Porphyry copper-gold mineralisation in the Neara Arc: spotlight on the Booubyjan Intrusive Complex

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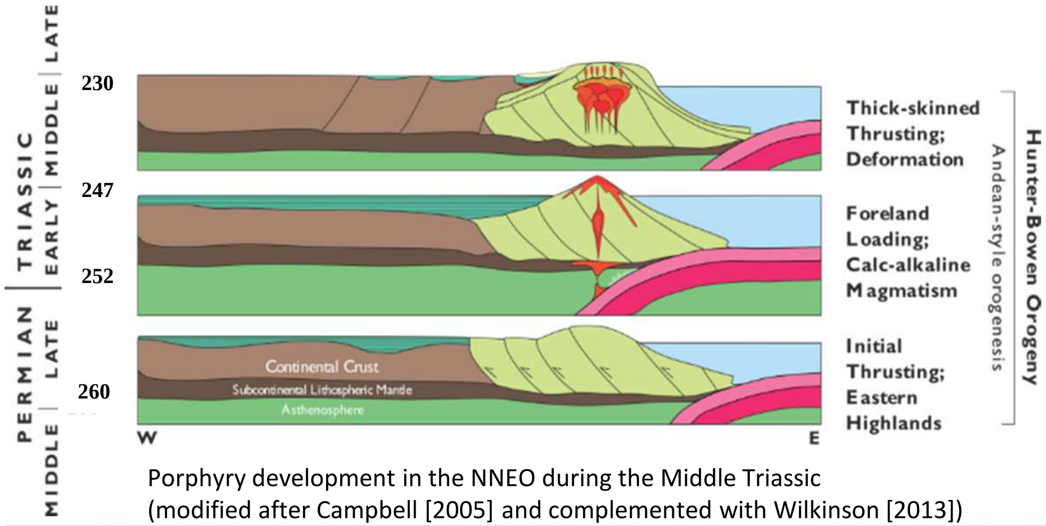
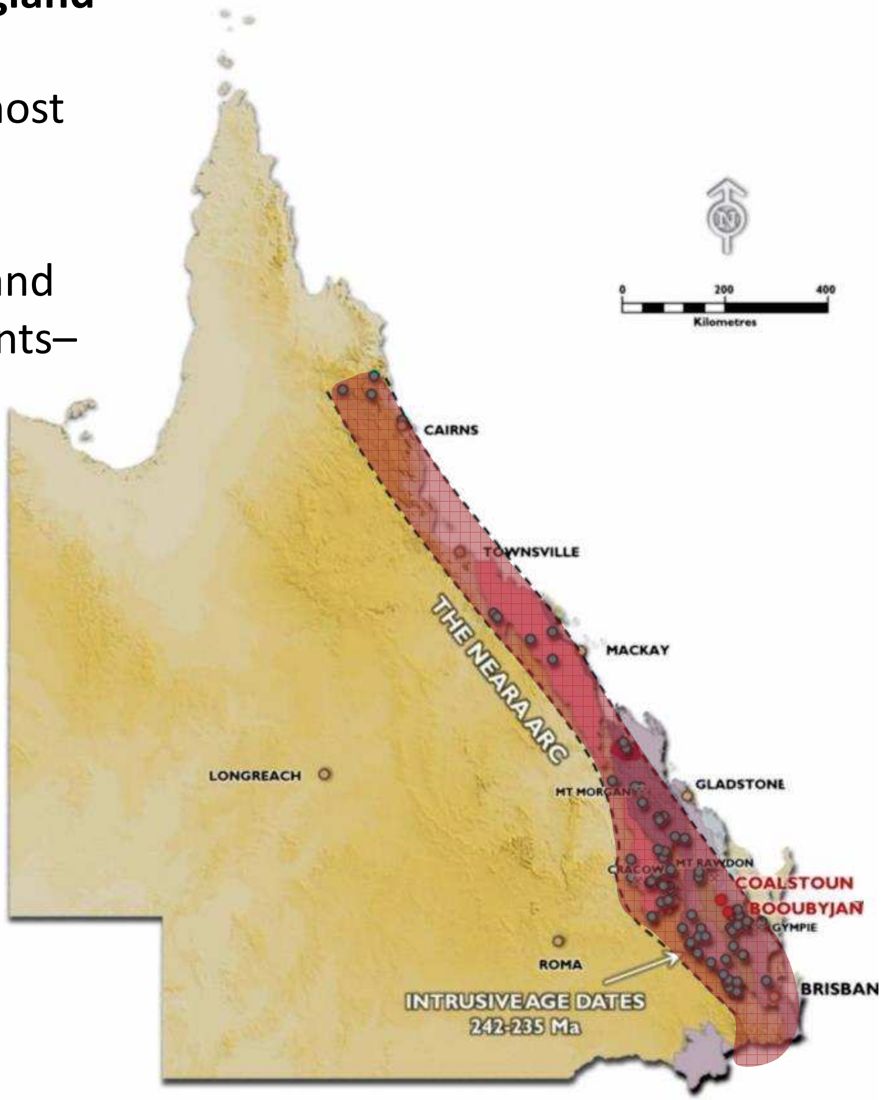
The Neara Arc

- **Andean style orogenesis** in the **Northern New England Orogen** during the **Late Permian-Early Triassic**.
  - Widespread I-type **calc-alkalic** magmatism, most voluminous in the 250-230Ma period – max production ~240Ma.
  - Coincident with the Hunter Bowen Orogeny and eruption of the Neara Volcanics and equivalents–establishment of the Neara Arc.
  - Associated **porphyry emplacement.**
  - **NNW trending mineralisation** parallel to subduction trend.



Porphyry development in the NNEO during the Middle Triassic (modified after Campbell [2005] and complemented with Wilkinson [2013])



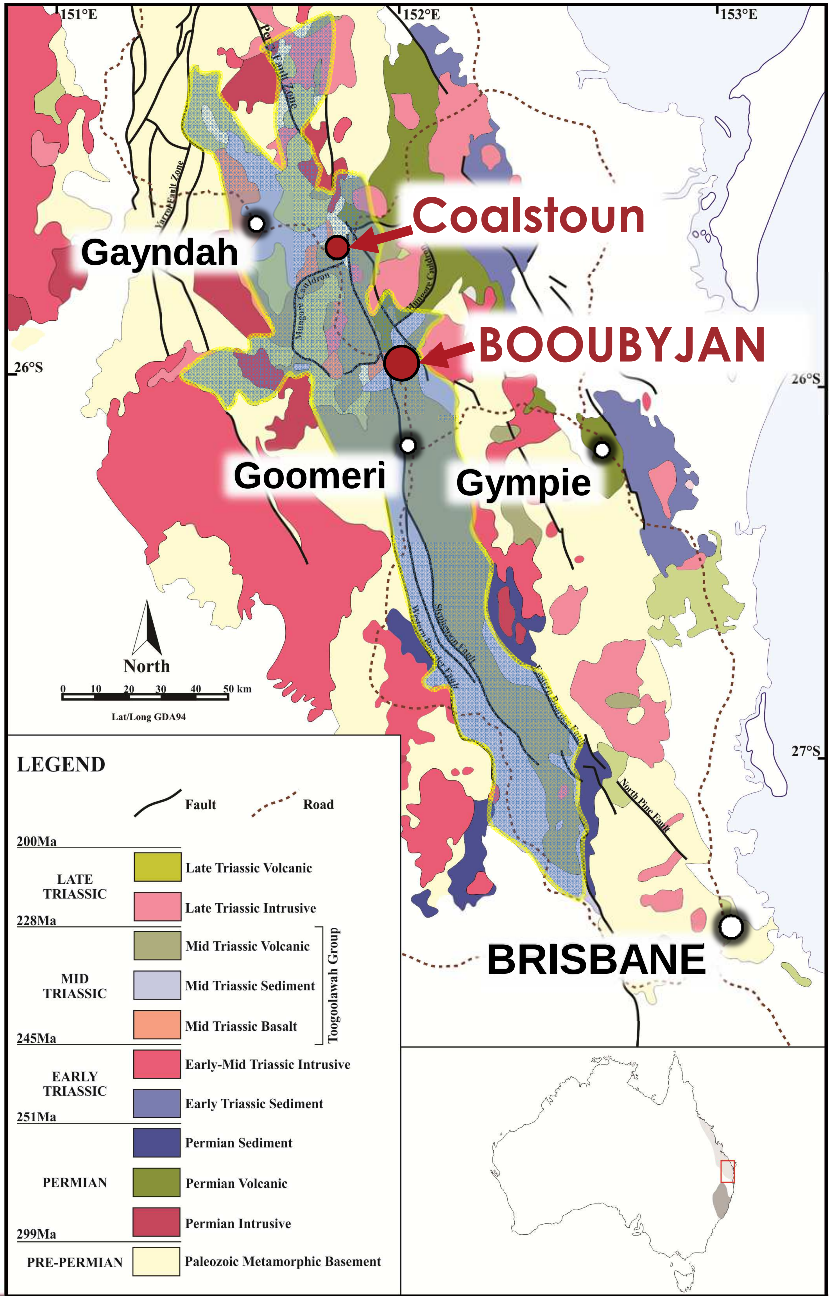
The Esk Basin

- Located within the **Northern New England Orogen**.
- Extent defined by the surface exposure of the **Early to Middle Triassic Toogoolawah Group**.
  - Esk Formation, Neara / Mt Marcella Volcanics, Bryden / Gayndah Formation.
  - Deposited in **foreland basin**.
- Neara/ **Mt Marcella Volcanics** consistent geologically and geochemically with **continental margin arc**.

