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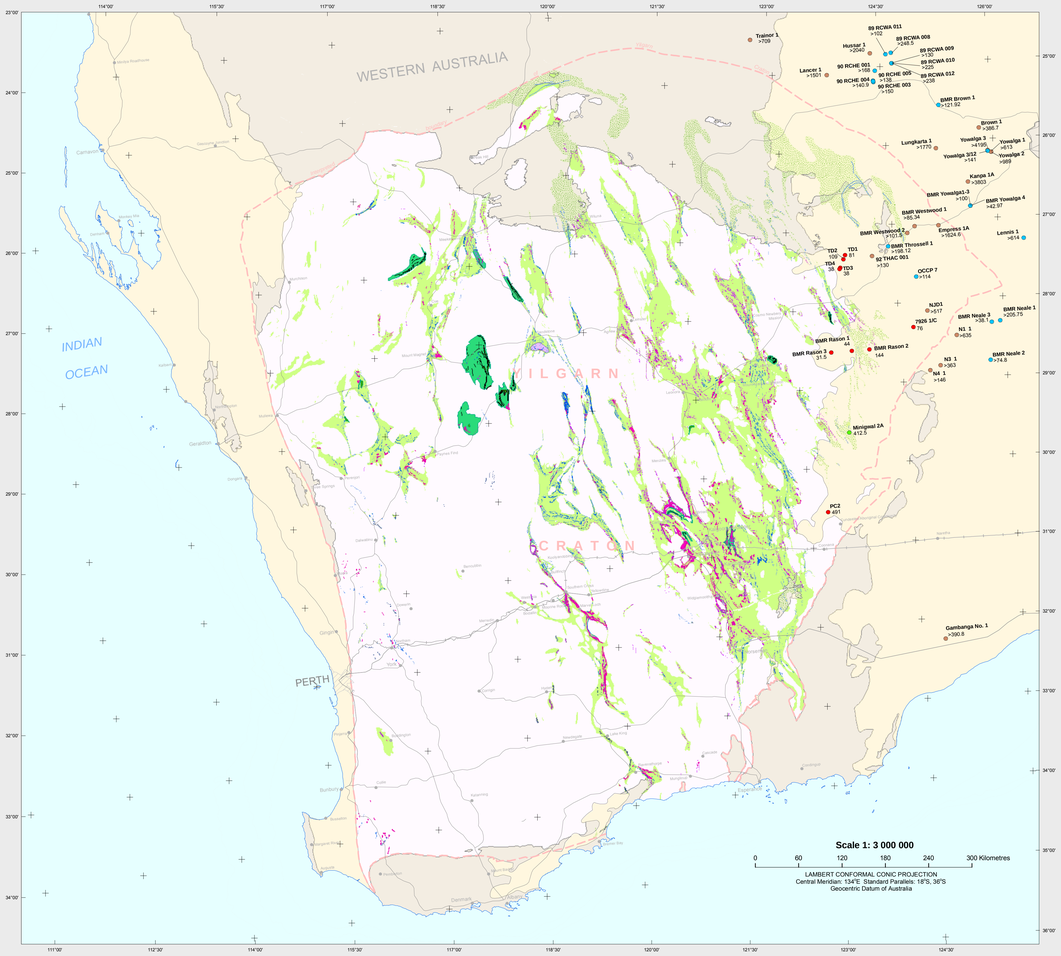
AUSTRALIAN ARCHEAN MAFIC-ULTRAMAFIC MAGMATIC EVENTS: YILGARN CRATON, WESTERN AUSTRALIA

Interpreted Distribution of Archean Mafic-Ultramafic Rocks



Interpreted Distribution of Archean Mafic-Ultramafic Rocks (left)

This map depicts outcropping Archean ultramafic-mafic igneous rocks, layered mafic-ultramafic intrusions, and interpreted subsurface extensions of equivalent rocks under younger cover throughout the Yilgarn Craton. Outcrop locations, rock types and regional groupings, e.g., distribution of greenstone belts, were taken from the 1:250 000 Geological Map Series (compiled by the Geological Survey of Western Australia and Geoscience Australia). The distribution of subsurface equivalent rocks within the craton was largely derived from an interpretation of aeromagnetic data contained in the National Airborne Geophysical Database (Geoscience Australia; as at 2007). Stratigraphic continuity was used to assign rock type information from exposed outcrop to adjacent aeromagnetic anomalies over concealed areas. Some anomalies remain unassigned

