Hydrothermal alteration footprints for epithermal deposits, Hauraki Goldfield, New Zealand

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Hauraki Goldfield

Low / intermediate sulfidation epithermal

~12.3 Moz Au  ~54.9 Moz Ag

- Andesite (from which 90 % of Au recovered)
- Rhyolite
- Meta-sediments

Au-Ag mostly occurs in quartz veins

- Length:  200 to 1,600 m  (rarely 4.5 km)
- Vertical:  ≥700 m  (170 to 330 m mined)
- Width:  0.3 to 5 m  (locally 25 m)

Veins surrounded by extensive zoned alteration

(Christie et al., 2001)
Alteration extent

Field mapping and geophysics, but limitations

Alteration footprints
>6 to <50 km² (120 km²)

~12 km² Waihi vein system

~42 km² Maratoto, Golden Cross, Komata, Waitekauri

Larger alteration halos enclose several vein systems

(OceanaGold)
Alteration intensity

Alteration of volcanic rocks ranges from weak to strong (>70 to 100 %)

For strongly altered igneous rocks the original textures often preserved, but for some can be completely destroyed

Typically volcanic rocks hosting veins are strongly altered over 100’s to 1,000’s m

Included within strongly altered rock can be lenses of less altered rock / ‘hard bars’
The rocks are replaced by a variety of alteration minerals. The more common include:

- Quartz
- Adularia
- Albite
- Illite
- Illite-smectite (IS)
- Smectite
- Chlorite
- Calcite
- Pyrite
- Buddingtonite & NH$_4$-illite

Less common (rare):

- Corrensite
- Chlorite-smectite
- Siderite
- Epidote
- Kaolinite
- Alunite

Many require the use of analytical techniques to identify e.g. XRD, hyperspectral, petrography.
Focus on:

Alteration mapped at many deposits to varying levels of detail

Focus on alteration at:

- Karangahake
- Favona and Martha
- Golden Cross
- Waitekauri
- Wharekirauponga

(Torckler et al., 2016)
Karangahake alteration (XRD)

(A) Map of Mt Karangahake 544 m

Rhyolite
Quartz vein
Contour (20m interval)
Demagnetised zone
Radiometric K anomaly

0 1 km

(B) Map of Adularia

0 1 km

(C) Map of Albite

0 1 km

(D) Map of Illite

IS
Smectite

0 1 km

(E) Map of Chlorite

0 1 km

(F) Map of Calcite

0 1 km

NZ epithermal gold workshop 2018

(Stuart et al., 2006; Simpson et al., in review)

GNS Science
Favona (XRD)

- Widespread adularia
- Localised albite
- Zoned illite, IS

Favona vein parallels / transects illite / IS contact

(Simpson and Mauk, 2007)
Martha alteration (XRD)

(Castendyk et al., 2005)
Waitekauri (XRD)

2 km drill line sections

- Widespread adularia
- Albite below adularia (Scotia)
- Zoned illite, IS, smectite

(Simpson and Mauk, 2011)
Golden Cross (XRD)

- Widespread adularia
- Illite with IS carapace

(Simpson et al., 2001)
Hyperspectral (SWIR) reflectance spectroscopy

- Rapid, non-destructive field based mineral identification technique able to identify many alteration minerals (but no all)  
  e.g. illite, IS, smectite, chlorite, calcite, NH₄-minerals, kaolinite, alunite

- Illite, IS, smectite distinguished based on H₂O/Al-OH ratio  
  (ideally calibrated against XRD)

Waitekauri calculated H₂O/Al-OH depth ratio versus XRD clay mineral identification
There are differences **but** the same broad trends are identified from both techniques.
NH₄-minerals Favona (SWIR)

NH₄-minerals = buddingtonite (NH₄-feldspar) and NH₄-illite
**NH₄-minerals**

**WKP (SWIR)**

**NH₄-minerals broadly coincidental with sheeted vein zones and in the hanging wall of wider quartz veins**

**But not all veins occur in rocks with NH₄-minerals**
Alteration Minerals and Vein Proximity

(Data for drill hole UW462, Bodger (2015))
Alteration Mineral Quantification

Alteration mineral percentages

- XRD (SIROQUANT software or equivalent)
- Automated mineralogy
  (TESCAN Integrated Mineral Analyser / TIMA)

Mineral quantification reveals the abundance of some minerals change with proximity to veins

Adularia
Albite + calcite + illite
Albite + calcite + plagioclase
Adularia abundance increases towards the Maria, Mystery and Welcome/Crown veins.
Quantification Adularia: Karangahake

At Karangahake many rocks have adularia > quartz
Summary

Key alteration minerals zoned around veins are:

- Adularia and albite
- Illite, illite-smectite, smectite
- $NH_4$-minerals

Quartz veins occur in rocks altered to adularia, and/or illite. Some quartz veins in illite-smectite altered rocks (at / near illite boundary)

- Illite, IS, smectite define broad outline of the alteration system and the hotter core (100’s m to km’s lateral scale)
- Adularia outlines areas of high fluid flux (150 to +500 m lateral scale)
- $NH_4$-minerals, when present, occur proximal to veins (10’s to ~200 m)
- Adularia coextensive with illite
- Adularia can be coextensive with illite-smectite & locally smectite
- Albite at depth, coextensive with or boarding adularia
- $NH_4$-minerals proximal to veins
Analytical Exploration Tools

Hyperspectral (5 to 15 second scans)
  • Illite, illite-smectite, smectite, NH₄-minerals, plus others

Portable XRD (1 to 5 minute scans)
  • Mineral identification / Mineral quantification – require longer scans

Portable XRF (40 to 90 seconds scans)
  • K/Al ratio can be used as proxy for adularia (Hughes and Barker 2017)

At Karangahake rocks with a K/Al ratio ≥0.4 have adularia
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