Deposit location within the Esk Basin, NNEO, QLD

Booubyjan Intrusive Complex

- Located within the Esk Basin.
- 80km NW of Gympie, 32km N of Goomeri.
- Hosted within the Middle Triassic (**237** Ma) andesitic volcanics and derived sediments of the **Mount Marcella Volcanics.**
- Similarities with **Coalstoun**, ~40km NNW.
- **High-K calc-alkaline andesitic** volcanism associated with **porphyry mineralisation event.**
  - Coalstoun porphyry : K-Ar age 235 ± 4 Ma (Ashley et al., 1978).
  - Booubyjan K-Ar age: 258.2 ± 14.6 Ma and 260.0 ± 18.9 Ma (Harvey *et al.*, 2008) – erroneous dates, **U-Pb dating planned.**

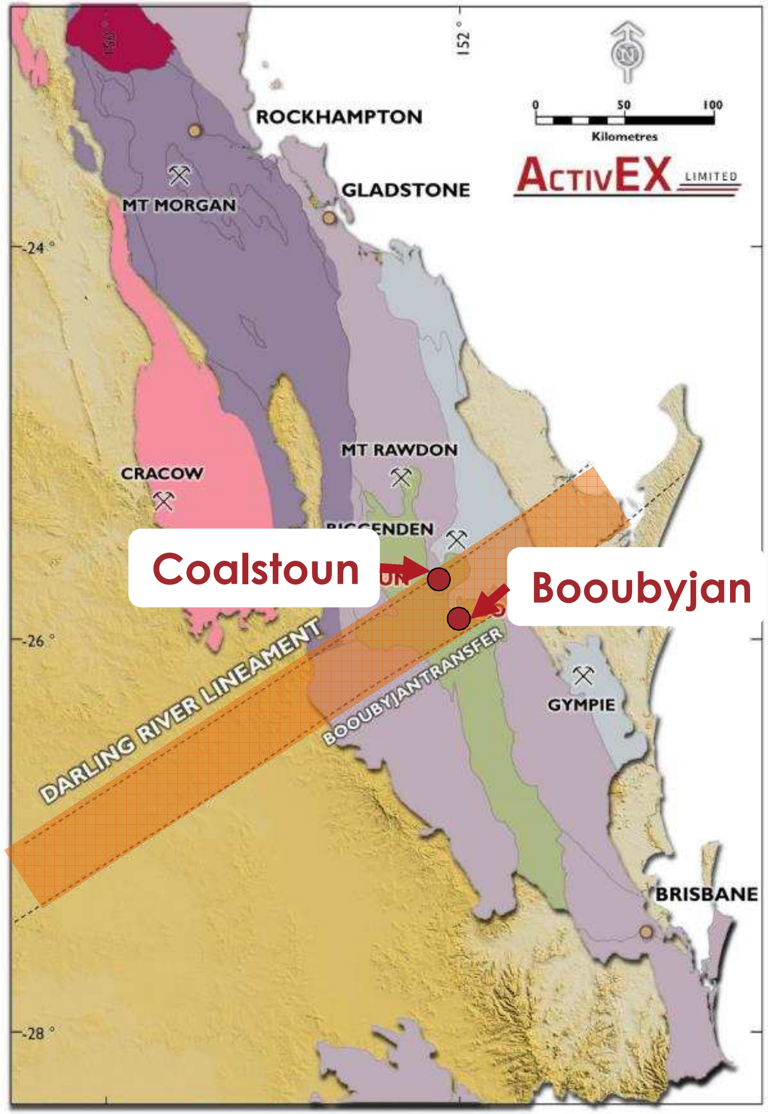


Regional geology of deposit area. Modified from Buck (2008)

Structural controls

- **Porphyry deposits**: require **dilatant** structures for the rapid ascent of deeply derived hydrous arc magmas.
  - Rise through zones of **crustal weakness.**
  - Shallow-level of crystallisation → **volatile exsolution**.

- **Darling River Lineament:**
  - Arc-traverse structural lineament.
  - Deep-seated, long-lived structure.
  - Inherited from **Rodinia breakup** *ca*. 900-750Ma
  - **~2000 Km** NE-strike, up to **50 Km** wide.
  - Identified from geological, structural, geomorphological, and geophysical features.
  - **Crustal weakness** → favored igneous activity and porphyry emplacement.

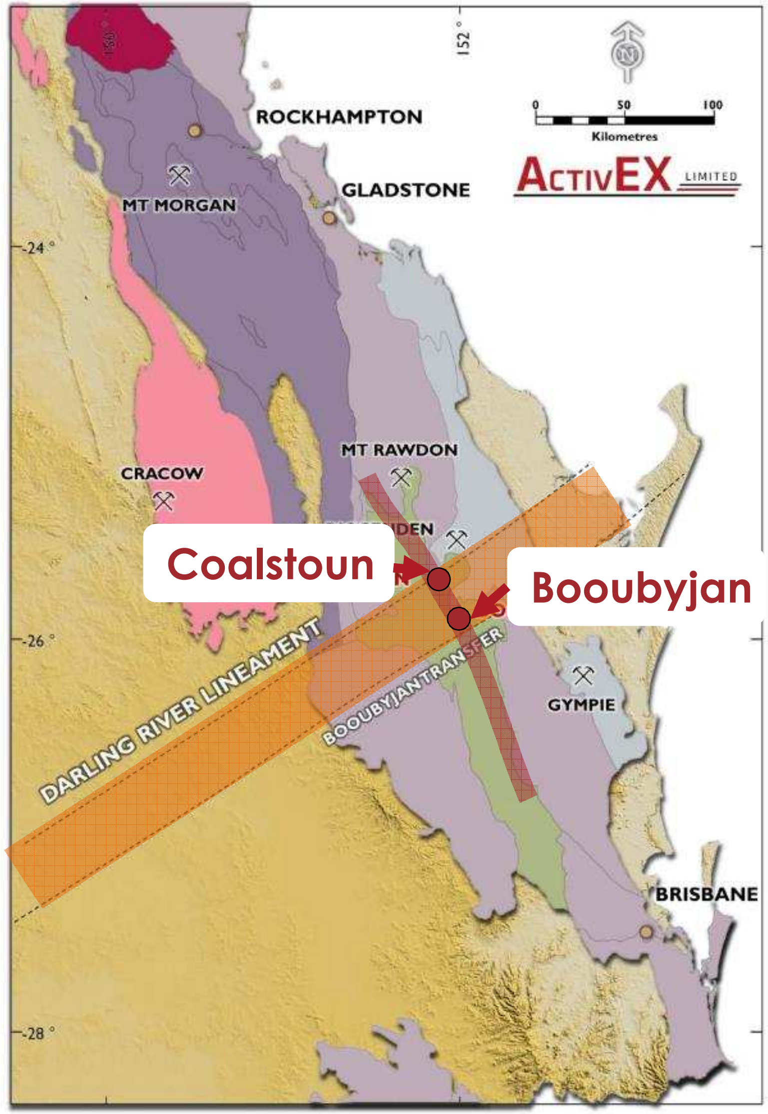


250k regional geology of deposit area

Structural controls

- **Perry Fault System**
  - NNW-trending fault zone (arc parallel)
  - Separates the Coastal Block from the Gympie Basin.
  - Parallel to eastern boundary of the Esk Basin.
  - Well defined topographically and geologically.
  - Sinistral strike-slip movement up to 8km.
  - Disrupted by ENE-trending structures.

- **Darling River Lineament and Perry Fault:**
  - **Dilatant structures** formed at the intersection.
  - Controlled emplacement of mineral deposits in the area.



