Developing Indicator Minerals for Nickel Sulfide Exploration

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We highlight the chemical changes in minerals that indicate prospectivity for nickel sulfide in intrusions and komatiitic systems

Case Studies

Komatiite Systems

- Emu Lake
- Highway + Goongarrie
- Carlingup Range
- Widgiemooltha
- Black Swan

Intrusion-Hosted Systems

- Cathedrals belt
- Carr Boyd
- Western Gawler

World class Ni deposits/mines

- Nova-Bollinger, Australia
- Norilsk-Talnakh, Siberia
- Kabanga, Africa
- Sakatti, Finland
- Kevitsa, Finland
- Kotalahti, Finland
- Curaçá Valley, Brazil
- Savannah, Australia

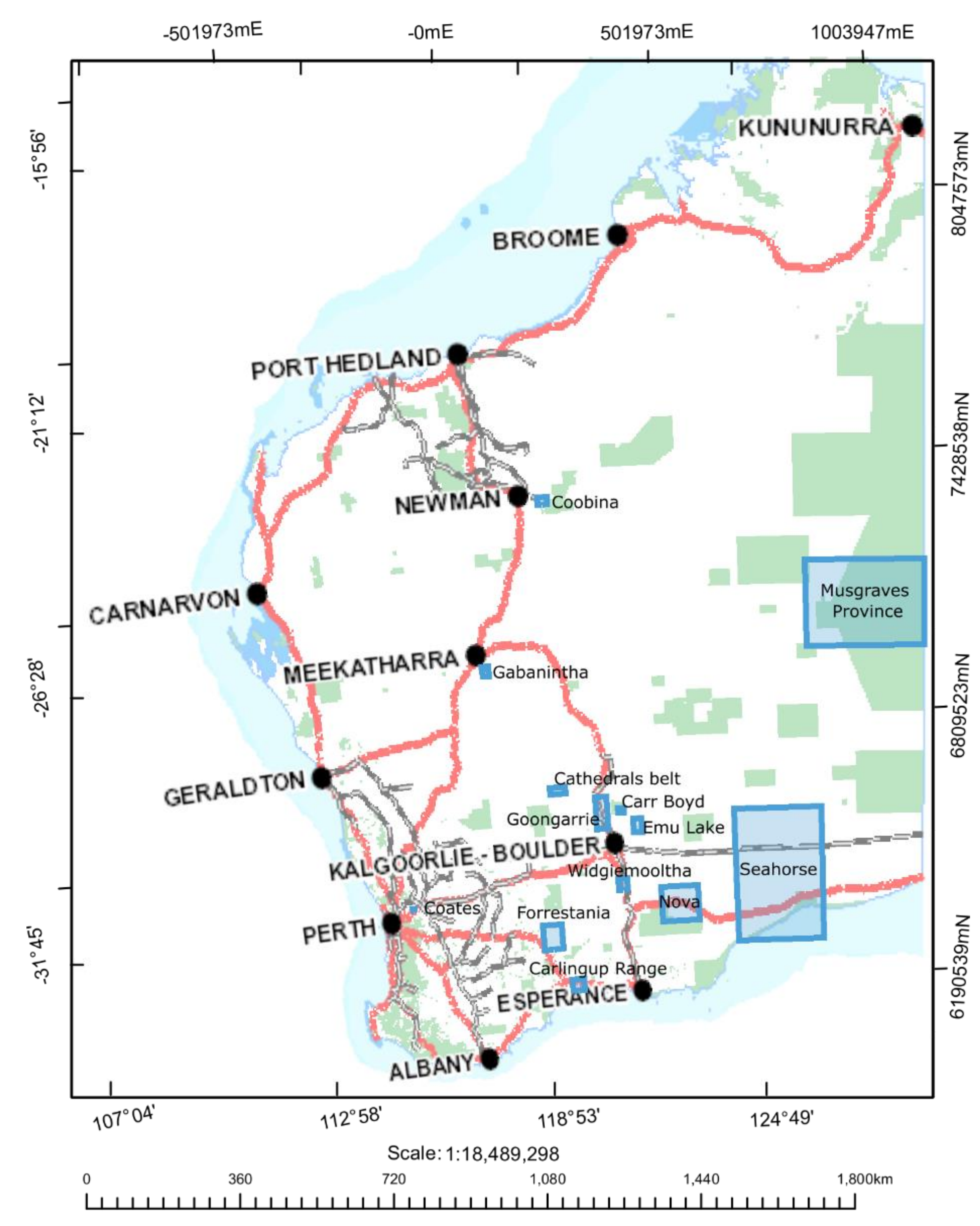

Figure 1: Location of the case studies used in this study, except the Western Gawler in South Australia.

