapping structures, inflow measurements and water chemistry sampling.

TUI MINE



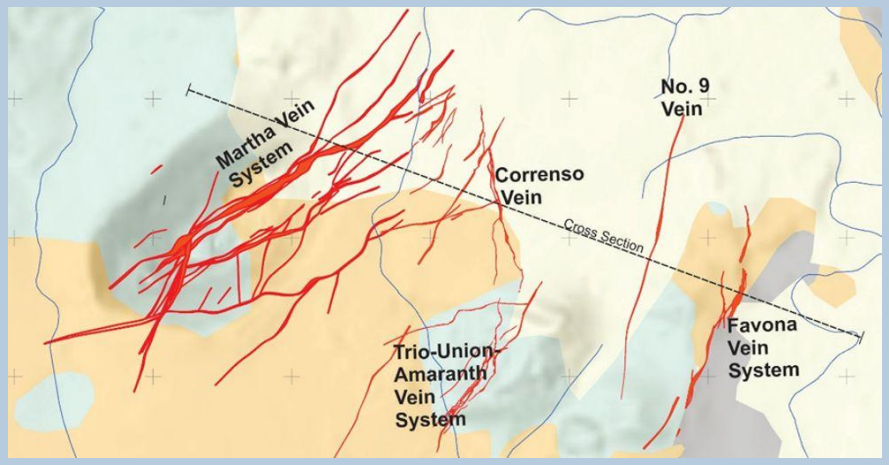
- The investigations showed that small inflows of poor-quality water occurred through the vein.
- Low inflows of clean water occurred though late phase structures.
- <u>High inflows occurred where veins were crosscut by late phase structures.</u>

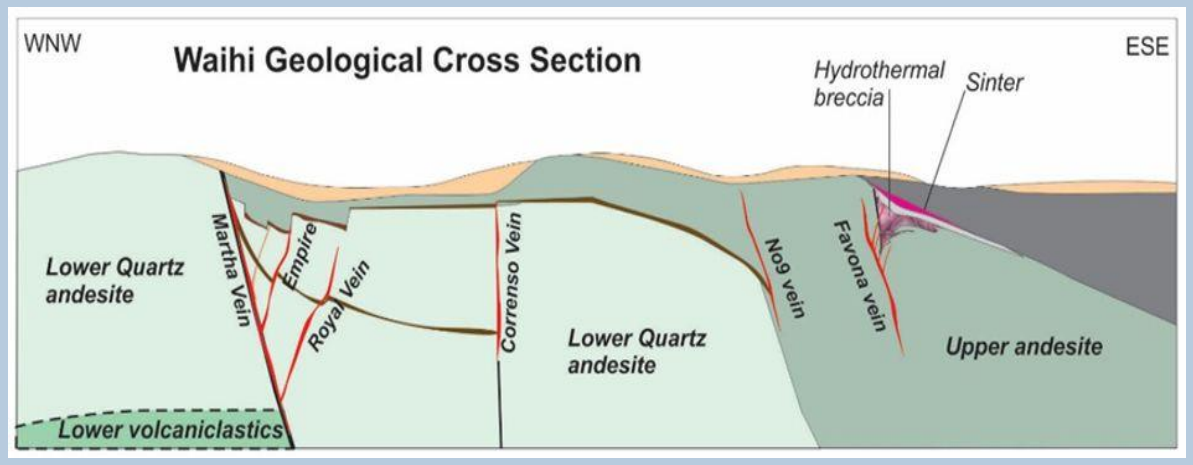
WAIHI MINES

- The Martha vein system was historically mined from 1878 to 1952 for gold.
- Mining operations ceased and the underground workings were allowed to flood.
- The mine reopened again in 1988 as open cast.
- In 2004 the operation went underground and continues to operate.