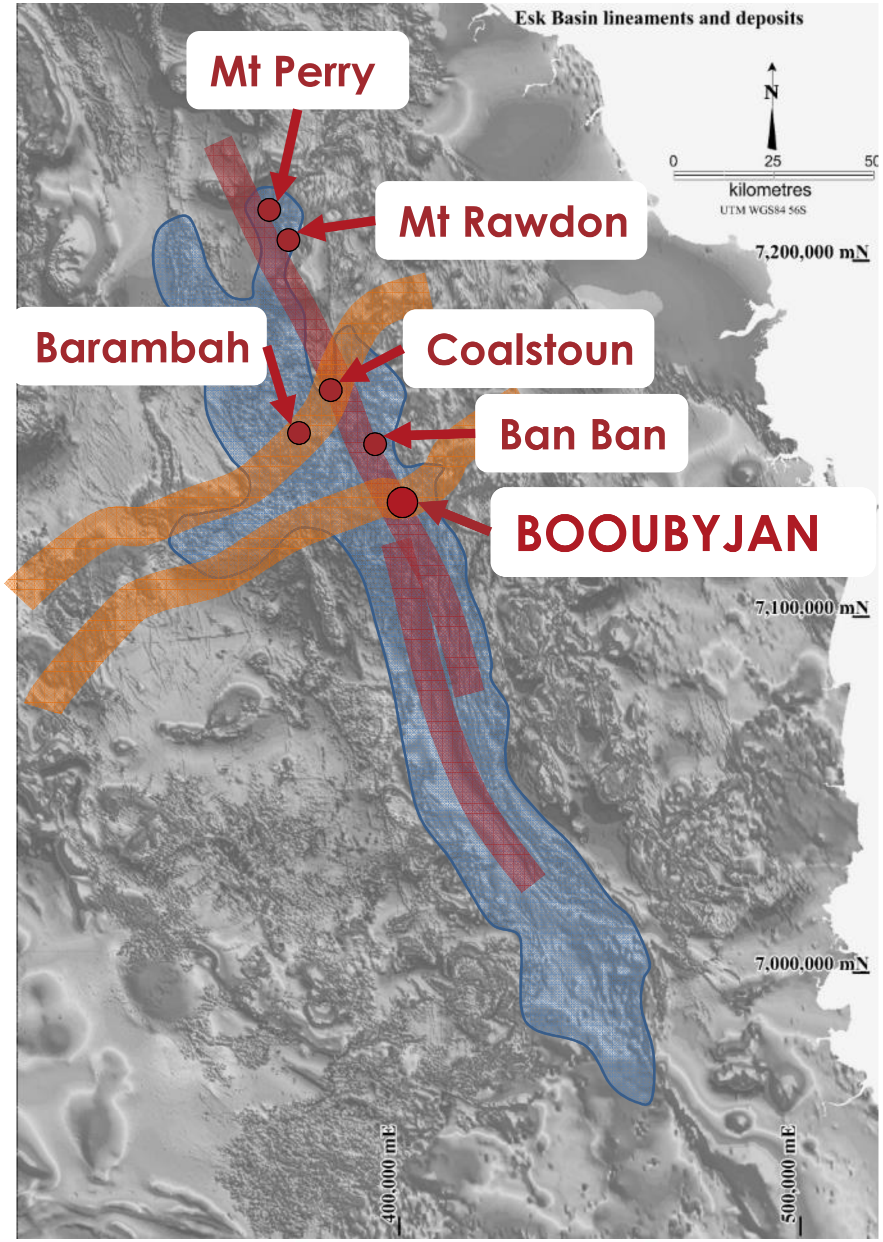
250k regional geology of deposit area

Booubyjan

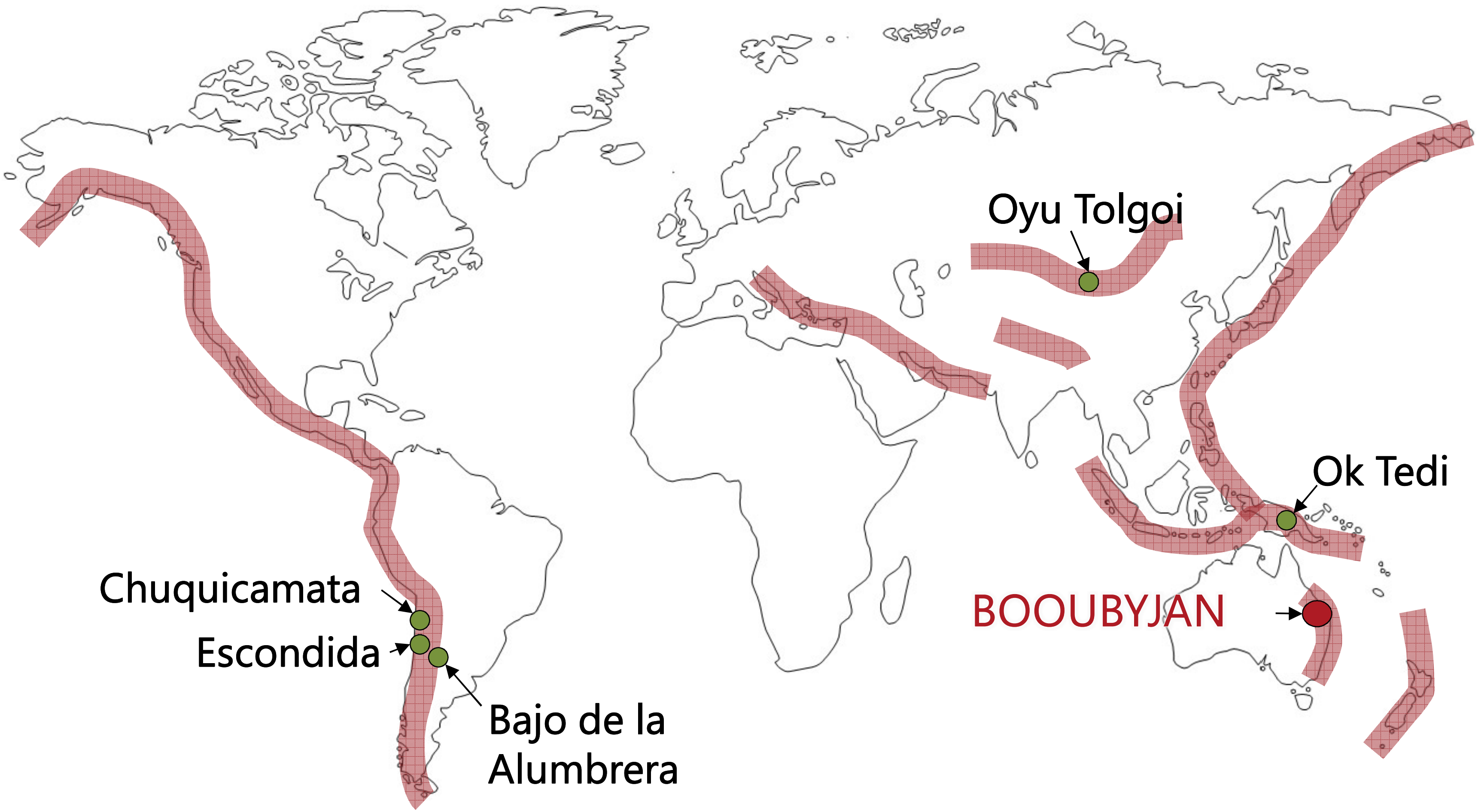
- Found at the intersection of the ENE-trending **Darling River Lineament** and the NNW-trending **Perry Fault System.**

- Other mineral deposits in the Esk Basin include:
    - **Mt Perry** mesothermal Cu-Au.
    - **Mt Rawdon** breccia-hosted Au.
    - **Coalstoun** Cu-(Au) porphyry.
    - **Ban Ban** Zn skarn.
    - **Barambah** epithermal Au.

- Demonstrate the overall prospectivity of the Esk Basin and the influence of the Perry Fault.

