The greenfield Grapple and Bumblebee discoveries of the western Aileron Province: First constraints on sulfide mineralising processes

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NTGS Aileron Province Copper Study
Project under the CORE initiative to study the temporal and genetic relationship between the copper-endowed mineral systems in the Aileron Province

Legend
- Cu mineral systems in this study

after McGloin et al (2016) AGES Abstract
Aileron Province (simplified):
- Sedimentary rocks with maximum depositional ages between ca 1.86 and 1.79 Ga
- Extensive magmatism and metamorphism between ca 1.82 and 1.69 Ga
- Localised magmatism in the southeast during the ca 1.64–1.63 Ga Liebig Orogeny
- Periodic localised metamorphism and deformation until ca 1.56 Ga, and during younger events including the Alice Springs Orogeny and Larapinta Event
Warumpi Province (*simplified*):
- Bound to the Aileron Province by the Central Australian Suture
- Metasedimentary successions at ca 1.66–1.64 Ga and 1.64–1.60 Ga
- Magmatic rocks at ca 1.68–1.66 Ga, 1.64–1.63 Ga, and 1.61–1.60 Ga
- Extensive magmatism associated with the Liebig Orogeny at ca 1.64 Ga.
Independence Group’s Lake Mackay Project

Greenfields polymetallic sulfide mineralisation (Cu-Zn-Au-Ag-Pb)
Bumblebee
Grapple
Aileron Province
Lander Rock Formation
Du Faur Suite
Nyirripi Beds
Du Faur Suite
Andrew Young Igneous Complex
Warumpi Province
Central Australian Suture
Lander Rock Formation
10 km
Independence Group’s Lake Mackay Project

Metasedimentary host rock (Lander Rock Formation)
Independence Group’s Lake Mackay Project

Intruded by mafic igneous rocks
Independence Group’s Lake Mackay Project

Mineralisation occurs mainly in layered brecciated lenses in the Lander Rock Formation between two large mafic sills.
Mineralisation at Grapple and Bumblebee

Net-textured pyrrhotite within S2 fabric in the Lander Rock Formation – interpreted as metamorphosed diagenetic pyrite

Chalcopyrite–pyrite-bearing quartz vein that cross cuts a foliated amphibole–quartz mafic rock
Arsenopyrite within a pyrrhotite breccia. The breccia engulfs clasts of altered country rock.

Sulfide stringers overprinting mafic rock with an amphibole–quartz–clinopyroxene–carbonate assemblage. Garnet is common, but not shown in this photomicrograph.
Pyrrhotite breccia mineralogy

Arsenopyrite within a pyrrhotite breccia.

Intergrowths within the arsenopyrite grains.

Arsenopyrite, Chalcopyrite, Galena, Pyrrhotite, Löllingite, Chalcopyrite.
Sulfide mineralisation

Brecciated Lander Rock Formation hosting the sulfide mineralisation

Two possible explanations:
• Durchbewegung texture
• Intrusion-related
Lander Rock Formation – Timing of deposition

Mineralisation is hosted within the Lander Rock Formation

U–Pb SHRIMP
Maximum Depositional Age
ca 1855 Ma

- Regionally, maximum depositional ages span the range ca 1.87 – 1.84 Ga and earliest metamorphism recorded at ca 1.81 Ga.

- The maximum depositional age provides a maximum constraint on timing of mineralisation.
Direct dating of mineralisation

- Re–Os age of ca 1.96 Ga of arsenopyrite yielded ages that were older than the timing of maximum deposition of the host ca 1.84–1.81 Ga Lander Rock Formation.

- Pb model ages of ca 1.84–1.83 Ga were obtained for sulfides within the breccias at Grapple – this is a plausible deposition age.

- Pb model ages support possibility that sulfide mineralisation formed syn-genetically.

- No rocks at Grapple or Bumblebee are currently interpreted as metaexhalites or metavolcanics.
Mafic rock intruding the Lander Rock Formation

- Spatially associated with sulfide mineralisation
- Interpreted to intrude the Lander Rock Formation

- Main population at ca 1867 Ma is older than the host Lander Rock Formation (Max dep ca 1855 Ma)
- Single analysis at 1629 ± 21 Ma
Lander Rock Formation – Timing of deformation

Abundant monazite overprints the main $S_2$ fabric, and has an internal microstructure consistent with hydrothermal dissolution–reprecipitation. Monazite that overprints mylonite fabric has age of 1668 ± 7 Ma.

Mafic rock – early phase pre-dating main $S_2$ fabric

Zircon in the mafic rocks show evidence for disturbance at ca 1.64–1.63 Ga

Intercept 1635 ± 12 Ma

Intercept 1627 ± 31 Ma

data-point error ellipses are 68.3% conf.

data-point error crosses are $1\sigma$
Mafic rock – late phase cross-cutting main $S_2$ fabric

- Intrudes deformed Lander Rock Formation
- Show evidence for disturbance at ca 1.64–1.63 Ga
Timing of sulfide mineralisation

- Host **Lander Rock Formation** was deposited after ca 1.84 but prior to ca 1.81 Ga.
- Sulfides in the breccia have Pb isotope model age of ca 1.84–1.83 Ga
- At least two phases of **mafic rock**; one phase intruded pre-deformation, and a second phase intruded between ca 1.67 Ga and 1.64 Ga.
- **Lander Rock Formation** was deformed at or before ca 1.67 Ga.
- The breccia that hosts the sulfide mineralisation was apparently brecciated post-deformation, after ca 1.67 Ga. This breccia hosts sulfide mineralisation.
- Extensive magmatism and associated fluid influx at ca 1.64 Ga.
Timing of sulfide mineralisation

Model 1: Syn-depositional

- Volcanic or sediment-hosted massive sulfide mineralisation formed syngenetically at ca 1.84 Ga.
- Sulfide mineralisation was deformed or remobilised after ca 1.67 Ga.
- No rocks at the prospects are currently interpreted as metavolcanics or metaexhalites.

Model 2: Epigenetic (intrusion related)

- The host-breccia cross-cuts the fabric of the Lander Rock Formation, suggesting this brecciation occurred after ca 1.67 Ga.
- Breccia formation and mineralisation has a magmatic-hydrothermal origin associated with regional ca 1.64 Ga magmatism.