The Yilgarn Craton has an area of at least 660 000 km^2. Granite and greenstone rock sequences throughout the craton mostly range in age from ~3.0 Ga to ~2.6 Ga, although some mafic igneous rocks as old as ~3.7 Ga occur in the west

Greenstone belts, which are composed largely of mafic volcanic rocks with lesser felsic volcanic, sedimentary, and ultramafic rocks, make up approximately 20% of the craton. Granite and granitic gneiss (shown in pale pink) constitute the other 80%. Ultramafic rocks (purple), which host significant nickel mineralisation, occur within regionally extensive north-northwest-trending linear greenstone belts (pale green), and are also depicted on the map

Strata-coincident aeromagnetic anomalies of at least moderate magnetisation generally correlate with banded iron formation (BIF; blue), or olivine-rich ultramafic rocks (komatiite; serpentinisation alteration produces magnetite as a co-product: purple), or magnetite-rich layers (black) in layered mafic and mafic-ultramafic intrusions (dark green). Units with extreme magnetisation (+ 1500 nT above average Yilgarn rock magnetisation) are almost exclusively associated with BIF. Generally, however, the amplitude of magnetic anomalies, from very high to moderately low levels, is not unique to any of the three rock associations, and reflects, amongst other things, magnetite content, susceptibility, and remanence, in combination with unit thickness, attitude (dip), and depth extent. Thus the distribution of outcropping and interpreted subsurface BIF has also been included both for magnetic interpretation context and to allow for possibly incorrect rock type assignment in areas of cover

This interpretation does not address all subsurface ultramafic rocks. Ultramafic rock types such as pyroxenites and high-magnesium basalts are generally poorly magnetised and are not readily mapped by aeromagnetic data

The Yilgarn Craton, as portrayed by Whitaker and Bastrakova (2002), extends under laterally extensive Paleoproterozoic (brown) basin cover in the north and Phanerozoic (beige) cover in the east. The subsurface boundaries of the craton in these areas were located by gradients in aeromagnetic and gravity data which truncate the widespread internal north to north-northwest lithological/anomaly trends. Across these boundaries the crust is inferred to be different in composition and to have undergone different deformational histories. The interpreted extent of subsurface greenstone belts underneath basin cover (indicated by paler green with stipple) was also defined using a combination of aeromagnetic and gravity data

Greenstone belts under the basin cover may also be prospective for komatiite-related nickel deposits as inferred from the presence of ultramafic rocks in regionally adjacent sub-cropping belts. The thicker cover precludes geophysical mapping of all but extremely magnetised BIF units in these belts. Selected drill hole data have been added in the area of cover to provide information on depths to basement

Distribution and Characterisation Maps (left and right)

Ultramafic rocks
- *Thin occurrence, interpreted from magnetics*
- *Thick occurrence, interpreted from magnetics*
- *Thin occurrence outcrop*
- *Thick occurrence outcrop*

Layered mafic-ultramafic intrusions and sills
- *Magnetite layering, interpreted from magnetics*
- *Layered mafic-ultramafic intrusion or sill extent, interpreted from magnetics*
- *Boundary of layered mafic-ultramafic intrusion*
- *Layered mafic-ultramafic intrusion outcrop*

Banded iron formation
- *Thin occurrence, interpreted from magnetics*
- *Thick occurrence, interpreted from magnetics*
- *Thin occurrence outcrop*
- *Thick occurrence outcrop*

- *Yilgarn Craton boundary*
- *Possible banded iron formation or Archean ultramafic rock, interpreted from magnetics*
- *Possible banded iron formation, interpreted from magnetics*
- *Phanerozoic rocks, undivided outcrop/subcrop*
- *Proterozoic rocks, undivided outcrop/subcrop*
- *Archean greenstone sequences, undivided and under basin cover*
- *Archean greenstone sequences, undivided outcrop/subcrop*
- *Archean granite or granitic gneiss, undivided outcrop/subcrop*

Drillhole with depth (m) to basement
- *Permian rocks*
- *Proterozoic rocks*
- *Archean granite or granitic gneiss*
- *Archean greenstone*

Bottom-hole rock type

Minigwal 2A 412.5

Characterisation Map (right)

- *Dated komatiite or associated rock and age in millions of years* (>2720±14)
- *Aluminium-undepleted komatiite rock (AUDK; Al_2O_3/TiO_2 = 15-25)*
- *Aluminium-depleted komatiite rock (ADK; Al_2O_3/TiO_2 <15)*
- *Aluminium-depleted and undepleted komatiite rock*
- *Nickel sulphide deposit*