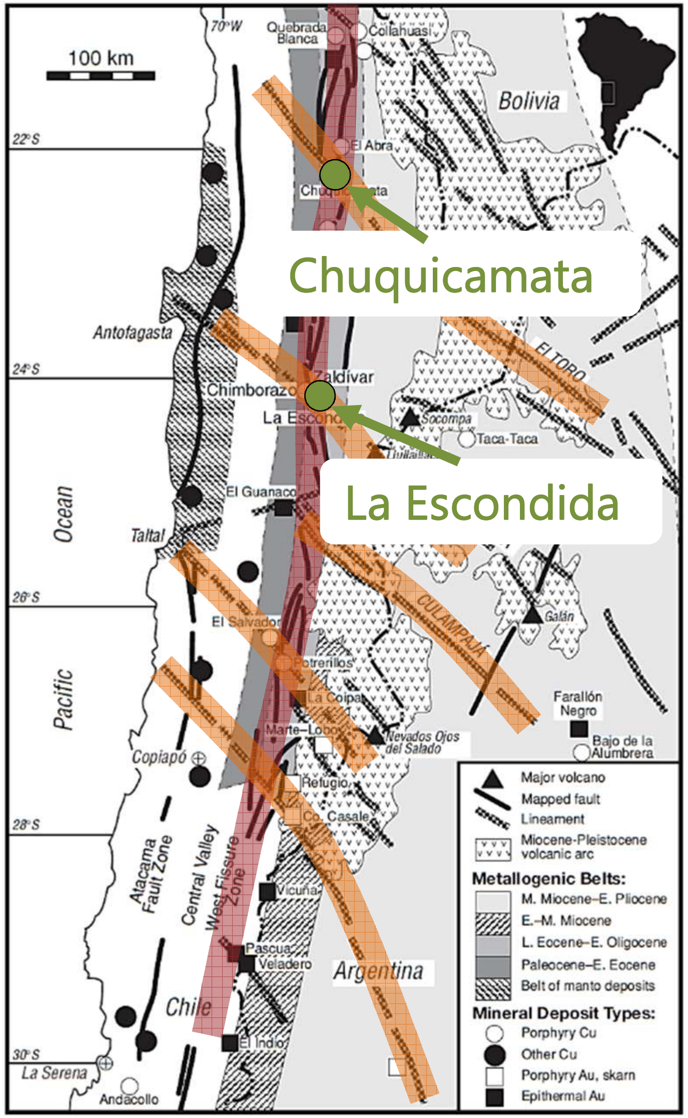


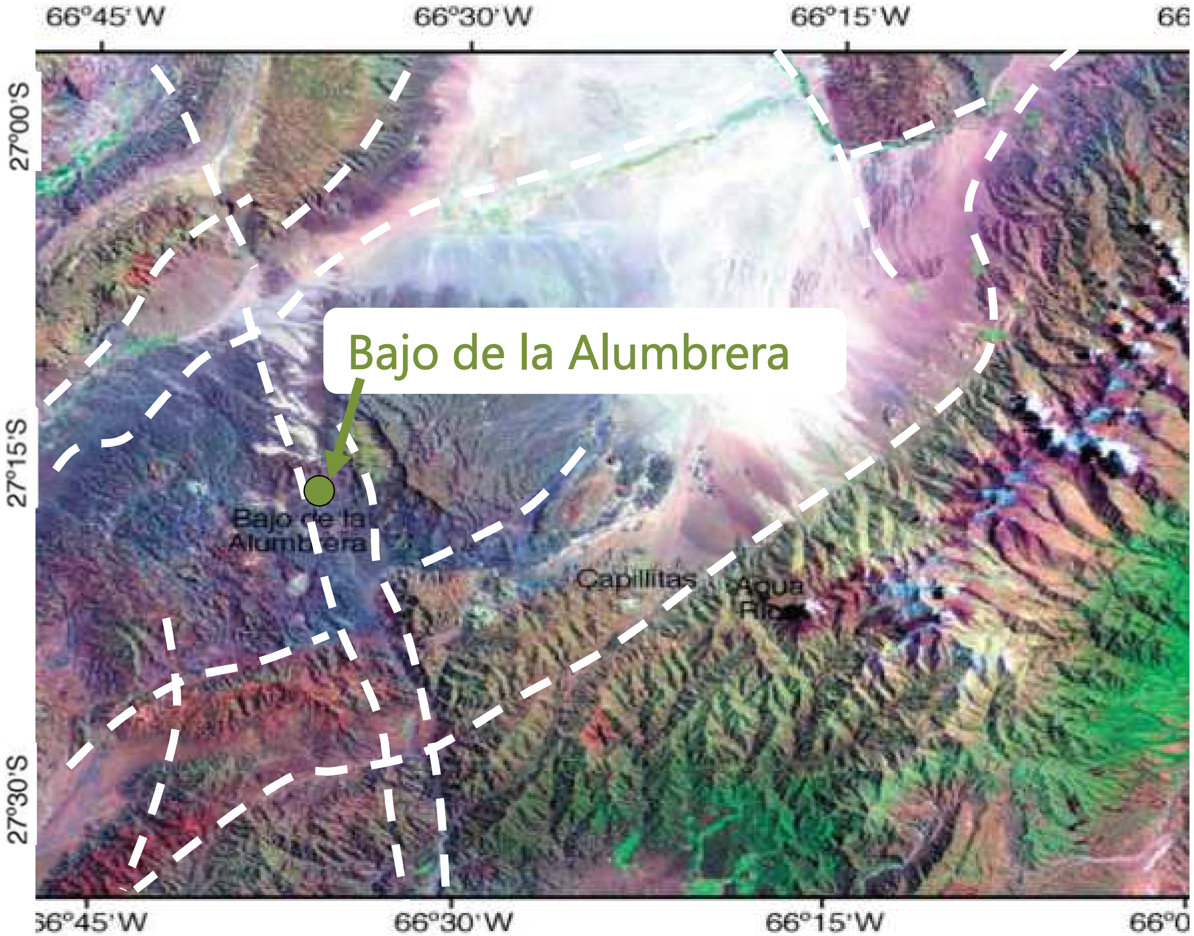
Porphyry belts and deposit examples



Location of porphyry deposit examples cited in this presentation

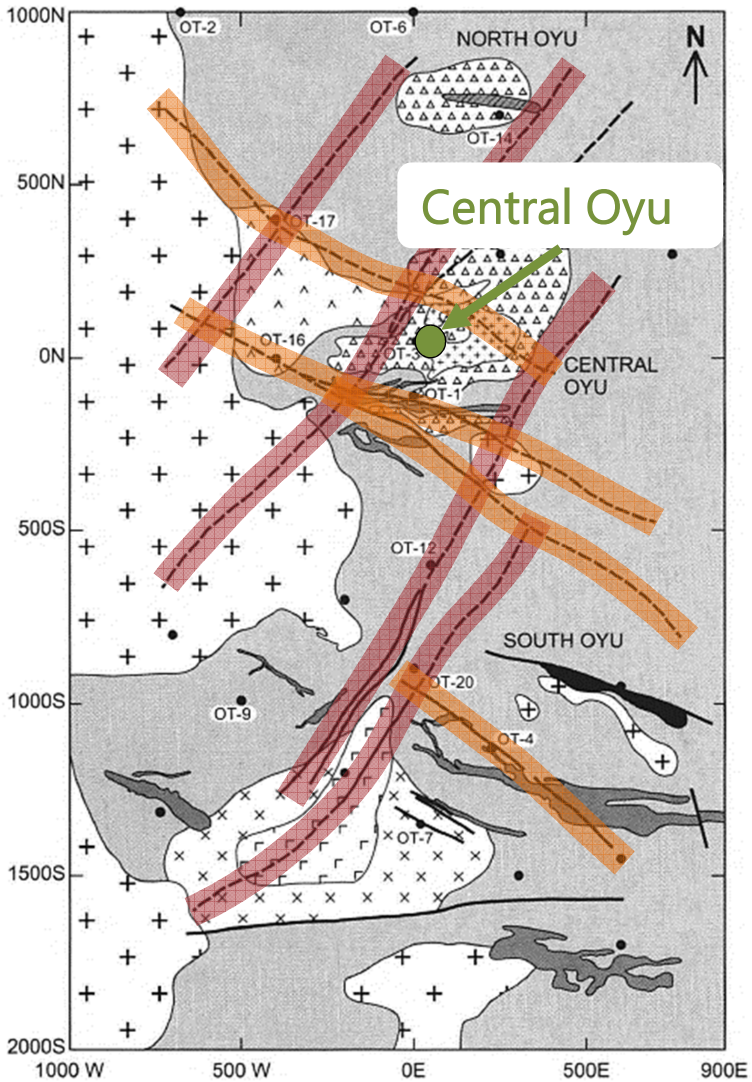
Examples: Northern Chile and Argentina

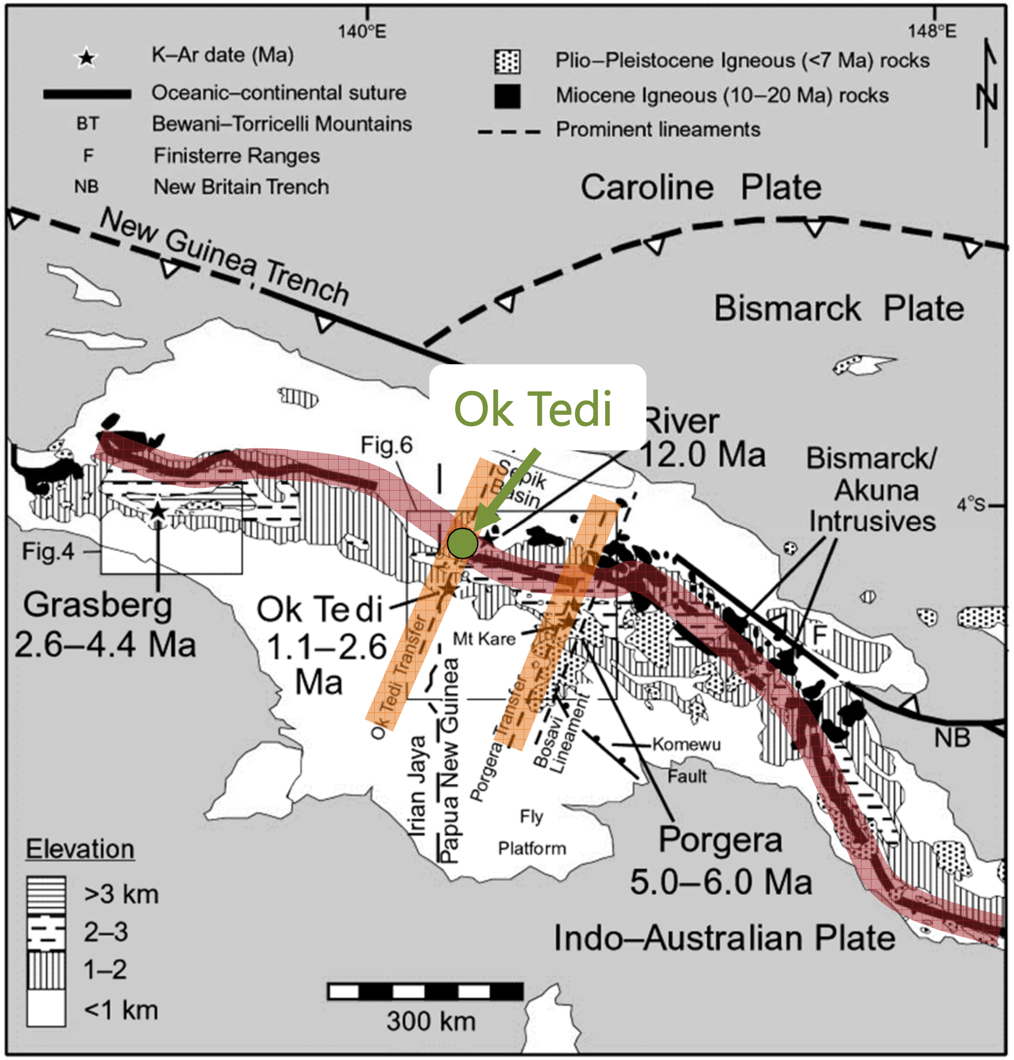




Left: Chuquicamata and La Escondida in Northern Chile (Richards, 2001)
Right: Bajo de la Alumbrera district in Argentina (Chernicoff *et al.*, 2002)

Examples: Mongolia and New Guinea





Left: Oyu Tolgoi, South Gobi region of Mongolia (Perelló *et al.*, 2001)
Right: Ok Tedi, New Guinea. Hill *et al.*, 2002.

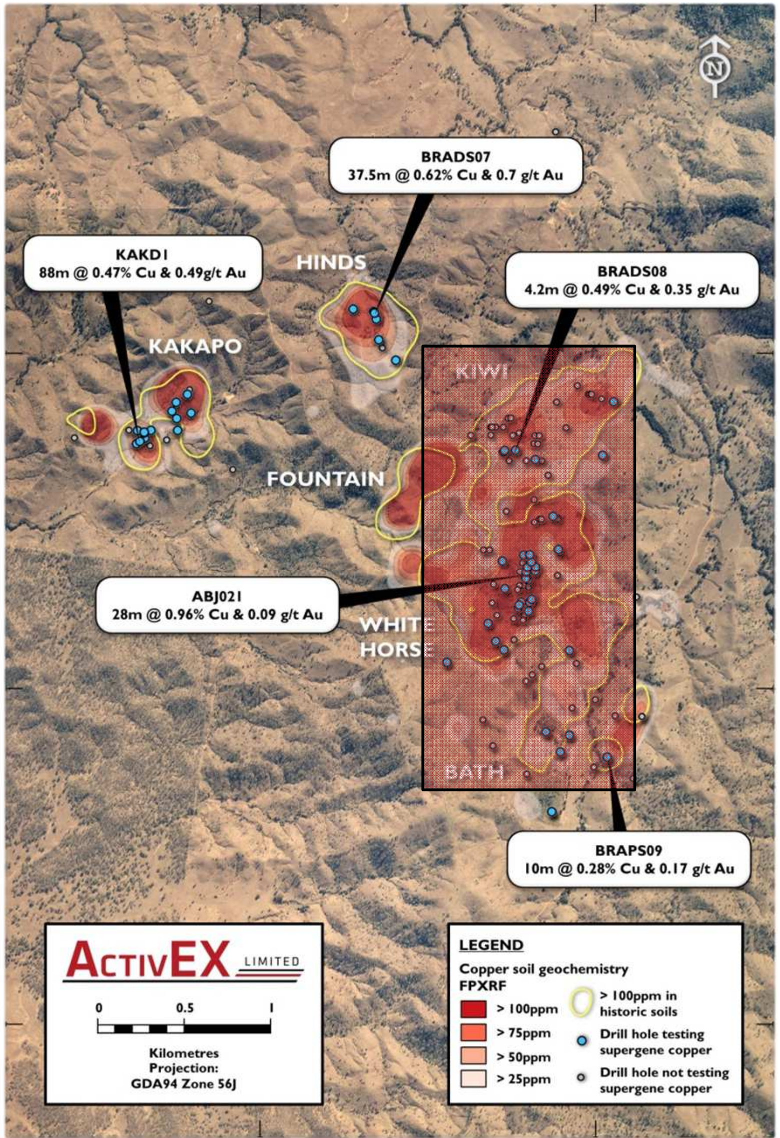
Booubyjan Intrusive Complex

- **Exploration since the late 1960s:**
  - Kennecott: regional stream sampling 1967-1970.
  - Numerous companies since 1970, targeting largely **Cu at the White Horse Porphyry** and **Kiwi Porphyry.**
  - **Less** exploration at the **Kakapo Porphyry** and **Hinds Porphyry.**

- Best intersections:
  - **28m @ 0.96% Cu** & 0.09g/t Au (White Horse).
  - **37.5m @ 0.62% Cu & 0.7g/t Au** (Hinds).
  - **88m @ 0.47% Cu & 0.49g/t Au** (Kakapo).

- ActivEX concentrating on the **White Horse-Kiwi-Bath system** (2005-present).

- **Kakapo-Hinds** contain significantly more Au and needs more work to define the system.