Analysis Methods

Samples were measured using the scanning electron microscope (SEM) with automated mineralogy software (TIMA) to measure their mineral volumes and major element mineral chemistry. Intra-grain chemical zonation was measured using XRF mappers including the Bruker M4, Maia Mapper and the XFM beamline at the Australian Synchrotron. Trace elements in minerals were measured using the laser ablation inductively coupled plasma mass spectrometer (LA-ICP-MS). This allows analysis of ~60 elements in each mineral. A series of machine learning models were trained on mineral chemistry data, providing a range of potential data-driven indicators.

Sampling

The major and trace element signatures for prospectivity that were developed in this study were collected in-situ from well-characterised rock samples. These signatures were then applied to ex-situ minerals to assess prospectivity.

Indicator minerals can be sampled at the surface, in soil, regolith, transported cover or stream sediments. Stream sampling has been done on a continental scale with Geoscience Australia's Heavy Mineral Map of Australia which allows for continent scale surface prospectivity maps to be created. Indicator minerals can also be very useful in areas of deep cover where indicator minerals can be sampled at unconformities (Fig 2) allowing a wider footprint of sampling and prospectivity assessment with sparse drilling. Indicator minerals can also be used in-situ in intrusions to determine the likelihood of sulfide presence with minimal drilling.

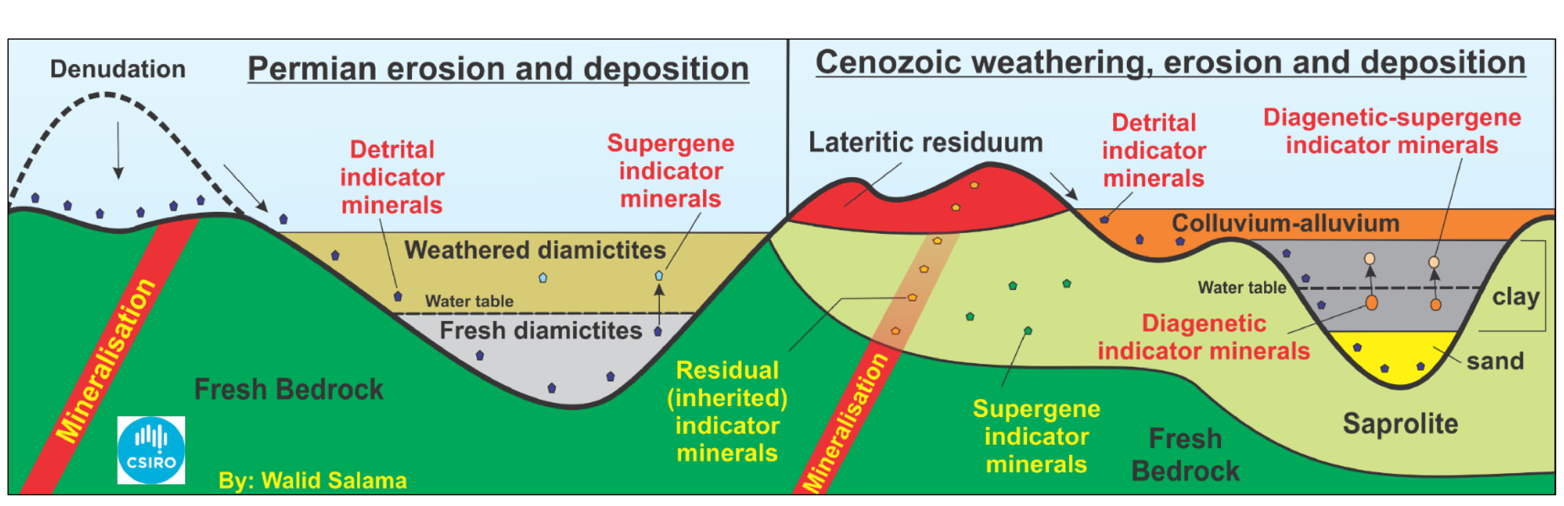

Figure 2: Schematic illustration showing where different types of indicator minerals and sulfides may be found in the landscape.