Interpreted dominant age (in billion years: Ga) and compositional groups of komatiitic rocks
- (1) *~2.72-2.69 Ga; AUDK + ADK (minor)*
- (2) *~2.87-2.70 Ga; AUDK + ADK (minor)*
- (3) *~2.93-2.70 Ga*
- (4) *~2.80-2.80 Ga*
- (5) *~3.00-2.90 Ga; ADK + AUDK (minor)*
- (6) *~3.01-2.74 Ga*
- (7) *~3.02-2.73 Ga; ADK + AUDK (minor)*
- *No age or compositional data*

Interpreted Characterisation of Komatiites (right)

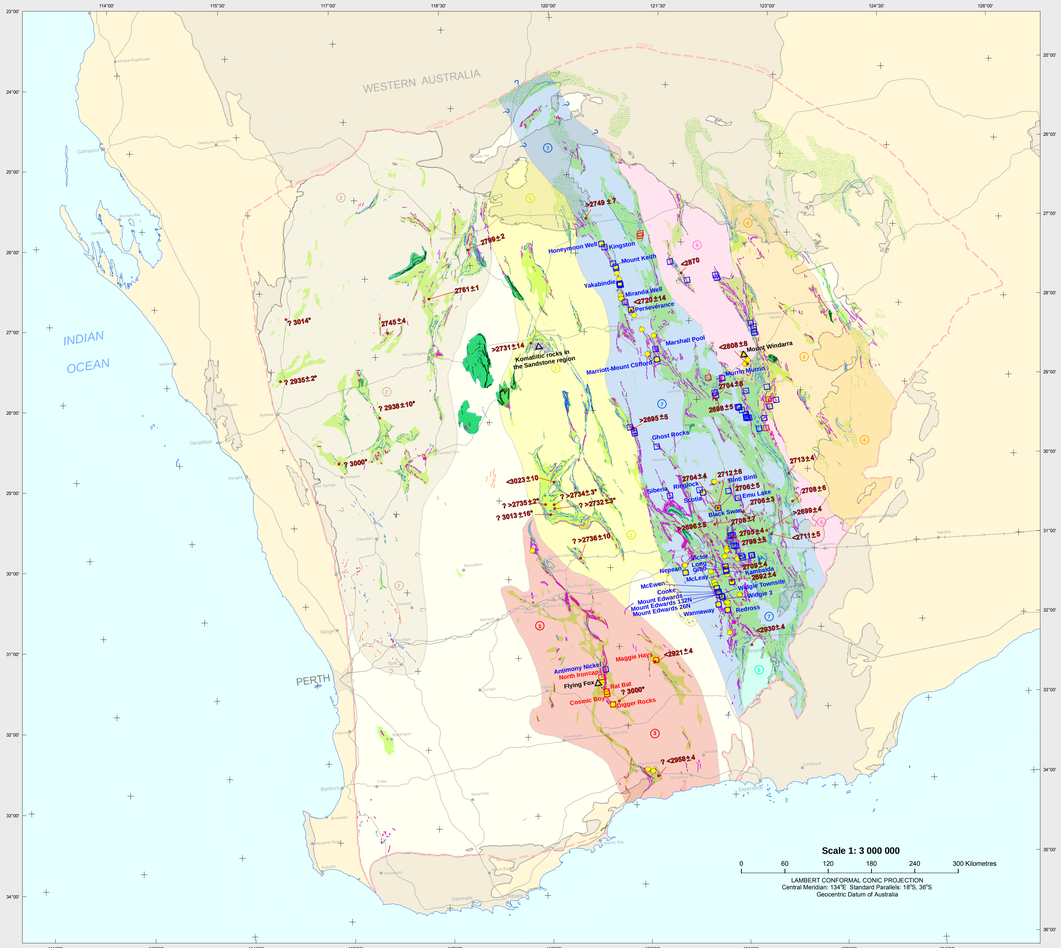
The geochronology data (most ages are summarised in Hoatson et al., 2006) of the Archean komatiitic sequences shown on this map include: U-Pb zircon ages of pyroclastic and felsic units intercalated with komatiitic sequences (i.e., direct age of komatiites); felsic footwall units (maximum age); felsic hangingwall units (minimum age); and felsic dykes cutting the komatiitic sequences (minimum age). Most of the ages in the west Yilgarn Craton prefixed by a ? indicate that the stratigraphic relationship between the dated rock and associated komatiitic rock has not been determined. Those ages shown with an * may have questionable significance based on recent geochronology and field mapping by the Geological Survey of Western Australia