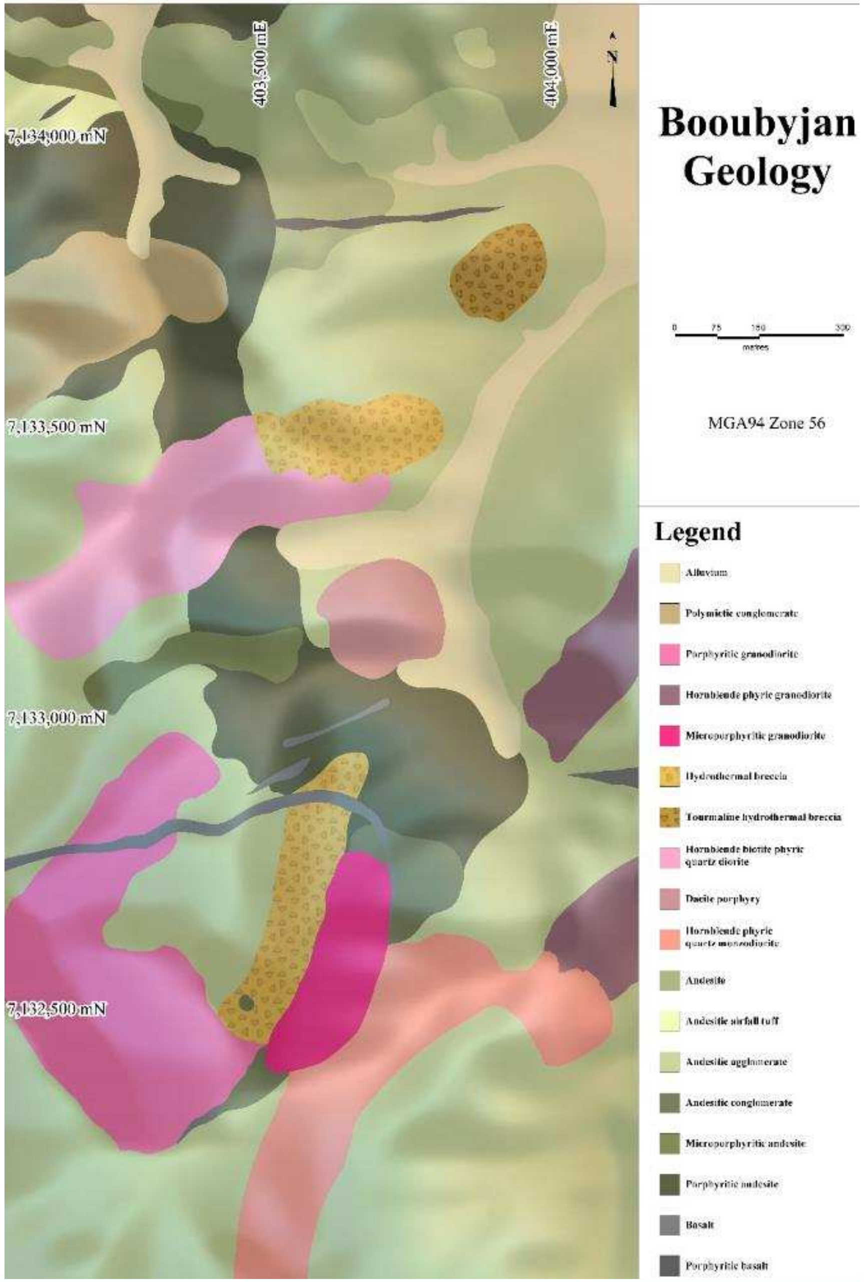
Local geology

- Dominated by the **Mt Marcella Volcanics.**
  - Andesitic pyroclastics, lavas and sediments.

- Co-magmatic I-type **porphyritic intrusives.**
  - Diorite, quartz diorite, quartz monzodiorite, and granodiorite.

- **Magmatic-hydrothermal breccias** peripheral to intrusive centres.
  - **Mineralised breccias.**
    - Quartz-magnetite vein fragments.
  - **Quartz-tourmaline ± pyrite** cement .
    - May grade to biotite-cemented breccia at depth, e.g. Los Bronces-Río Blanco in central Chile (Vargas *et al.*, 1999).

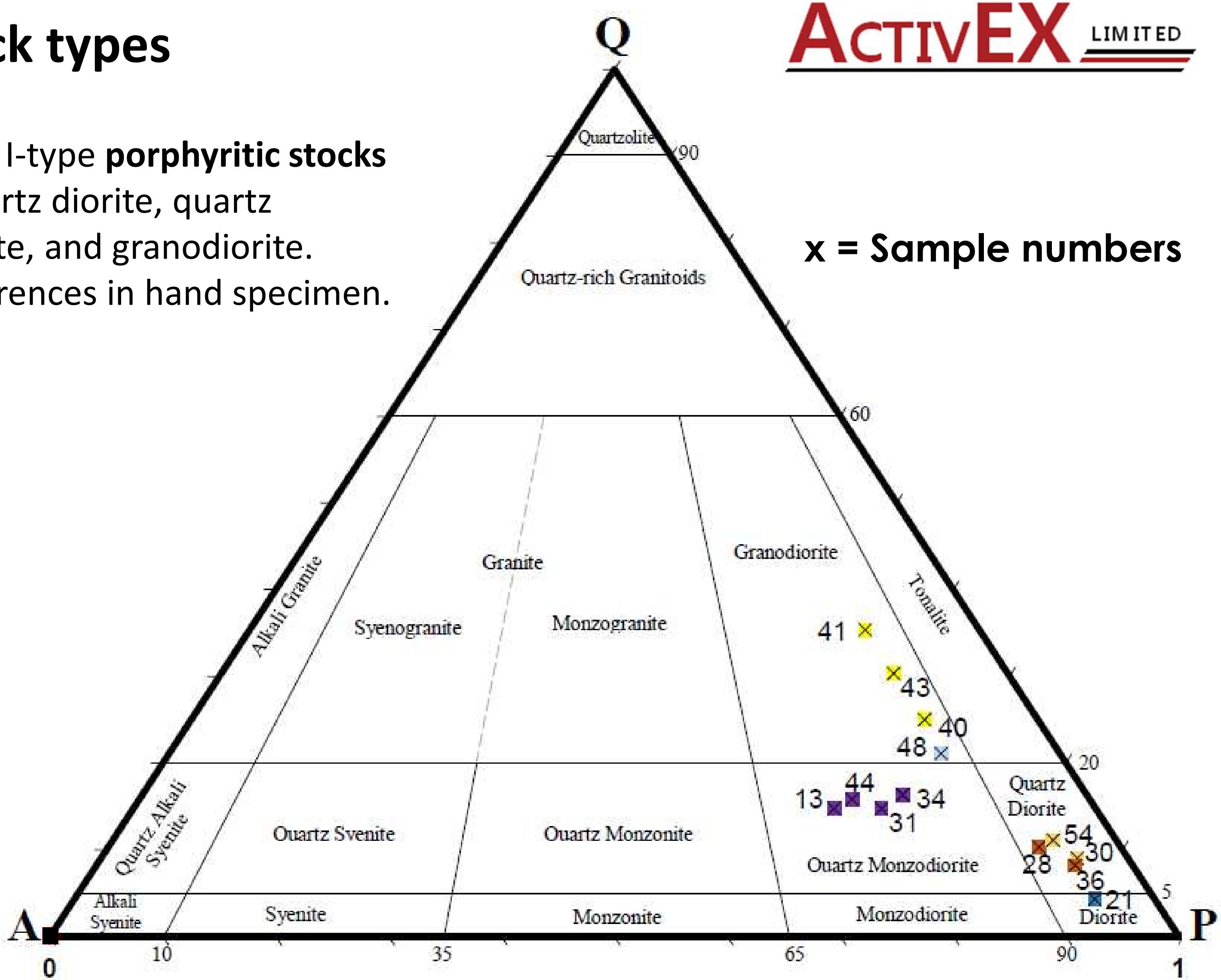
- Post-mineralisation mafic dykes and fluvial conglomerates.



Primary rock types

- Co-magmatic I-type **porphyritic stocks**
  - Diorite, quartz diorite, quartz monzodiorite, and granodiorite.
  - Subtle differences in hand specimen.