WAIHI MINES

Geology and Structure



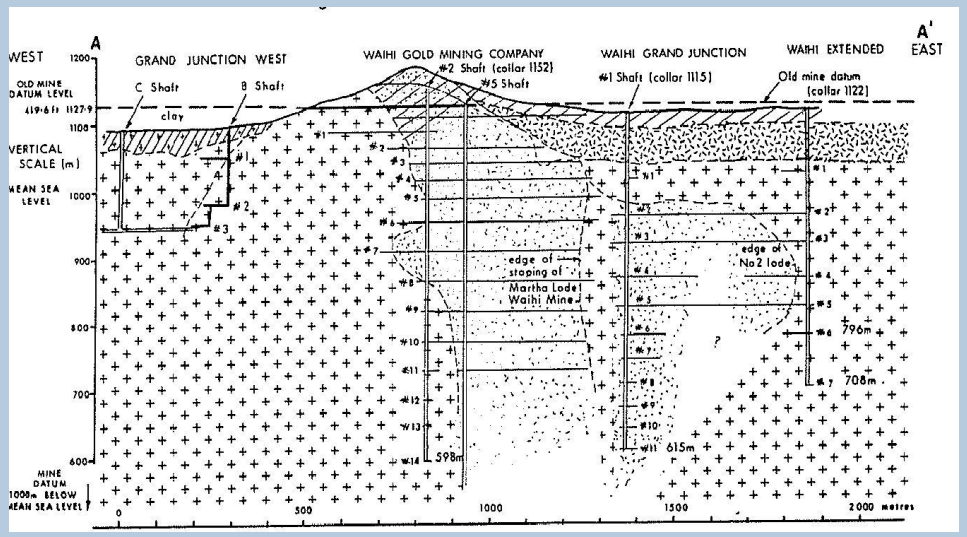


- Located within an alluvial plain
- It was a protruding ridge (Martha Hill)
- Made up of a series of vein systems
- Approximately 2000 m in length.

- Main veins with some stockwork
- Full system generally present
- Favona has complete upper system
- Post mineralisation cover is present

