The magmatic input in the formation of epithermal Au-Ag deposits of the Hauraki Goldfield, New Zealand

Martha open pit, Waihi

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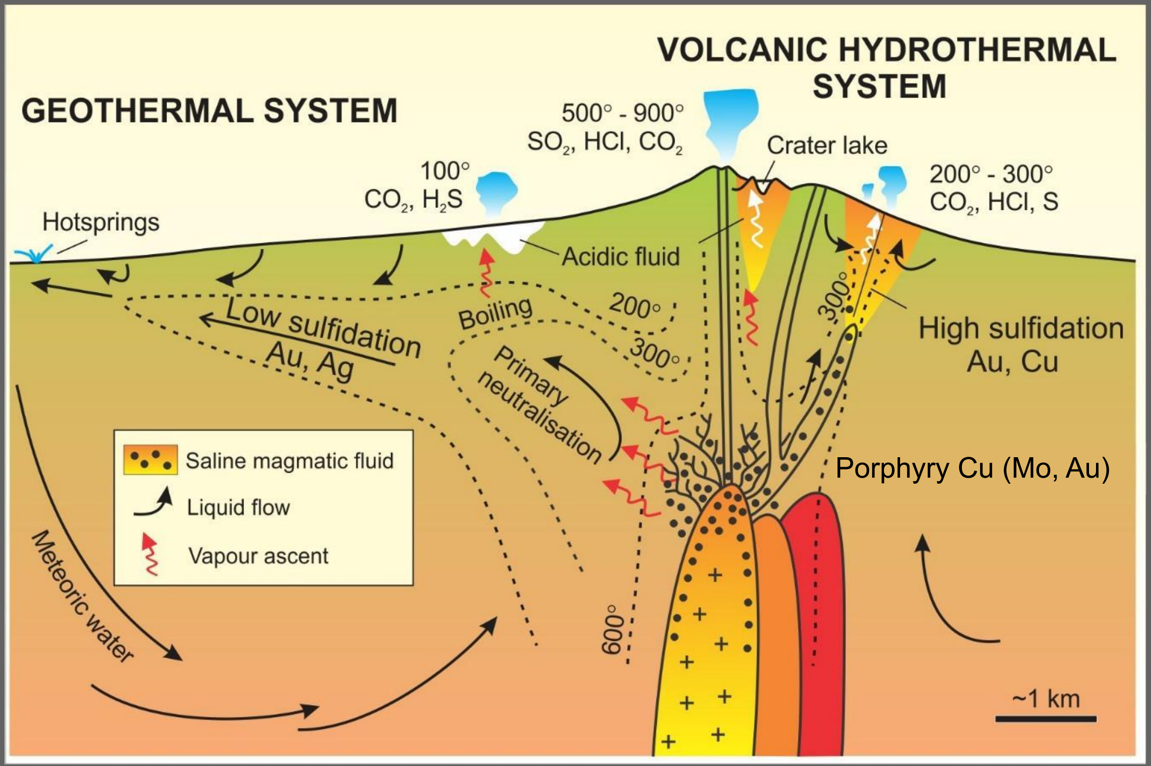
Mineral deposit models



Epithermal models
Hedenquist et al. (1996)

Cross sectional model showing the main near surface mineral deposit types associated with high level magmatic intrusions.

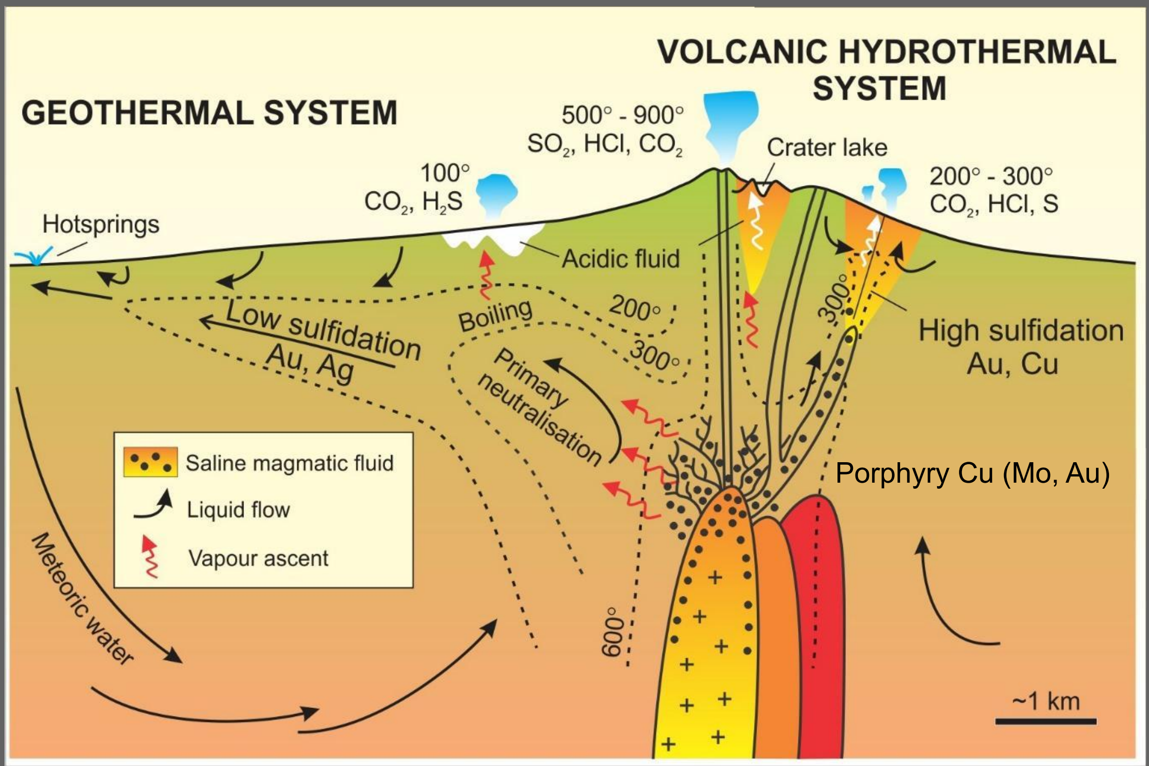
Porphyry copper deposits are proximal to the intrusions and formed predominantly by magmatic fluids.

Epithermal deposits of the Hauraki Goldfield are classified as Low sulphidation.