x = Sample numbers



Primary rock types


Horn-phyric granodiorite, E from WH


Horn-Bt-phyric Qtz diorite


Microgranodiorite, WH

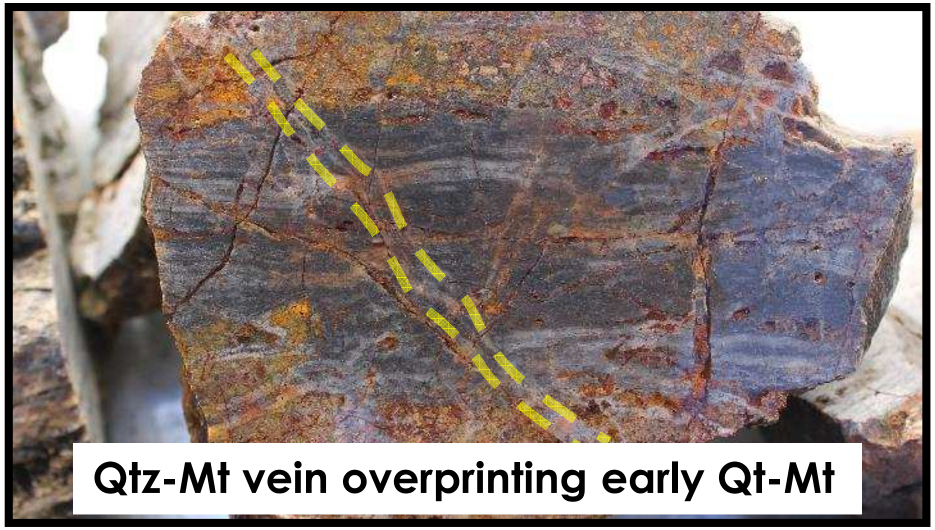
Andesite porphyry, N from WH

Veins

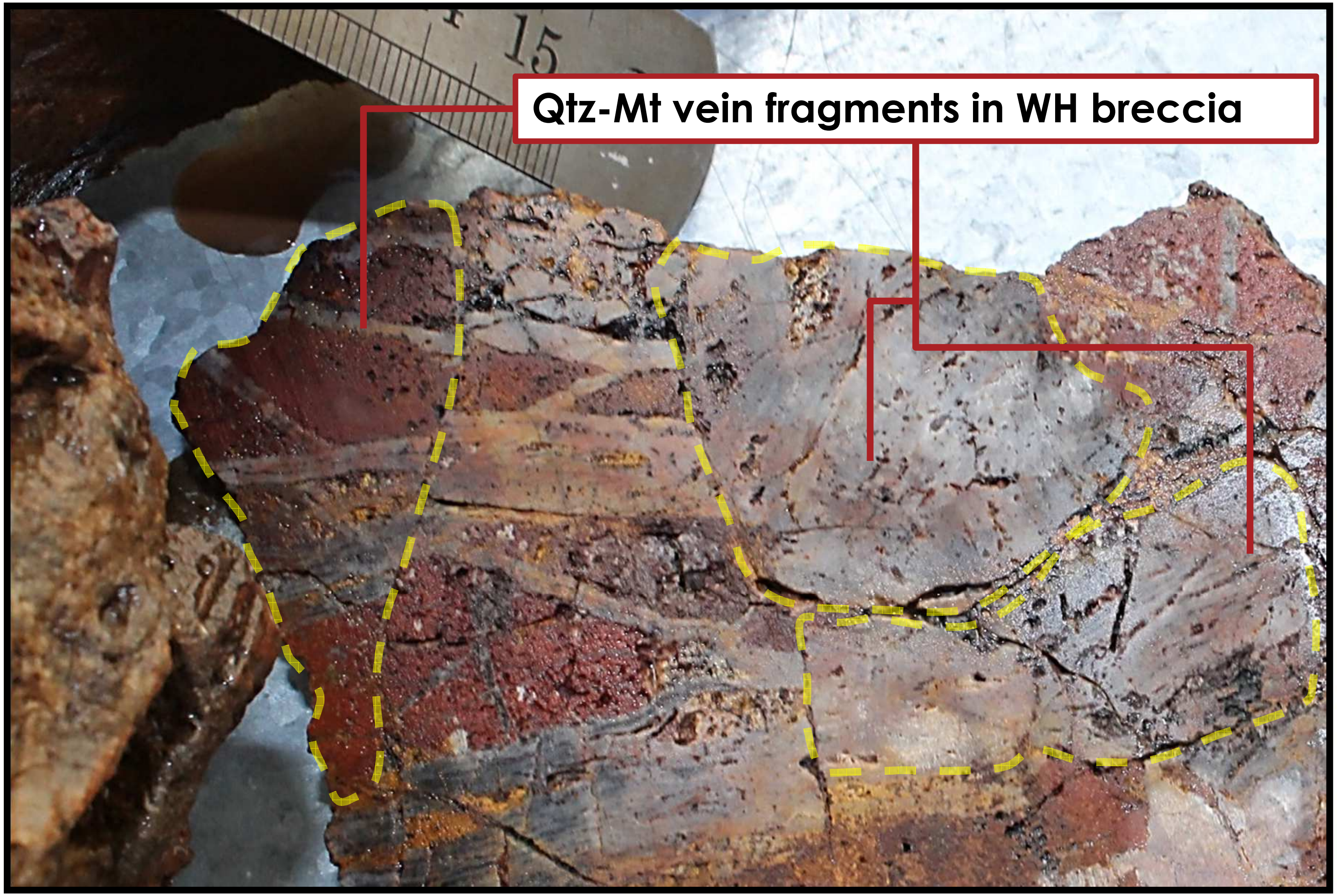
Sheeted laminated Qtz outcrop


Laminated Qtz + ex-sulfide boxwork


Laminated Qtz-Mt stockwork veins

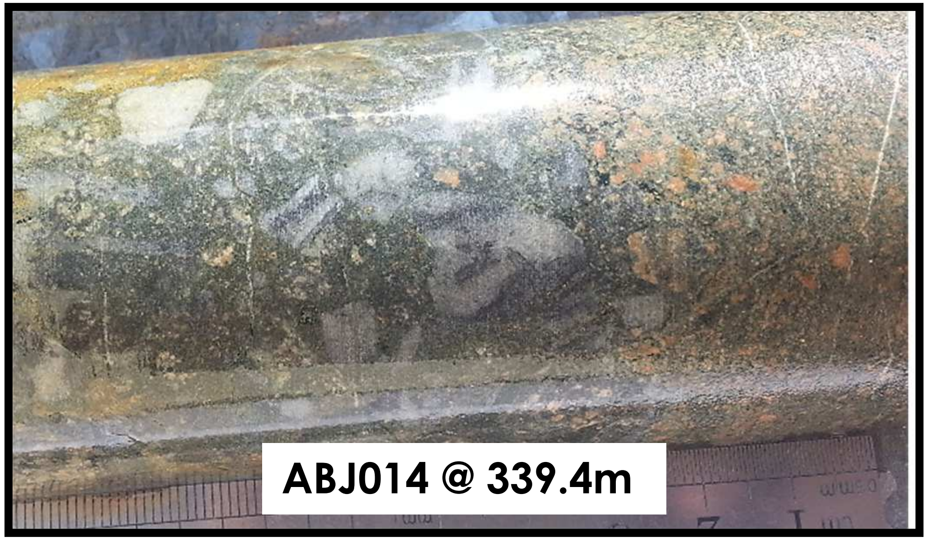

Qtz-Mt vein overprinting early Qt-Mt

Hydrothermal breccias



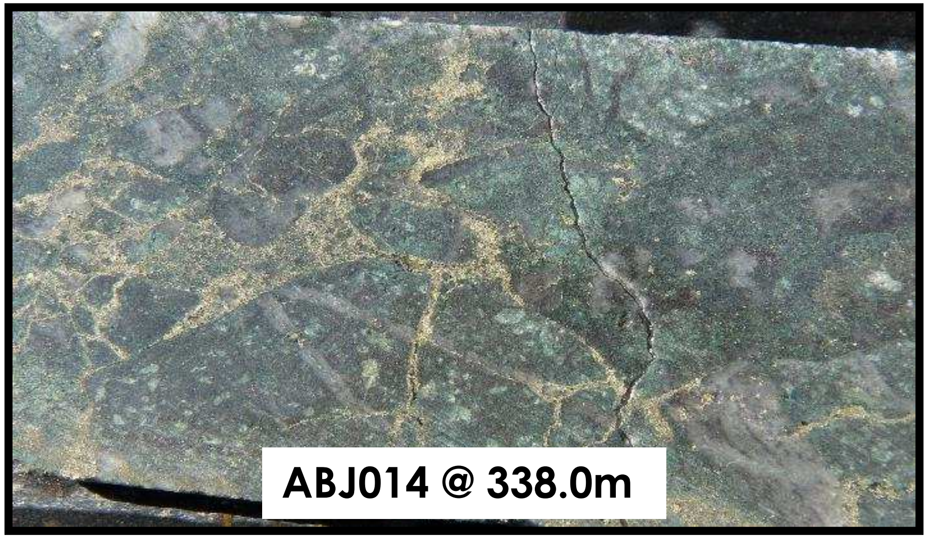
Hydrothermal breccias

White Horse surface sample



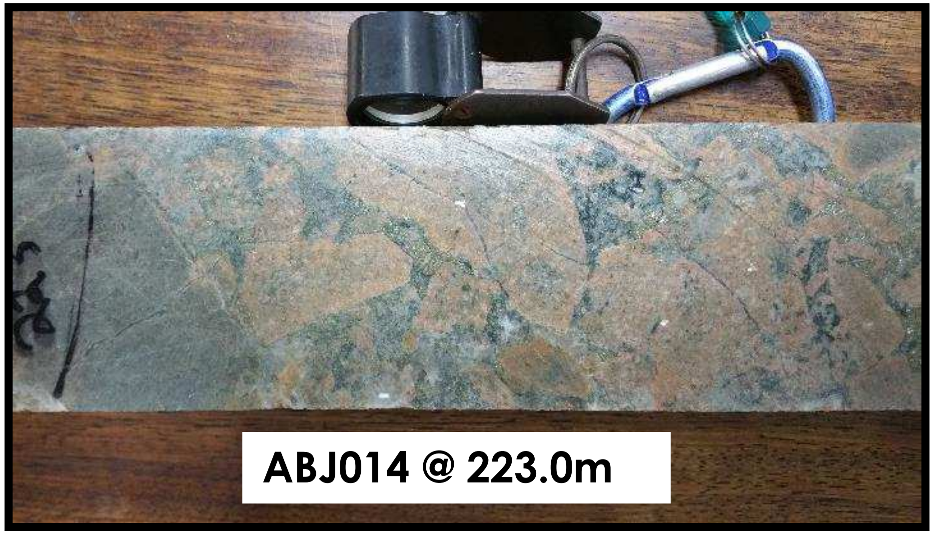
ABJ014 @ 339.4m

ABJ014 @ 349.7m



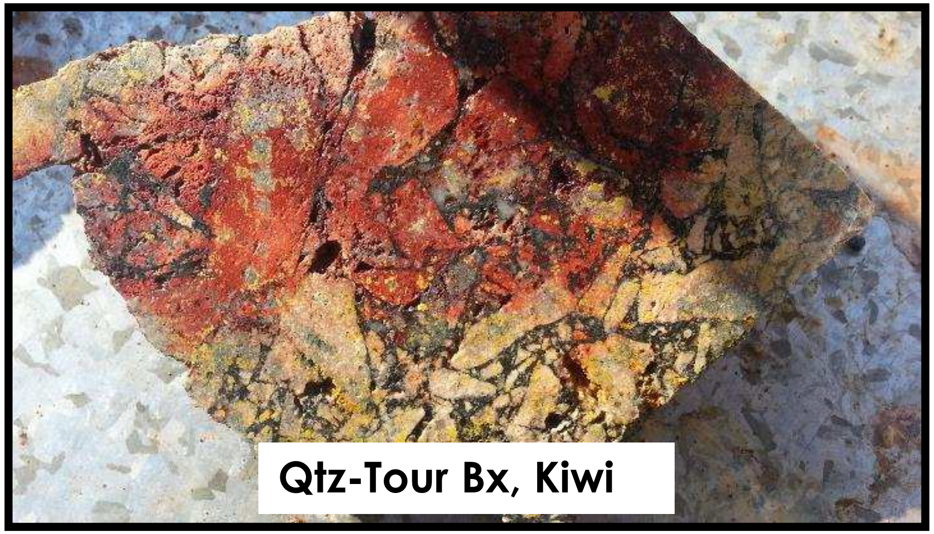
ABJ014 @ 338.0m

Hydrothermal breccias


ABJ014 @ 223.0m


ABJ014 @ 223.0m

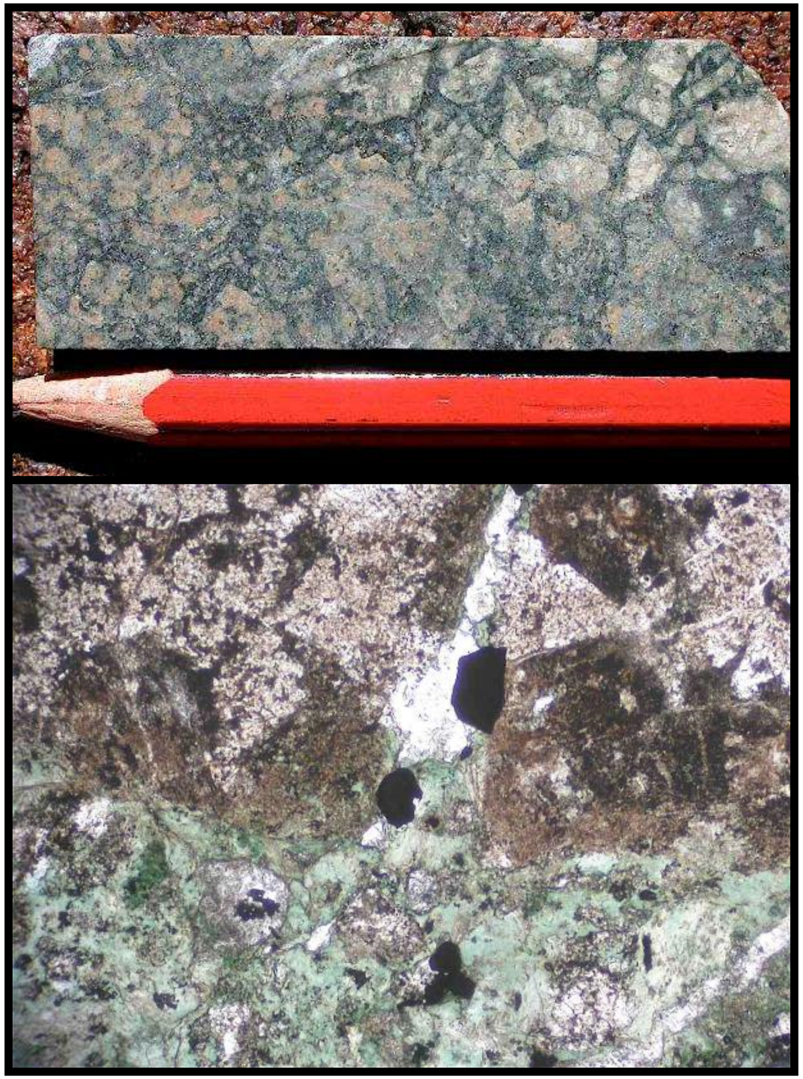

Qtz-Tour Bx, Kiwi


Qtz-Tour Bx, Kiwi

Hydrothermal alteration

- Multi-stage, overprinting alteration assemblages.
  - Polyphase hydrothermal history.
  - Controlled by the composition of the host rocks and the mineralising intrusions.

- **Potassic alteration:** most common in fragments within the magmatic-hydrothermal breccias.
  - Biotite-magnetite-anhydrite ± actinolite ± pyrite ± chalcopyrite ± bornite ± molybdenite; M-type veins.
  - Assemblage suggests that the hydrothermal fluids were relatively oxidised.
    - Stable anhydrite, pyrite and magnetite.
  - ↑ $K_2O/(Na_2O+K_2O)$, ↑ Cu, ↑ Mo, ↓ Sr/Ti.
  - Overprinted by propylitic alteration.

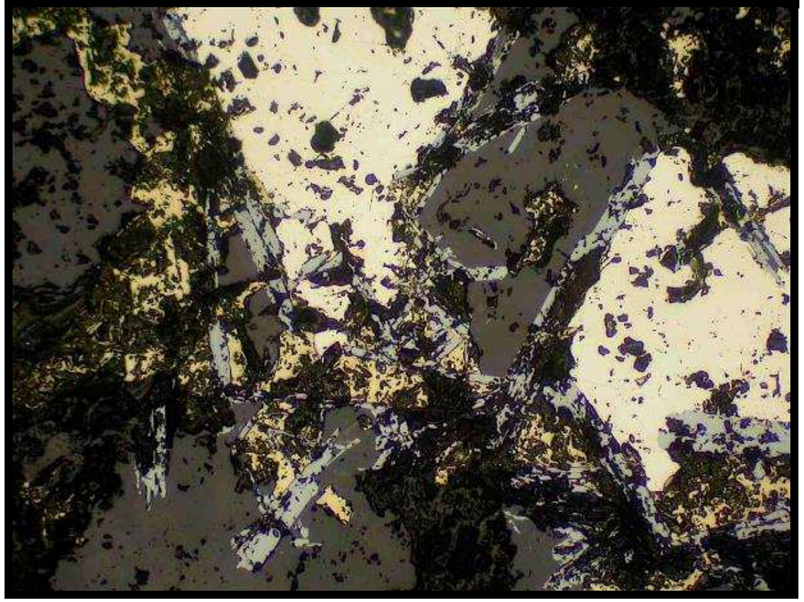


ABJ014 @ 381.4m

Hydrothermal alteration

- **Potassic alteration:**
  - Biotite-magnetite-anhydrite ± actinolite ± pyrite ± chalcopyrite ± bornite ± molybdenite