Olivine

Nickel depletion in olivine in komatiitic system has been shown to indicate sulfide saturation. In intrusion hosted systems, a variable nickel range in olivine with a constant Mg value is thought to indicate sulfide saturation (Barnes et al. 2023). The machine learning models suggest that Zn, Mg and As are the most important elements for distinguishing mineralised systems.

Pyroxene

Intra-grain zonation of chromium and titanium within clinopyroxene (Fig 3) or orthopyroxene are though to indicate open systems or conduit style intrusions (Schoneveld et al. 2020). Although not a direct indicator of sulfide saturation, it does indicate a higher likelihood of metal-rich sulfide due to the high through-put of silicate magma in these systems allowing metal-enrichment of any sulfide.

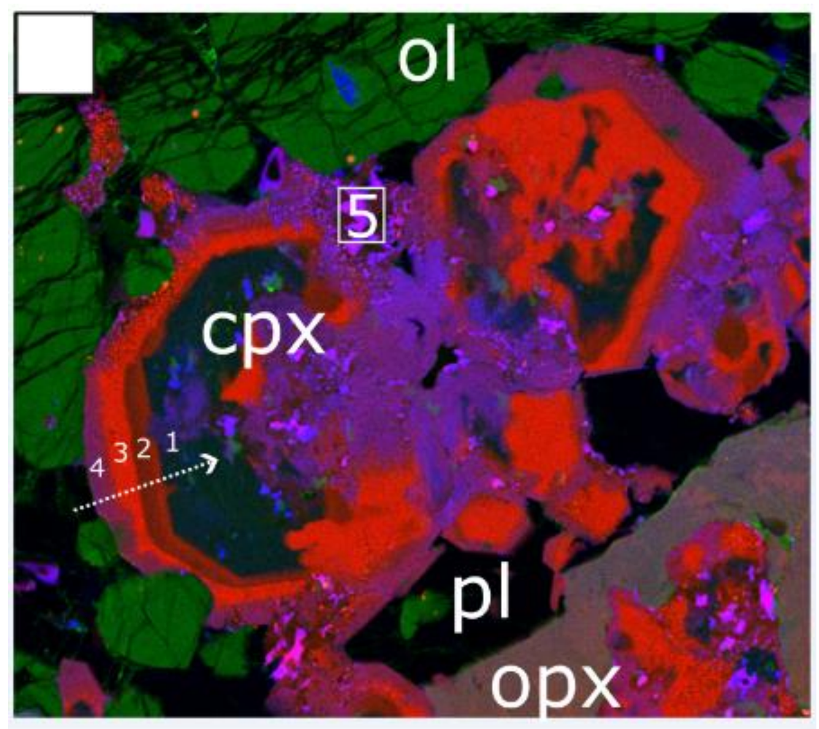

Figure 3: An XRF image of a clinopyroxene (cpx) surrounded by plagioclase (pl), olivine (ol) and orthopyroxene (opx). Image is a false colour stack where red= chromium concentration, blue = titanium and green = manganese.

Spinel

The major elements of the spinel group give a good indication of their host rock (Fig 4). The trace elements in the spinel give a confident prediction of whether the system is mineralised or unmineralised. The machine learning models outline that Co, Ga, V, and Ni are important in distinguishing the prospectivity of the sample. Trace elements in spinel also have the potential to indicate the volume of sulfide present, allowing it to be used as an indicator toward larger resources.