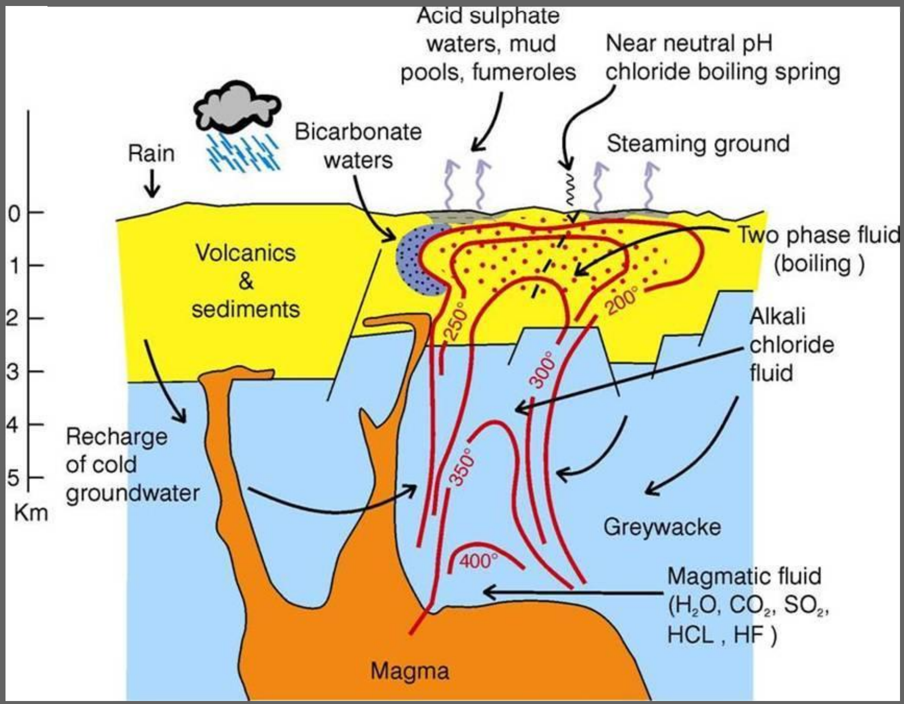
These types of deposits are formed distal from the magma with mineralisation mostly from heated, circulating meteoric water.

Mineral deposit models

Hedenquist et al. (1996)



- Low sulphidation model is based on the analogy of modern geothermal systems
- Fluid composition is mostly from wall rock interaction along the transport path

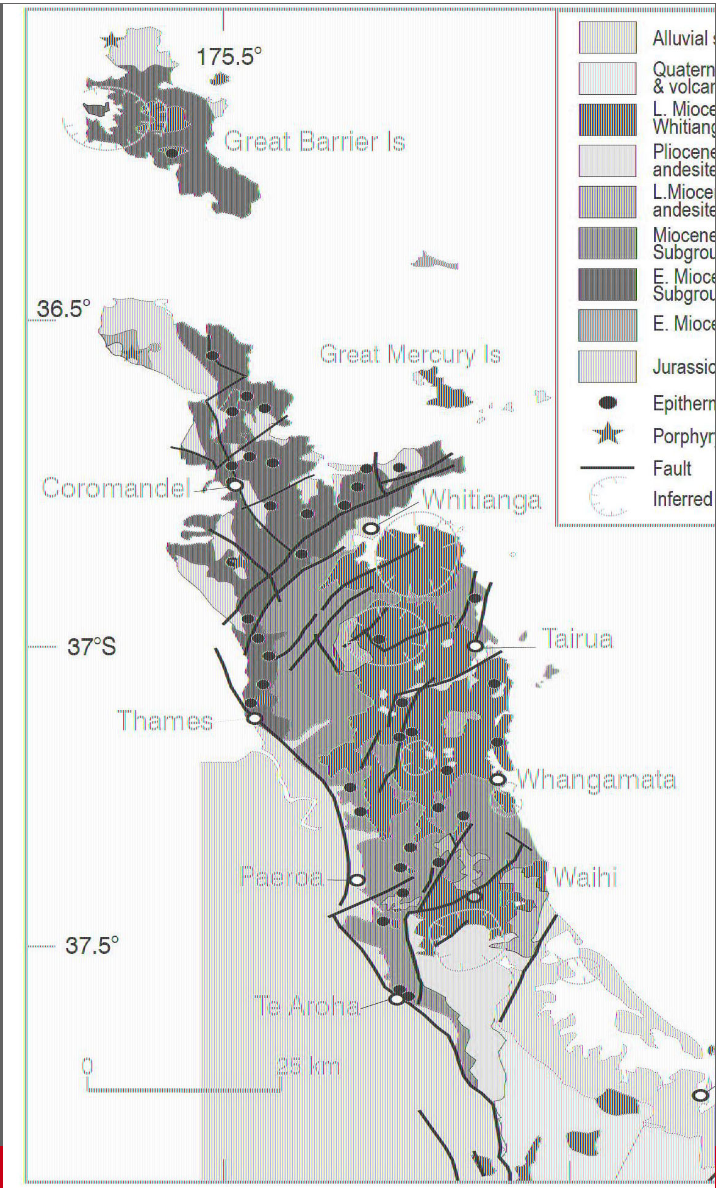


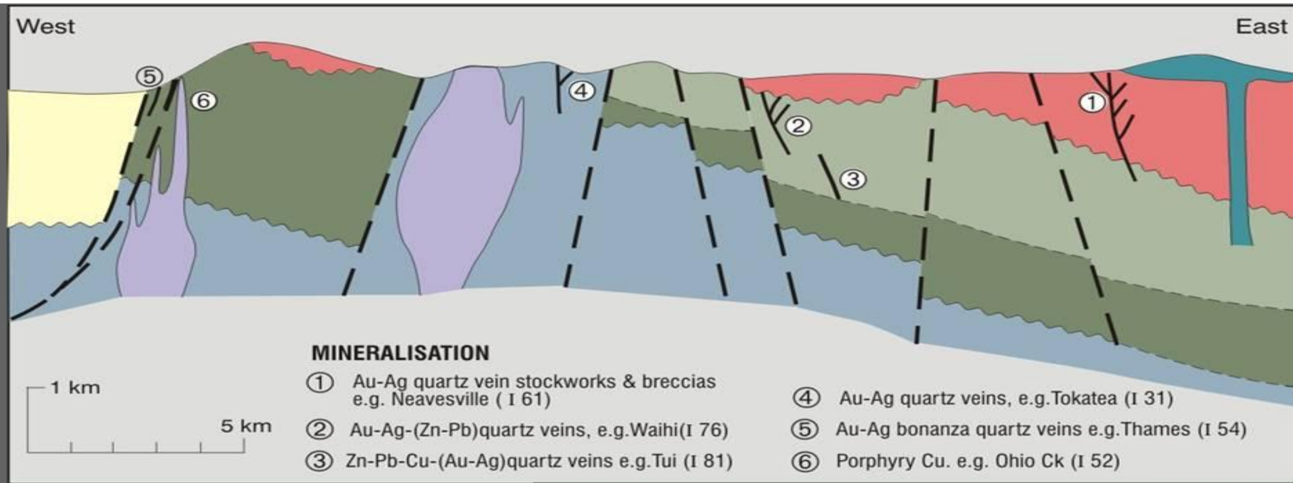
- What is the degree of magmatic input? Why should we care?
- The extent of magmatic supply may influence the metal budget and if recognisable, may provide an indicator of prospectivity useful in exploration

Geothermal system
Taupo Volcanic Zone
Henley & Ellis (1983)

Outline

- The geology and mineral deposits in the Hauraki Goldfield
- Seven possible indicators of magmatic fluid in the formation of the deposits
- Conclusions