    - Biotite-(magnetite-anhydrite) in former ferromagnesian sites and groundmass.
    - K-feldspar restricted to vein selvedges.
      - Fe- and Mg-rich host rocks and intrusives.

  - Overprinted by propylitic alteration
    - Plagioclase → Hem dusted albite ± (sericite, carbonate, chlorite, epidote).
    - Biotite → Chlorite with trace titanite and/or rutile ± (sericite, pyrite, hematite).
    - Anhydrite → gypsum.
    - Magnetite → (hematite).
      - Anhydrite and magnetite better preserved.



ABJ014 @ 397.6m

Hydrothermal alteration

- **Propylitic alteration**:
  - Most common at Booubyjan.
  - Chlorite-carbonate-albite ± epidote ± sericite ± gypsum ± hematite ± rutile.

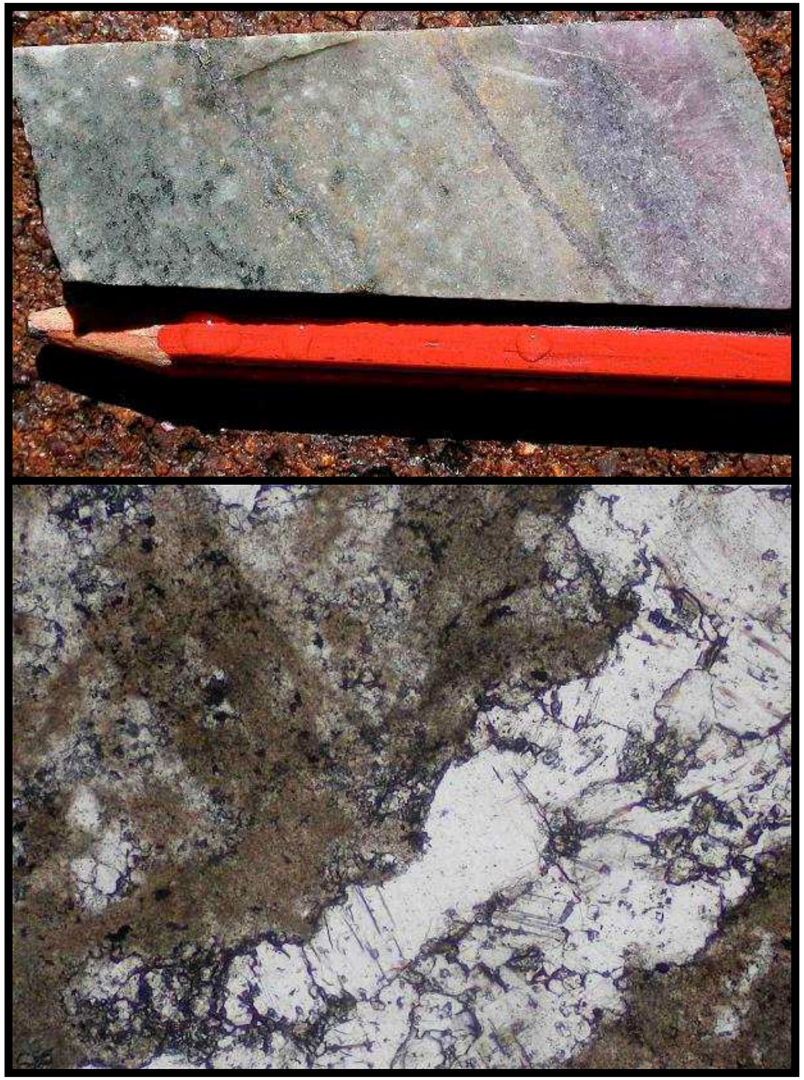
- Due to diagenesis / burial prior to, during, and post-emplacement of the intrusives, and possibly due to overprinting by nearby intrusives.
  - Assemblage suggests that the oxidation state of the fluids remained relatively high during retrograde alteration.
    - Stable epidote, hematite and gypsum.

Example of altered volcanic breccia, ABJ004 @ 125.9m

Hydrothermal alteration

- **Phyllic alteration:** irregularly overprints potassic and propylitic alteration.
  - Quartz-sericite-pyrite ± anhydrite ± chlorite.
  - Formed by acidic fluids from cooling intrusions.
  - Best developed at the fractured intrusion margins and within the more permeable pyroclastics.
  - Feldspars → sericite (± chlorite)
  - Ferromagnesian minerals → biotite → chlorite (± rutile, titanite)

- Influenced supergene enrichment at White Horse.



Porphyritic quartz microdiorite, ABJ014 @ 626.55m

Hydrothermal alteration

- **Supergene alteration:** best developed at White Horse – high pyrite content.