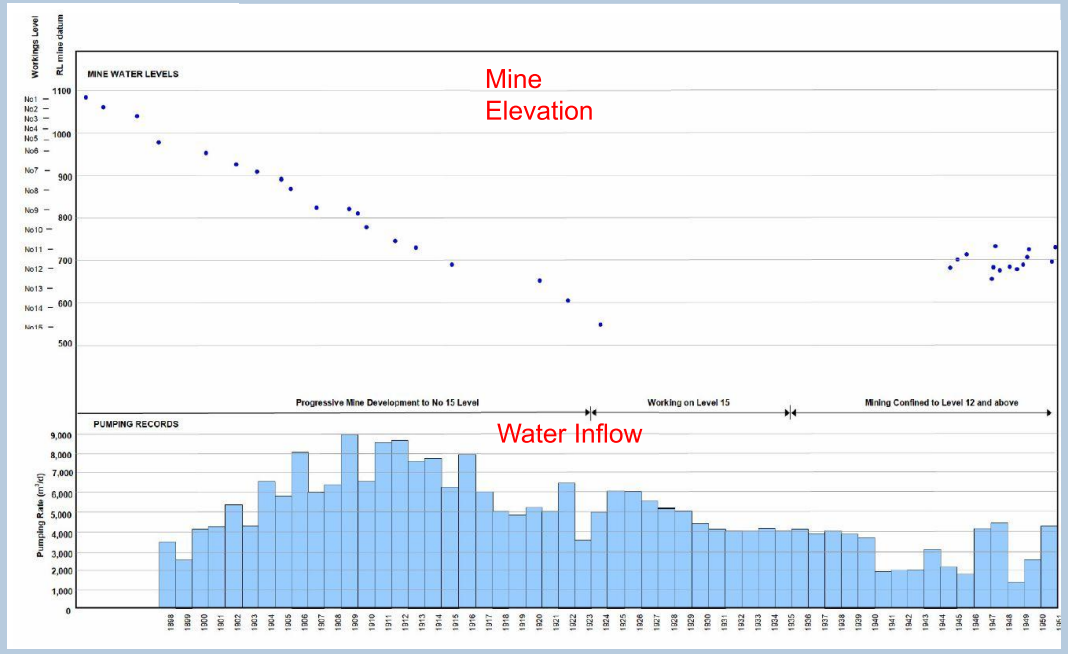
WAIHI MINES

Hydrogeology



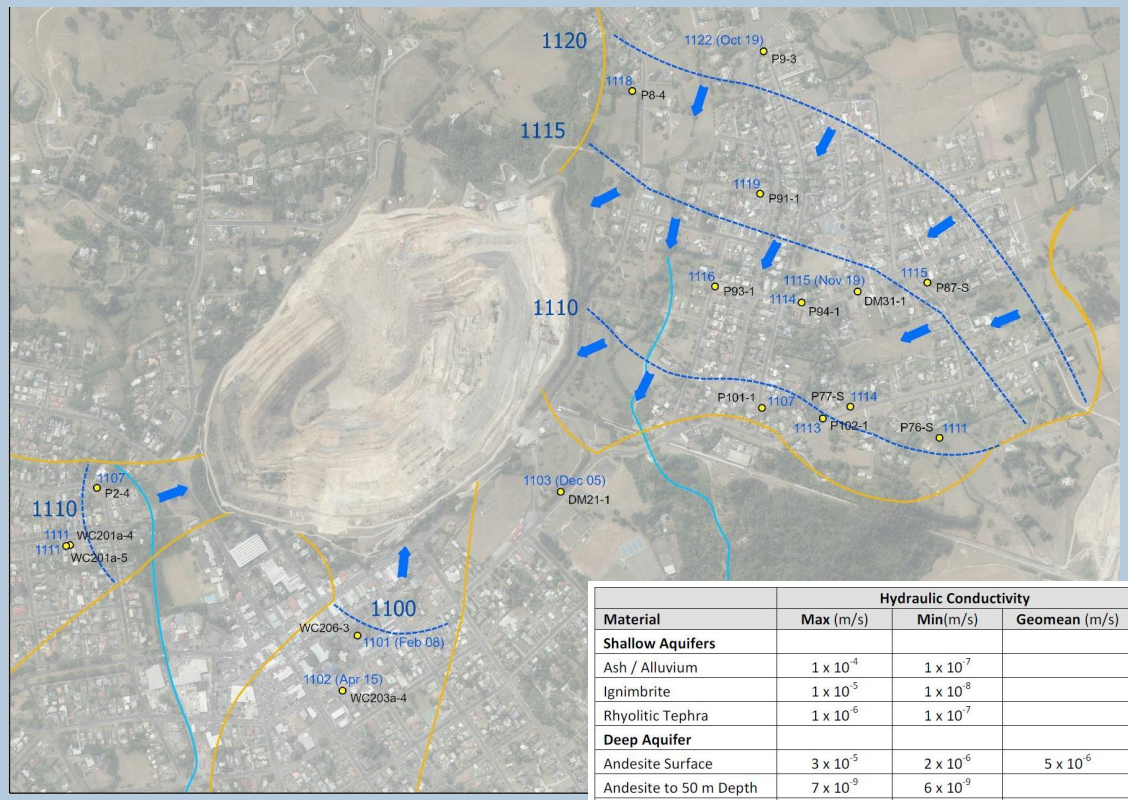
- The drawdown effect was elongated and extended at least 1500 m.
- No adverse effects were experienced.

- Previously dewatered to a depth of 550 m below ground level.
- Groundwater inflows reached up to 9,000 m^3/d and stabilized at 4,000 m^3/d at the lowest level.