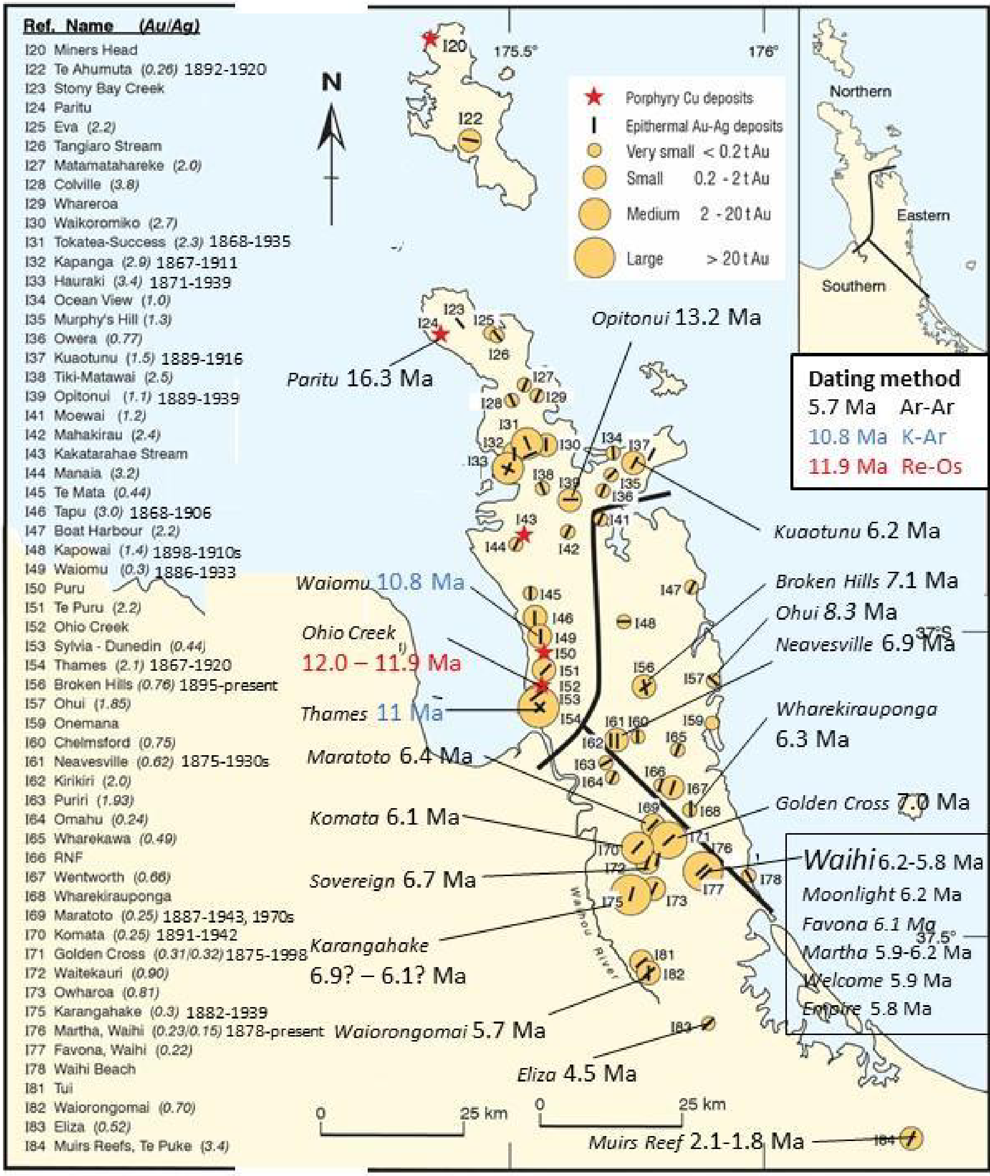




Block faulted and tilted to the southeast

- **Jurassic greywacke basement**
- **Coromandel Volcanic Zone (18 Ma to 2 Ma)**
- **Sub aerial volcanics & associated volcaniclastic sediments**
  - **1st period andesite and dacite (dark green) from 18 Ma to 2 Ma**
  - **2nd period andesite and dacite (pale green) from 11 Ma to 5 Ma**
  - **3rd period rhyolite (red) and minor basalt from 12 Ma to 2 Ma**
  - **4th period post mineral andesite (greenish blue) from 4 Ma to 2 Ma**

(Andesite stratovolcanoes and rhyolite several caldera complexes)