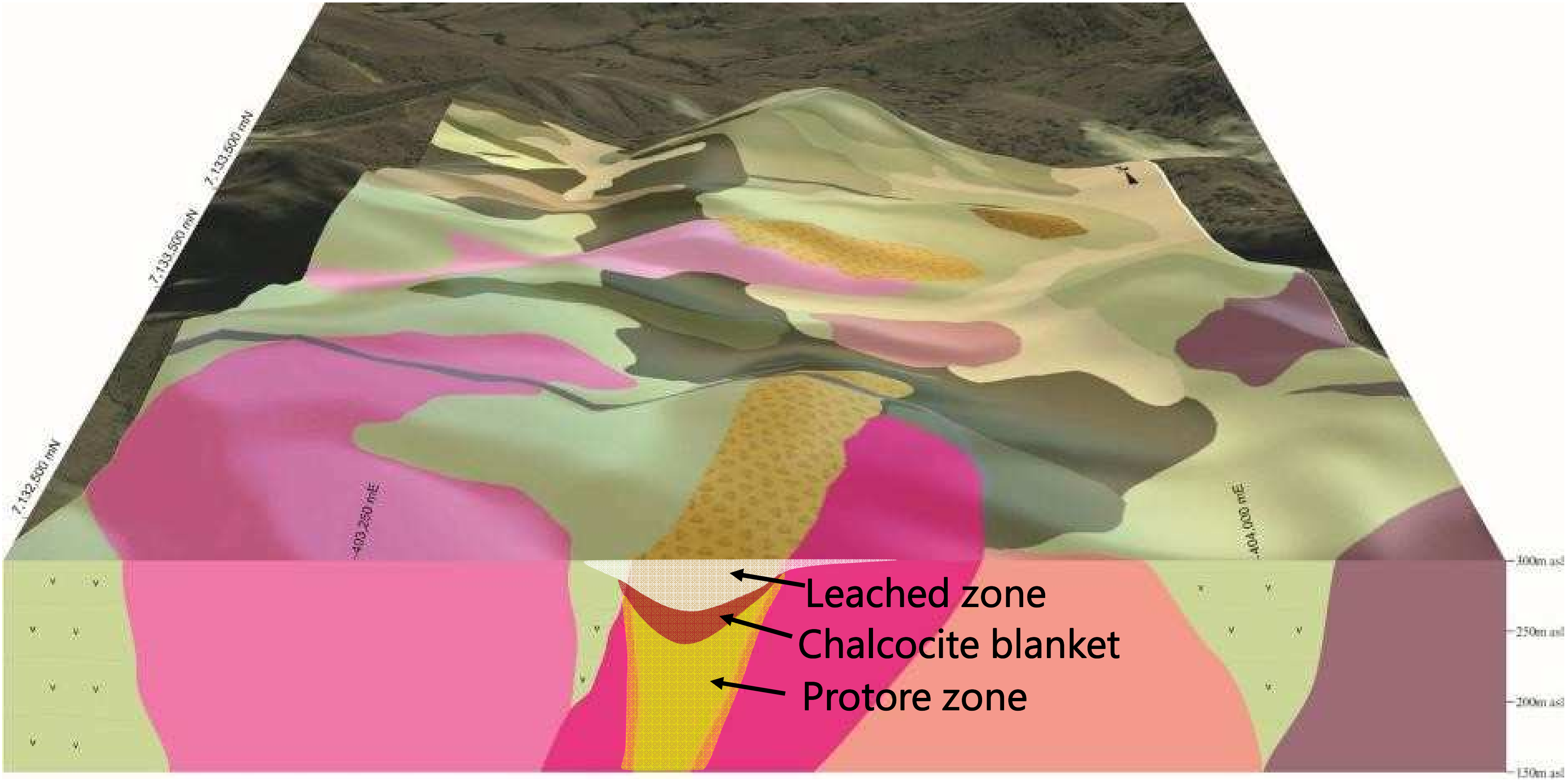
  - Sericite-illite - pyrophyllite - kaolinite-dickite - secondary silica ± jarosite, goethite and hematite.

  - Highly acidic fluids precipitate copper when it reaches the water table.
    - Pyrophyllite: pH 3-4

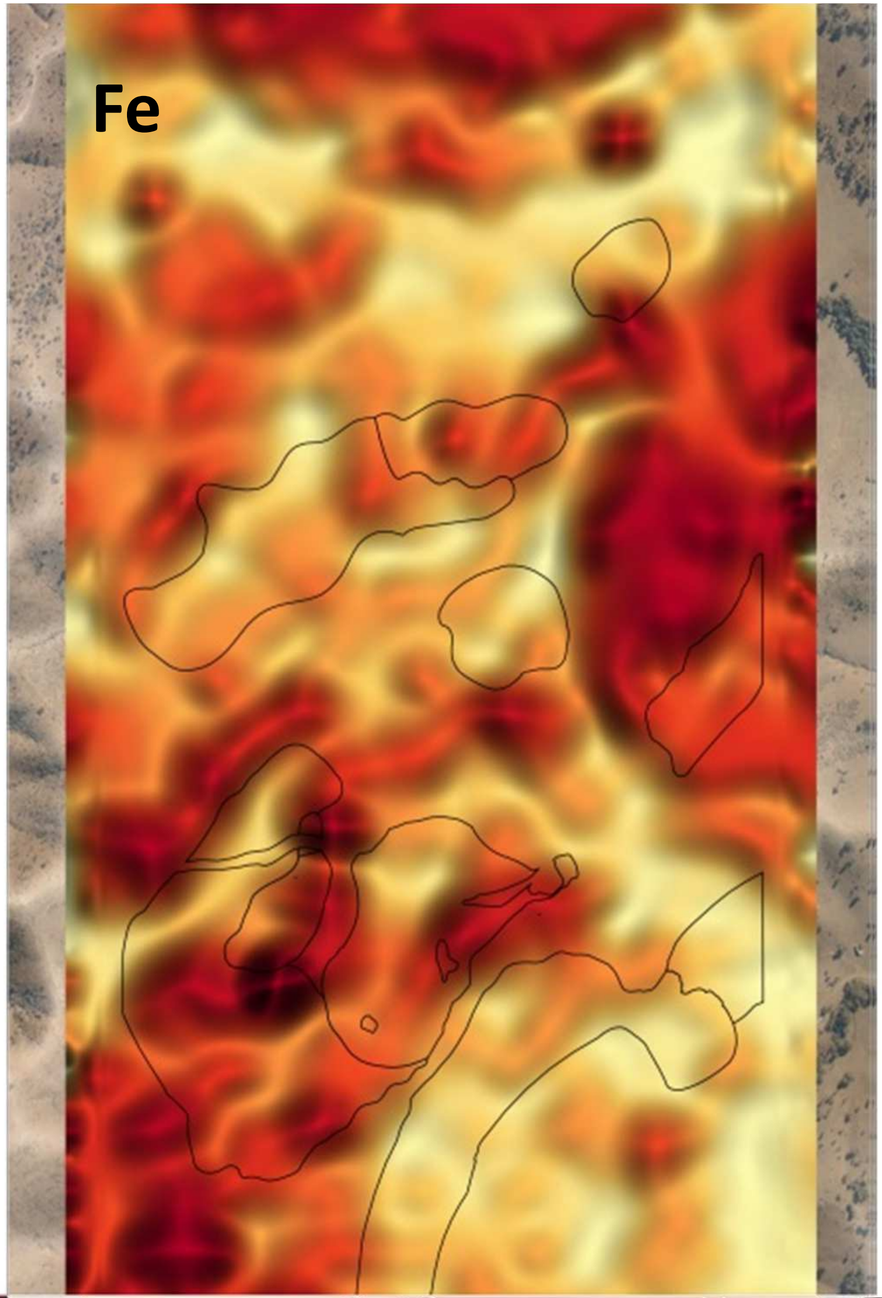
  - Chalcocite ± covellite precipitate around pyrite grains.

  - Leached, bleached and ferruginised outcrops at surface.

Supergene profile at White Horse



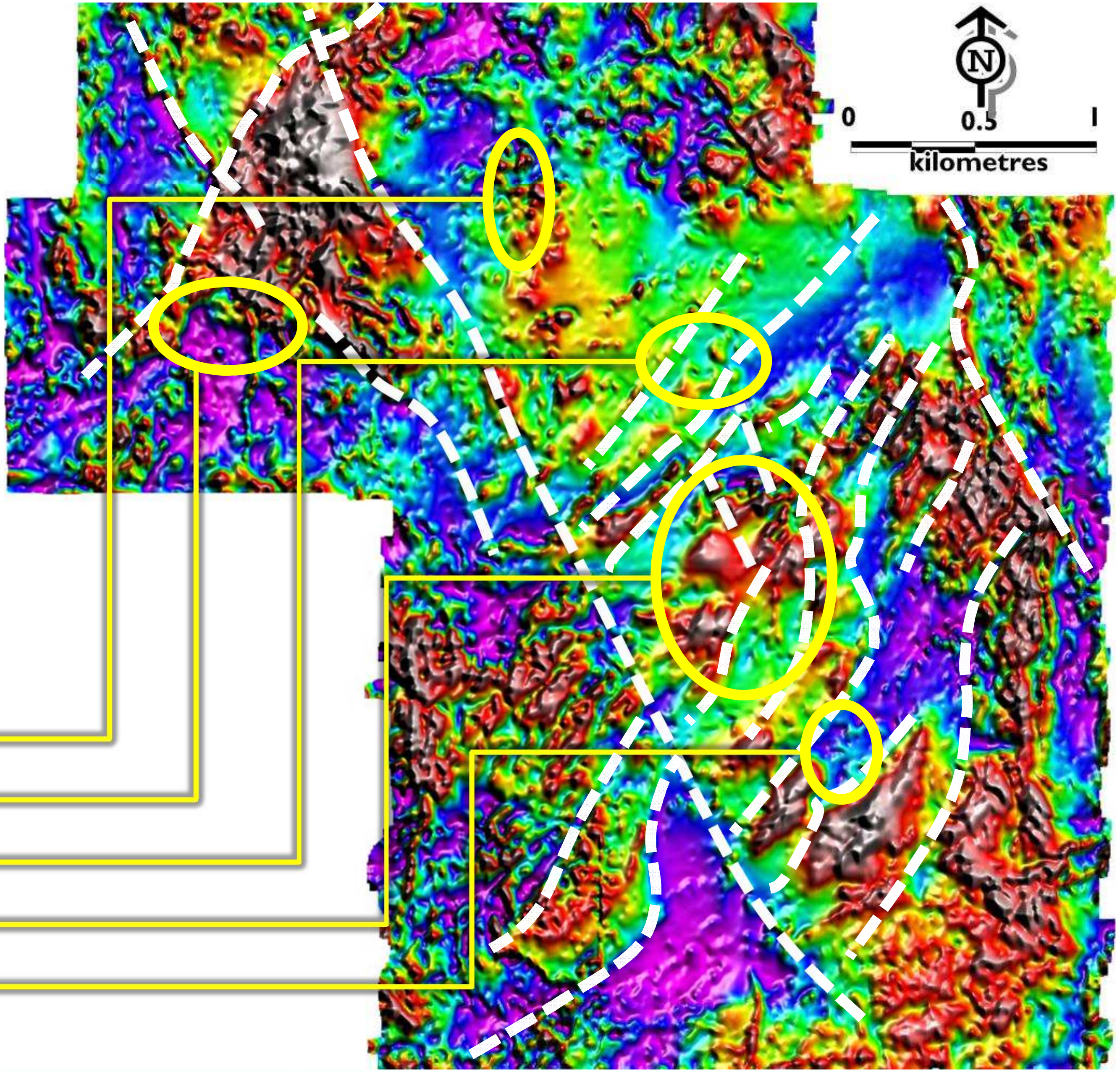
Soil Geochemistry (pXRF)



Geophysics

- **RTP TMI**
  - Two dominant trends: NE and NNW.

- **Complex interpretation:**
  - Primary magnetite in Mt Marcella Volcanics.
  - Production of hydrothermal magnetite during potassic alteration.
  - Destruction of magnetite during retrograde alteration.



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