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

Jose Veracruz\textsuperscript{1,2}, Paul Ashley\textsuperscript{2}, Joshua Leigh\textsuperscript{1}, Nancy Vickery\textsuperscript{2}, - (\textsuperscript{1}ActivEX Limited, \textsuperscript{2}University of New England)

JOSE VERACRUZ – Exploration Geologist
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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, Nearer / Mt Marcella Volcanics, Bryden / Gayndah Formation.
  - Deposited in foreland basin.

- Nearer/ Mt Marcella Volcanics consistent geologically and geochemically with continental margin arc.
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.

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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.
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.
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

Chuquicamata
Escondida
Bajo de la Alumbrera

Oyu Tolgoi
Ok Tedi
BOOUBYJAN

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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)

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Examples: Mongolia and New Guinea

Left: Oyu Tolgoi, South Gobi region of Mongolia (Perelló et al., 2001)


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Booubyjan Intrusive Complex

- Exploration since the late 1960s:
  - 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.

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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.
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

Qtz-Mt vein fragments in WH breccia
Hydrothermal breccias

White Horse surface sample

ABJ014 @ 339.4m

ABJ014 @ 349.7m

ABJ014 @ 338.0m
Hydrothermal breccias

ABJ014 @ 223.0m

Qtz-Tour Bx, Kiwi

ABJ014 @ 223.0m

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.
  - $\uparrow K_2O/(Na_2O+K_2O)$, $\uparrow Cu$, $\uparrow Mo$, $\downarrow Sr/Ti$.
  - Overprinted by propylitic alteration.
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.
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.
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.

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Supergene profile at White Horse

Leached zone
Chalcocite blanket
Protore zone
Soil Geochemistry (pXRF)

Fe

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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.
  
  Hinds  
  Kakapo  
  Kiwi  
  White Horse  
  Bath
Questions?
Ph 07 3174 4810
Fax 07 3236 4288

Suite 3402, Riverside Centre
123 Eagle St, Brisbane QLD 4000

PO Box 1533
Milton QLD 4064

admin@activex.com.au
wwwactivex.com.au