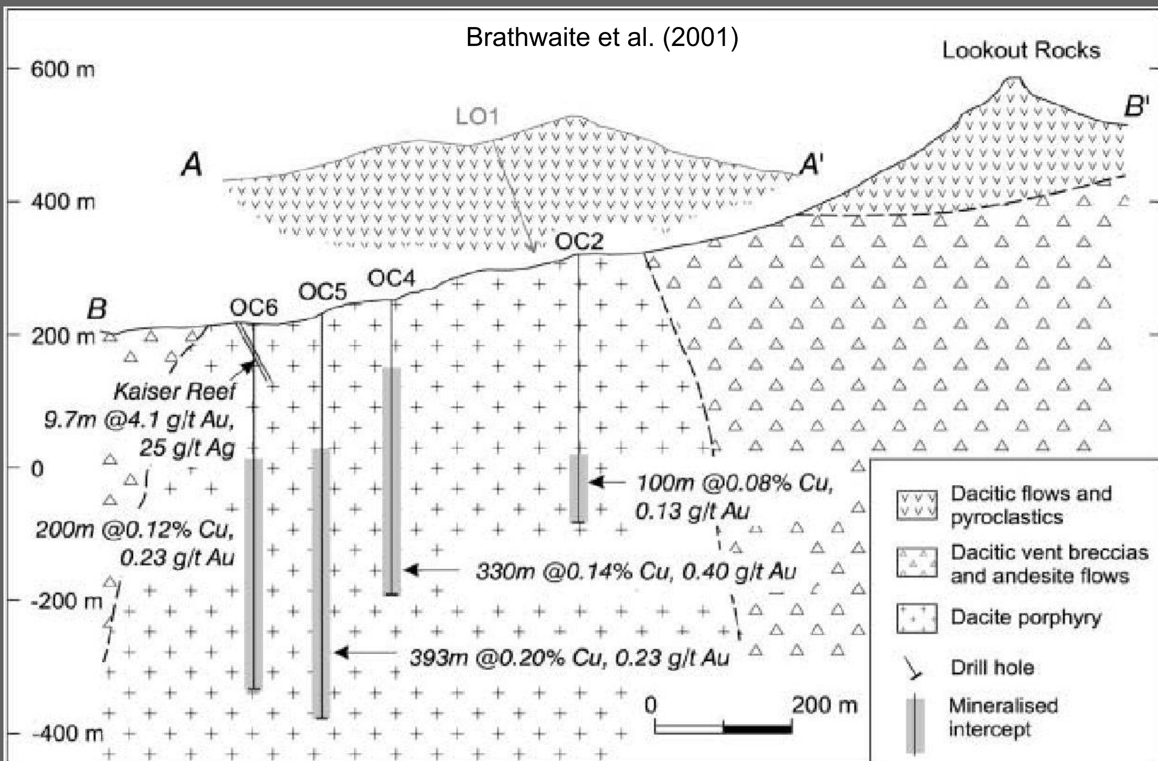


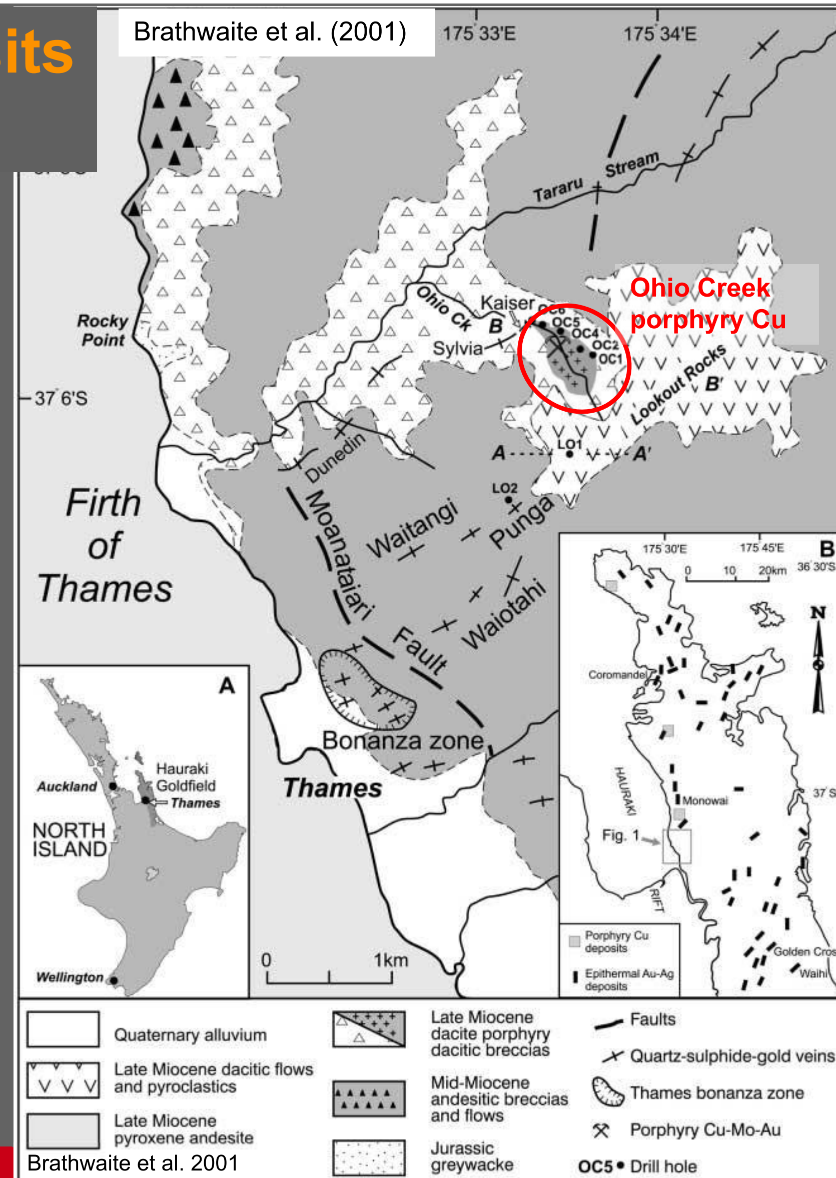
- **Porphyry Cu-Au (e.g. Miners Head, Paritu, Ohio Ck)**
- **50 Au-Ag epithermal deposits**
- **>12 M oz Au & >60 Moz Ag from 1862 – present**
- **Low sulphidation (to intermediate) epithermal**
- **Quartz veins**
- **Volcanic-related**
- **World class deposit, Martha in Waihi ~8 M oz Au**
- **Exploration from the 1980s resulted in several brownfields discoveries:**
  - **Golden Cross (early 1980s)**
  - **Moonlight (1987), Favona (2000), Trio (2003) and Corenso (2009) in Waihi**
  - **Wharekirauponga**

Seven possible indicators of magmatic fluid input

- Relationship with intrusive rocks - porphyry Cu deposits
- Ore mineralogy
- High salinity fluid in fluid inclusions
- Sulphur isotopes
- Lead isotopes
- Positive gravity anomalies
- Abundance of metals deposited

Relationship with porphyry copper deposits Kaiser & Sylvia veins Ohio Creek



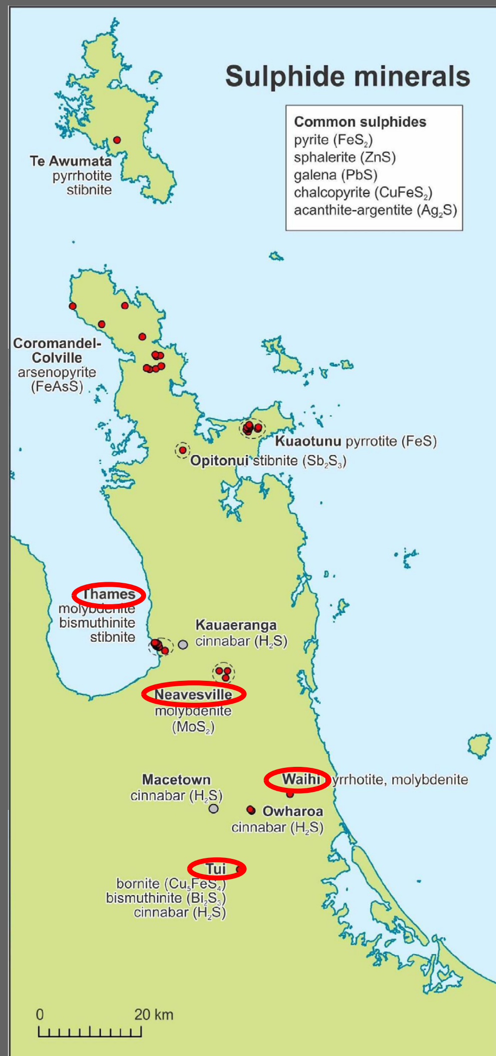


- Dacite stock and surrounding breccia
- Quartz vein stockwork with py, cp

Ore mineralogy

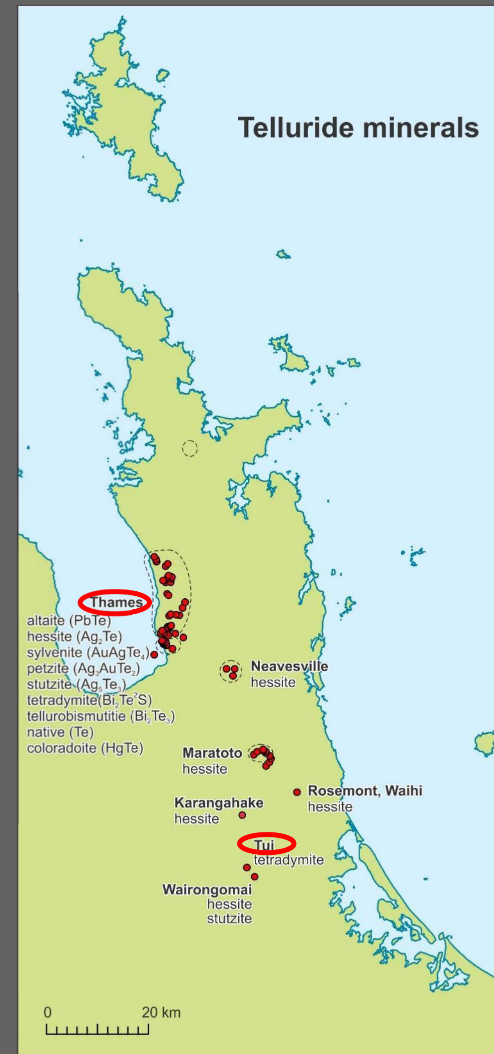
Sulphide minerals

- Bismuthinite – Bi_2S_3
  - Thames and Tui
- Bornite – Cu_5FeS_4
  - Tui
- Molybdenite – MoS_2
  - Thames, Neavesville and Waihi