WAIHI MINES

Hydrogeology

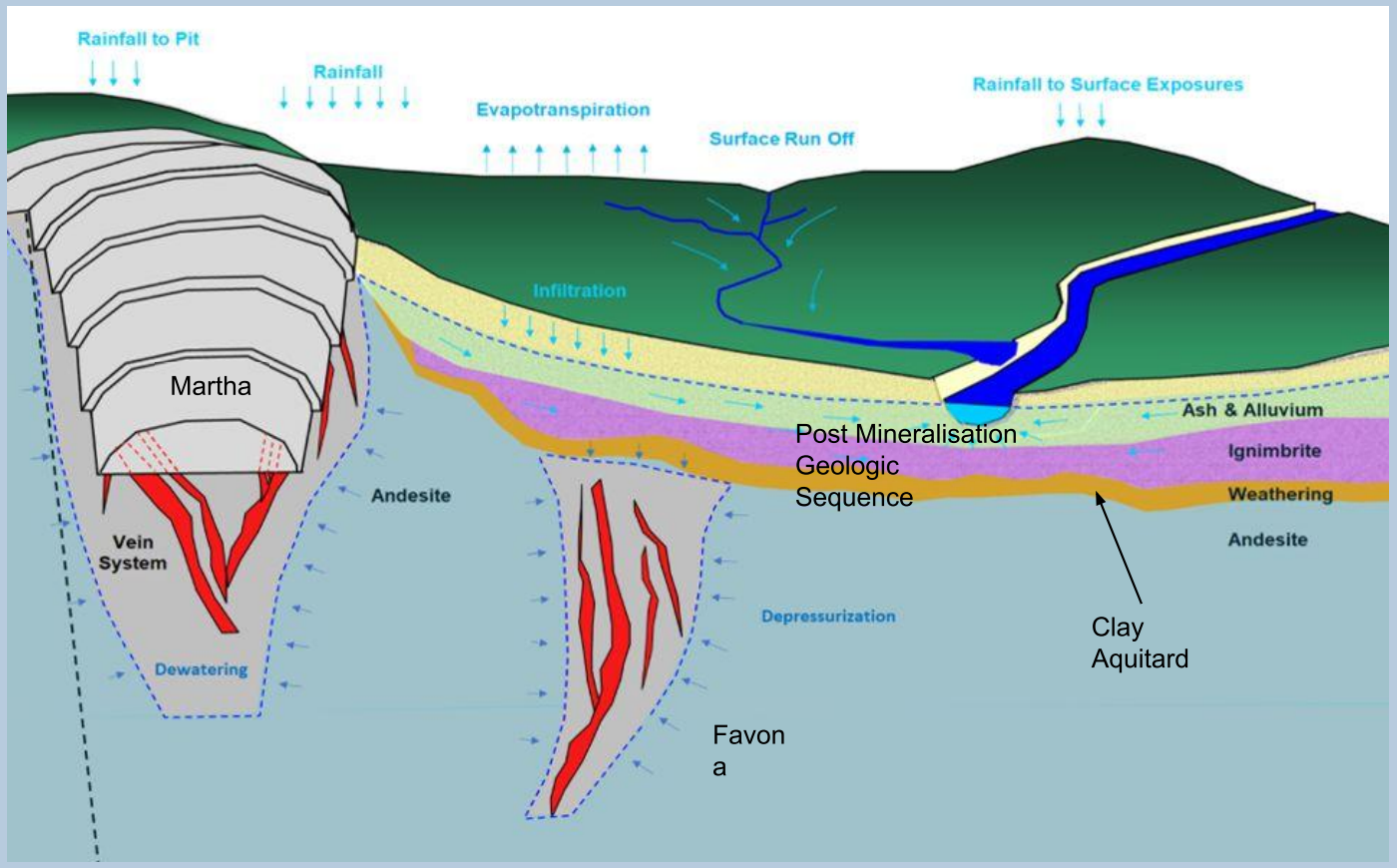


	Hydraulic Conductivity			Storativity	
Material	**Max** (m/s)	**Min**(m/s)	**Geomean** (m/s)	**Max**	**Min**
Shallow Aquifers					
Ash / Alluvium	1×10^{-4}	1×10^{-7}		0.3	0.1
Ignimbrite	1×10^{-5}	1×10^{-8}		0.01	0.001
Rhyolitic Tephra	1×10^{-6}	1×10^{-7}		0.1	0.05
Deep Aquifer					
Andesite Surface	3×10^{-5}	2×10^{-6}	5×10^{-6}	0.3	0.1
Andesite to 50 m Depth	7×10^{-9}	6×10^{-9}		0.01	0.005
Andesite to 100 m Depth	6×10^{-7}	6×10^{-9}	3×10^{-8}	0.01	0.005
Andesite	1×10^{-5}	1×10^{-8}		0.05	0.001
Un-Mined Vein	1×10^{-3}	1×10^{-7}		0.05	0.01

- Since modern mining commenced there has been a considerable improvement in the understanding of the hydrogeology in the area.
- Groundwater inflows are consistent with those observed during historic mining but nominally larger.
- Extensive monitoring of groundwater levels shows there is hydraulic separation between the shallow and deep groundwater systems.

WAIHI MINES

Hydrogeology



- Depressurization effects from mine dewatering does not propagate to the surface.
- Shallow groundwater and surface waters are not affected.
- <u>Separation of the shallow and deep groundwater systems occurs due to the clay aquitard at the base of the post mineralisation cover.</u>

CONCLUSIONS

- The epithermal vein systems in the Coromandel are hosted by either Andesite volcanics or Rhyolite volcanics. The hydraulic properties of the Andesite are generally consistent. Rhyolite hydraulic properties can vary widely.
- There are two hydraulic domains in many deposits: The stockwork system and the main vein. The hydraulic properties differ but they are connected.
- Alteration overprints can change the rockmass properties. Clay altered materials have high storage but low permeability. Silicified materials have low primary storage but high permeability and secondary storage due to fracturing.
- Understanding the structural geology is important to understanding groundwater inflows.
- Structure and anisotropy influence the drawdown envelope.
- Aquitards formed from weathering or alteration can protect the shallow groundwater system from the effects of deep dewatering.

ACKNOWLEDGEMENTS: Thanks to OceanaGold for use of Waihi figures