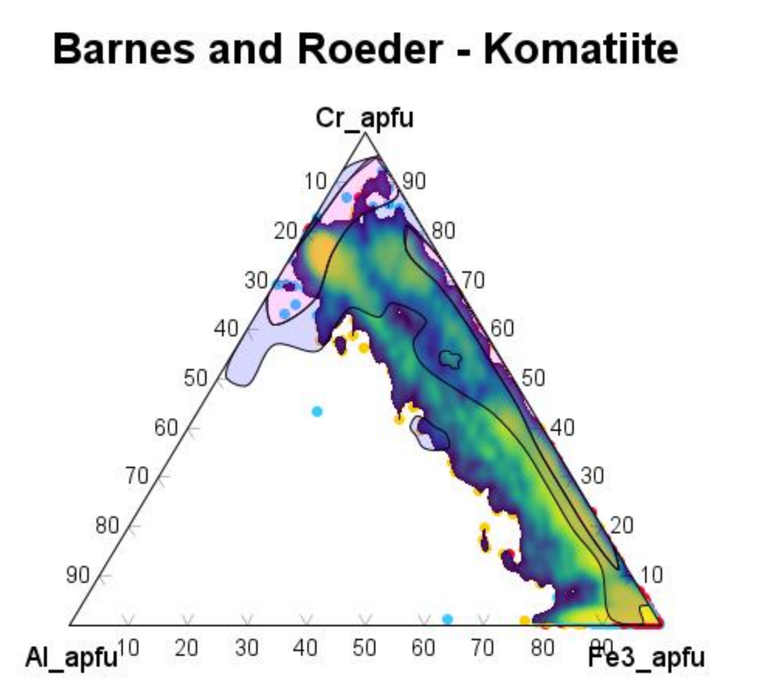

Figure 4: Major element compositions of spinel phases found in komatiite samples in this study compared with the fields defined by Barnes and Roeder 2001, in atoms per formula unit (apfu).

Ilmenite

The Mg content of ilmenite appears to indicate sulfide bearing units. Mg-Ilmenite were analysed and counted in the Heavy Mineral Map of Australia dataset (de Caritat et al. 2023), which gives the opportunity to create a prospectivity map for Ni across all of the Australia (Fig 5). The machine learning models based on the trace elements suggest that Cr and Nb are the most important for distinguishing mineralised from unmineralized samples. Ilmenite is found commonly at the surface in heavy mineral separates so it would be an ideal indicator mineral for widescale surface prospectivity mapping.

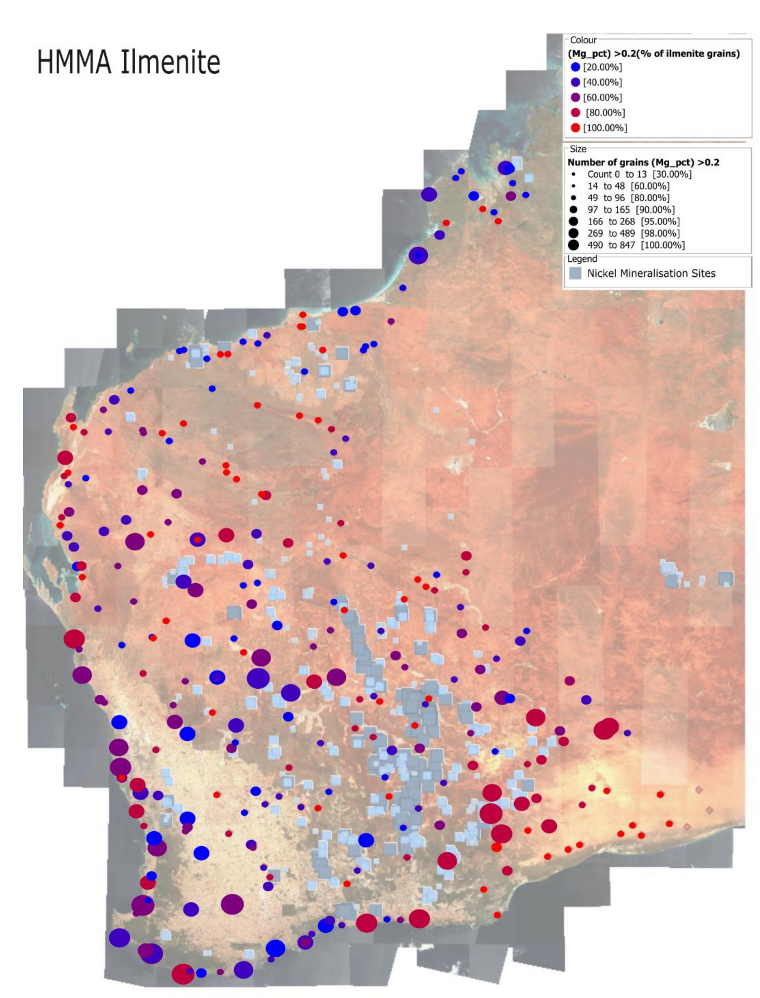

Figure 5: Proportion of High Mg-Ilmenite in samples from the Heavy Mineral Map of Australia (de Caritat et al. 2023) overlain on known Ni-occurrences within WA.

FOR FURTHER INFORMATION
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