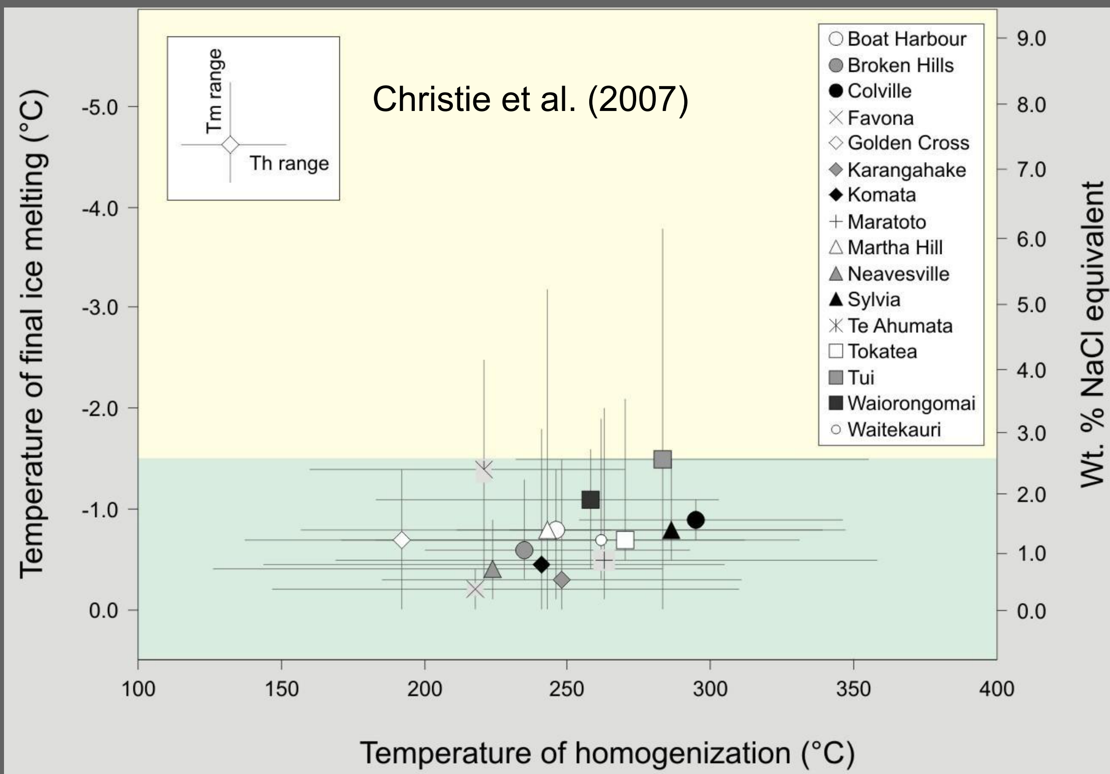


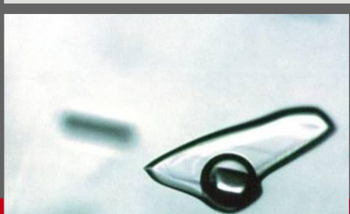
Telluride minerals

- Altaite – PbTe
  - Thames
- Tetradymite – Bi_2Te_2S
  - Thames and Tui
- Tellurobismutite – Bi_2Te_3
  - Thames

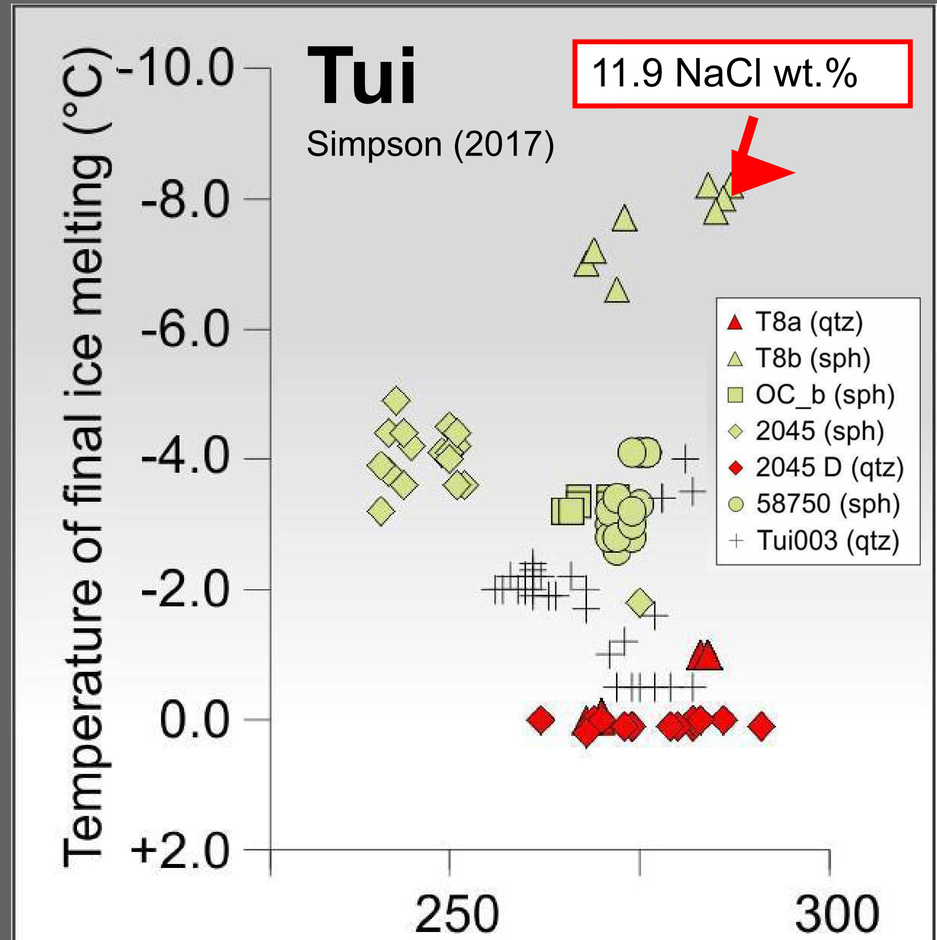


High salinity fluid in fluid inclusions





Sphalerite (Fyfe, 2014)
Martha 4.5 to 5.9 NaCl wt.%
Trio 6.8 NaCl wt.%



Tui	***T_h range***	***Salinity (NaCl wt.%)***
Quartz	253° to 291°C	0.00 to 6.45
Sphalerite	240° to 287°C	4.34 to 11.93

Sulphur isotope values

Magmatic sulphur is ~0 per mil δS^{34}_{CDT}

A

394 analyses: -3.1 to +4.6 per mil δS^{34}_{CDT}

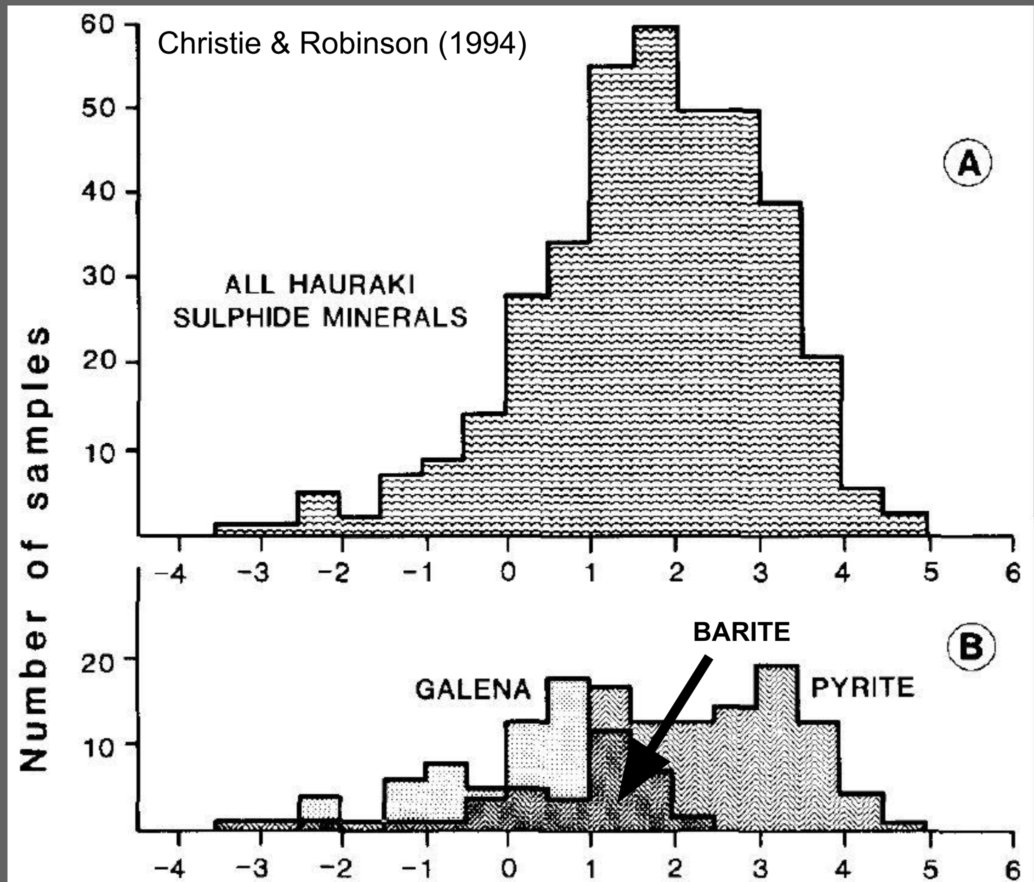
(Robinson 1974; Robinson & Christie 1980; de Ronde & Blattner 1988; Robinson & Merchant 1989; Christie & Robinson 1992)

B

Fractionation with temperature (chalcopyrite and sphalerite histograms would be between galena and pyrite)

Average fluid composition of +2 per mil, consistent with magmatic sulphur, possibly with some minor crustal contamination

per mil δS^{34}_{CDT}



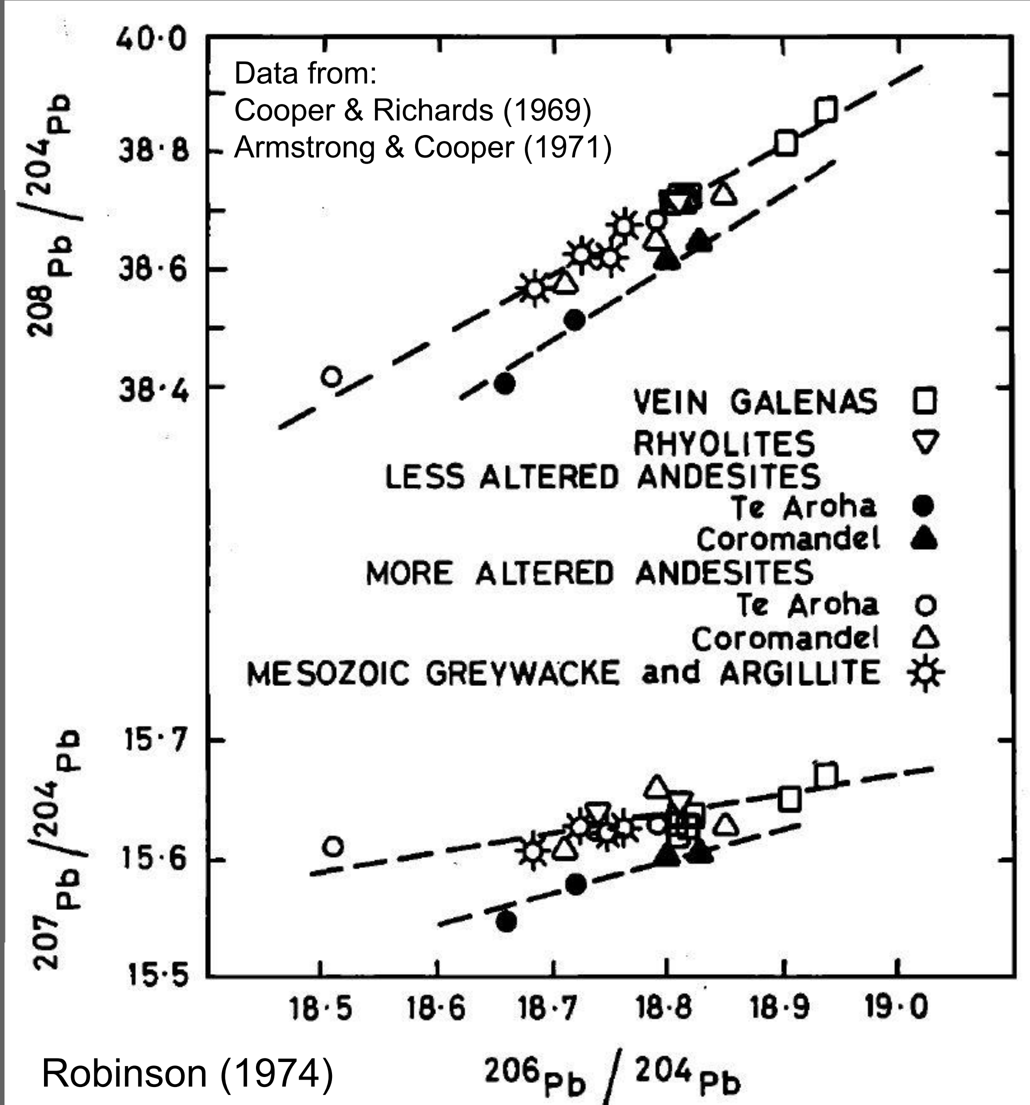
Lead isotopes

Lead from igneous or greywacke sources?

Cooper & Richards (1969) – galena and volcanics
Armstrong & Cooper (1971) - greywacke

Robinson (1974) noted that vein galena samples plot on the same linear trend as greywacke and rhyolites but different from the trend of andesites

He concluded that the lead in galena is probably from greywacke



Robinson (1974)

Gabites & Christie (1993, 1994) lead isotopes

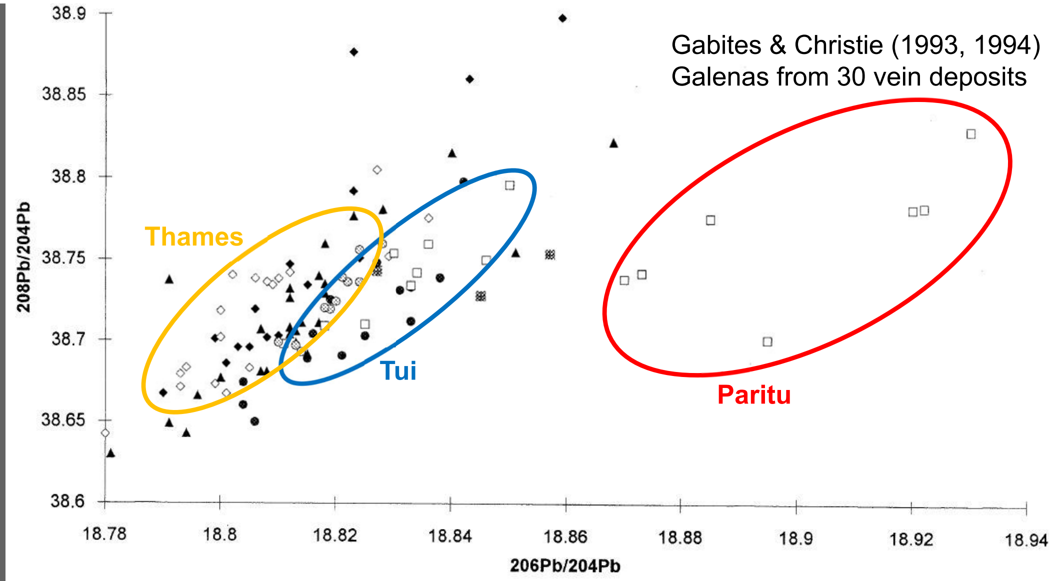
- Separation of deposits on different trend lines suggesting different lead batches or mixes of different sources

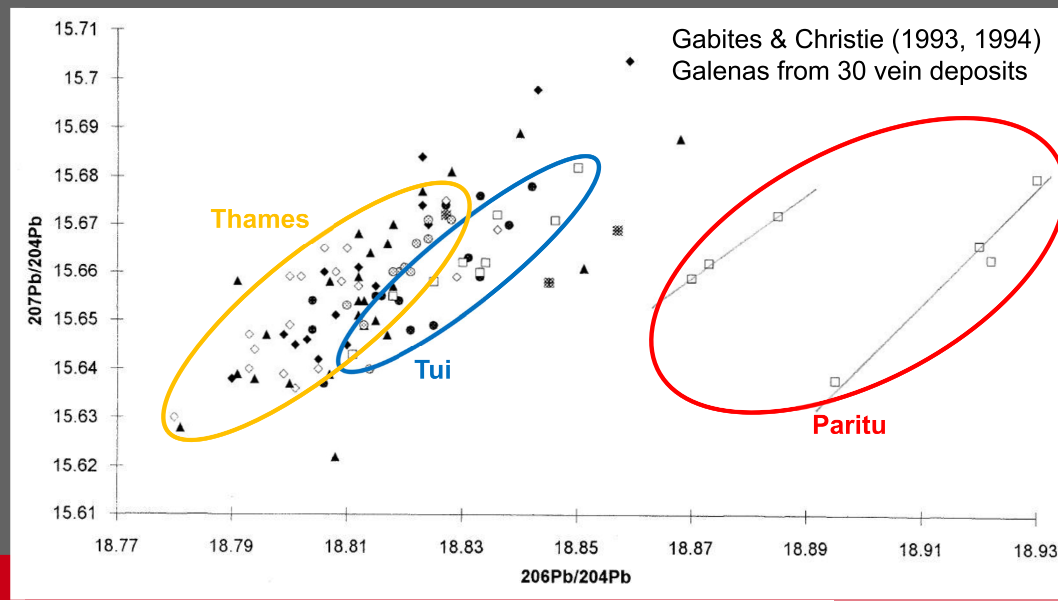
Most radiogenic

- **Paritu** (Doctors Ck, Sorry Mary Stm)
- **Coromandel area** (Tokatea, Preeces Pt, Petote Stm, Tiki Stm)
- **Tui**
- **Waiorongomai**
- **Waihi-Karangahake** (Talsiman)-**Waitekauri**
- **Thames** (Monowai, Zeehan, Comstock, Sylvia, Watchmans, Australian, Karaka Ck, May Queen)

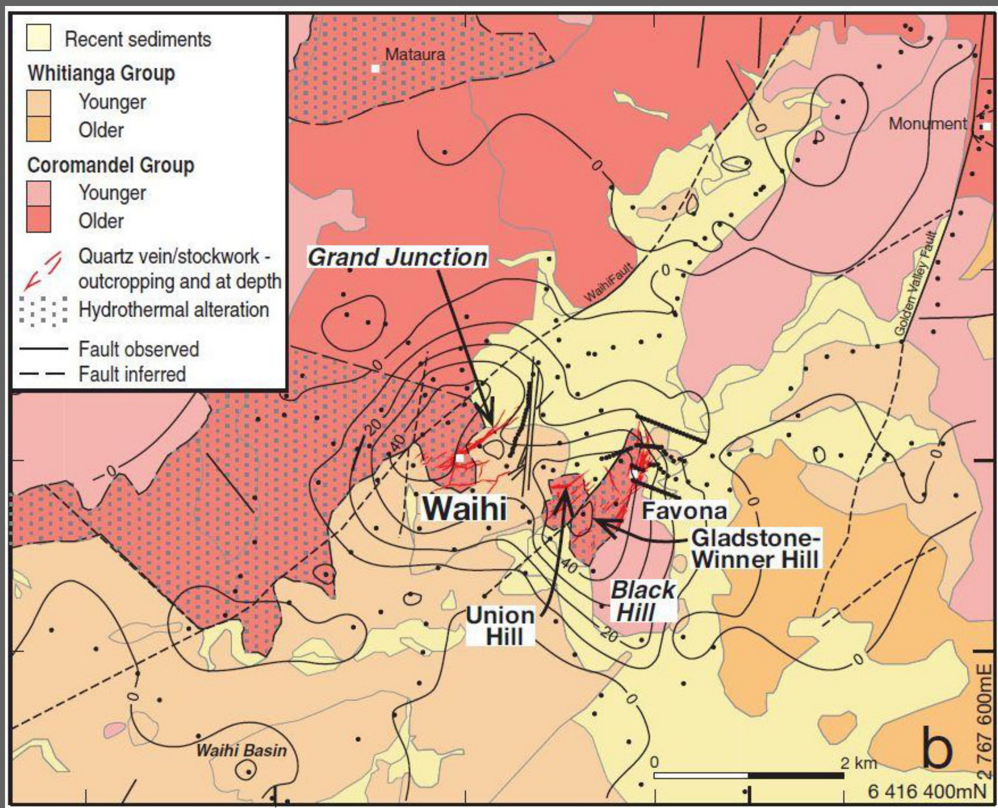
Least radiogenic

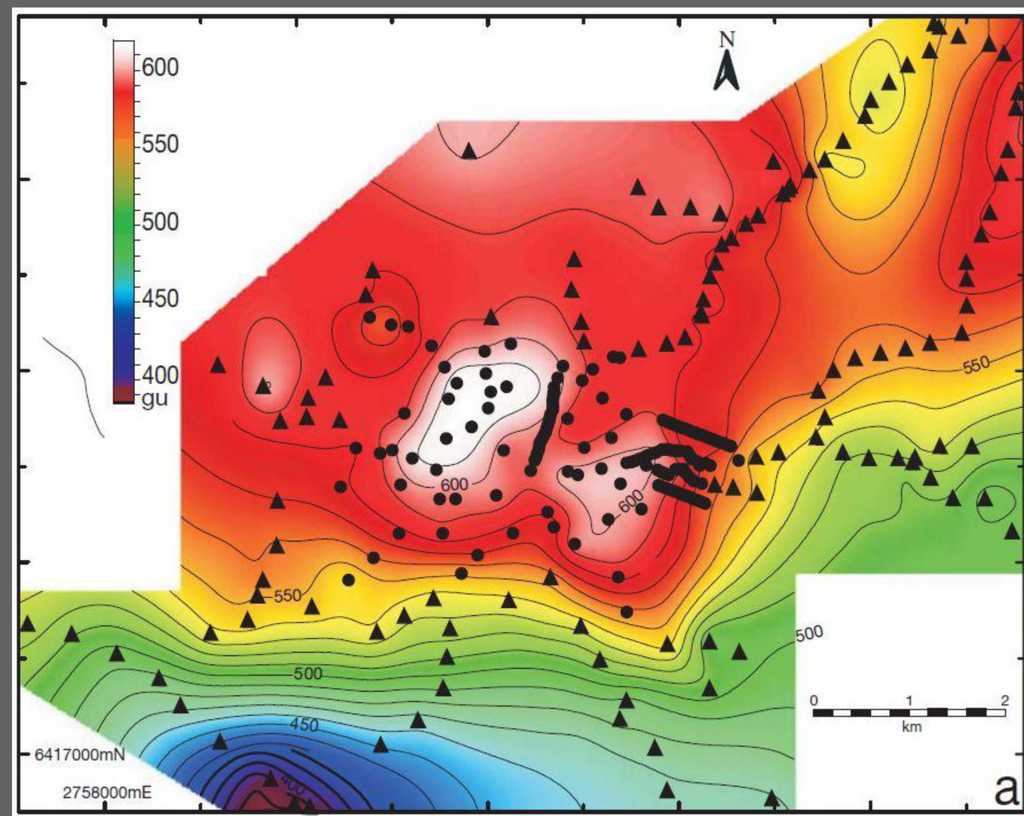
- Paritu = strongest magmatic signature?
- Decreasing radiogenic = decreasing magmatic signature? - **Not that simple**
- Variable mix of sedimentary and igneous sources likely between different deposits



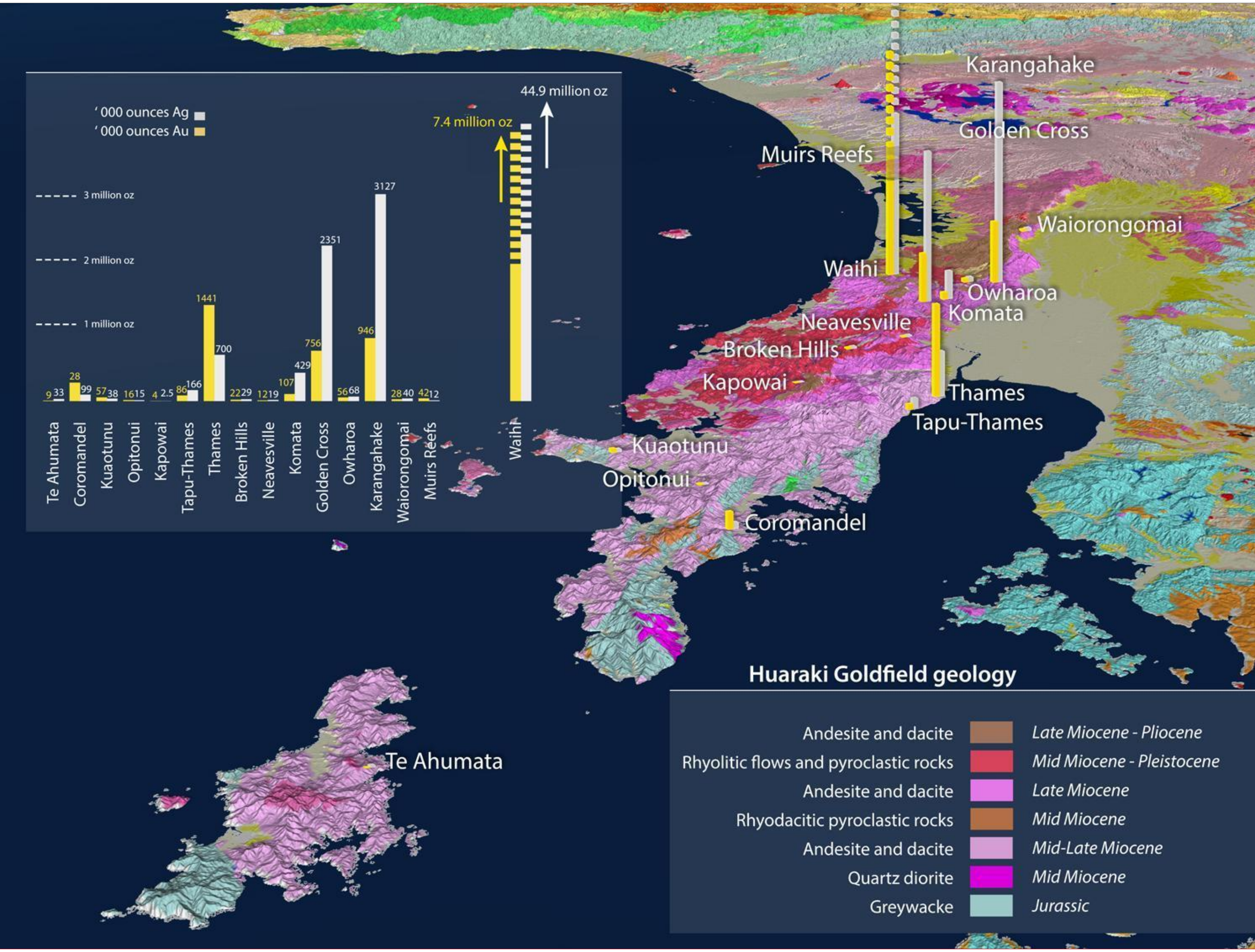


Positive gravity anomalies - Waihi





Morrell et al. (2011): positive gravity anomalies suggest twin magmatic intrusion heat and hydrothermal fluid sources beneath Waihi



Abundance of metals deposited

Histograms of Au and Ag production

Au = yellow bars

Ag = grey bars

Waihi production is off scale.

Thames, Golden Cross, Karangahake and Waihi are the large producers.

Conclusions - 1

Seven possible criteria for magmatic fluid input:

- **Spatial and temporal relationship with porphyry Cu deposits**
- **Ore mineralogy features**
- **High salinity fluid in fluid inclusions**
- **Sulphur isotope values near 0 per mil**
- **Lead isotopes**
- **Positive gravity anomalies**
- **Abundance of metals deposited**

Conclusions - 2

- None of these suggested criteria of magmatic input are definitive
- However, high temperature mineralogy and high salinity fluid inclusions provide the strongest indication of magmatic fluid pulses
- Revisit lead isotopes:
  - Better bracket the lead isotope magmatic signature?
  - Are andesitic or rhyolitic magmas the best source for mineralisation?
- Positive gravity anomalies could be due to an intrusion as speculated at Waihi. Are there more examples?
- We are some way from developing and applying an exploration tool for calibrating magmatic input