The komatiitic rocks of the Yilgarn Craton can be divided into two broad compositional groups (Barnes et al., 2004): (1) Al-undepleted komatiites (AUDK) or 'Munro-type' komatiites–Al_2O_3/TiO_2 ratios generally vary between 15 and 25, and they are typically depleted in incompatible trace elements; and

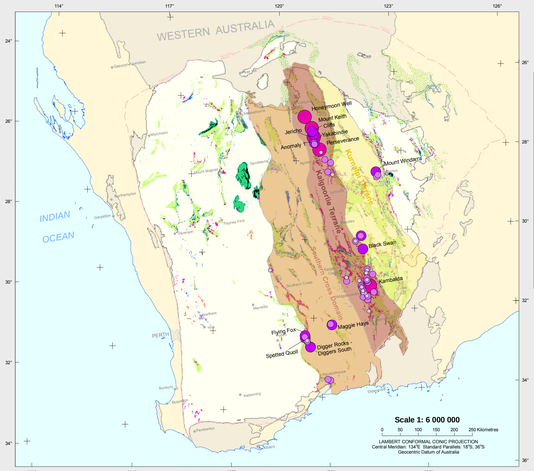
(2) Al-depleted komatiites (ADK) or 'Barberton-type' komatiites–Al_2O_3/TiO_2 ratios are <15, and they are enriched in incompatible trace elements

The two chemical groups of komatiites are inferred to result from different melting conditions in the mantle, with a garnet residue indicated by the Al-depleted lavas. Large-tonnage nickel sulphide deposits (Mount Keith) are generally associated with ~2.70 Ga AUDK, whereas smaller high-grade deposits (Flying Fox) are often associated with older ~3.00-2.90 Ga ADK

Interpreted Characterisation of Komatiites



Nickel Sulphide Resources
(past production and remaining resources)



Size of nickel sulphide deposits (left)
- *Mineral deposits with up to 10 000 tonnes of nickel*
- *Mineral deposits with 10 000 to 100 000 tonnes of nickel*
- *Mineral deposits with 100 000 to 1 million tonnes of nickel*
- *Mineral deposits with more than 1 million tonnes of nickel*

Nickel sulphide resources (left)
- Kumalpi Terrane *Up to 0.50 million tonnes of nickel*
- Southern Cross Domain *0.50 to 1.00 million tonnes of nickel*
- Kalgoorlie Terrane *1.00 to 12.00 million tonnes of nickel*
- *No resource data*

Neodymium two-stage model ages, in billion years (Ga) (right)
- * *Sample location*
- *2.48-2.10 Ga*
- *2.66-2.48 Ga*
- *2.80-2.66 Ga*
- *2.87-2.80 Ga*
- *2.91-2.87 Ga*
- *2.96-2.91 Ga*
- *3.02-2.96 Ga*
- *3.10-3.02 Ga*
- *3.15-3.10 Ga*
- *3.21-3.15 Ga*
- *3.27-3.21 Ga*
- *3.35-3.27 Ga*
- *3.67-3.35 Ga*

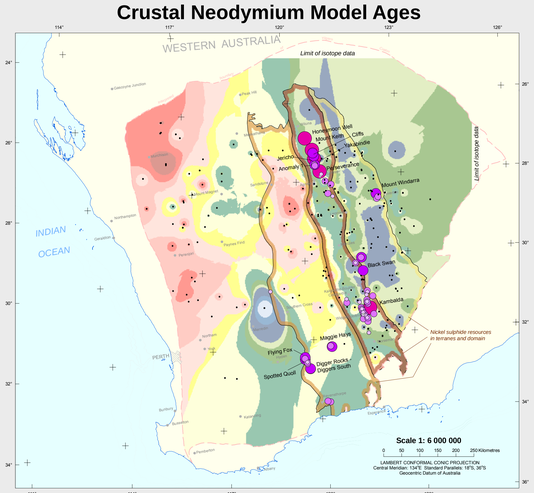
Crustal Neodymium Model Ages (right)

Model-based 'average' age of the crust as indicated by granitic rocks (using a two-stage evolution of Sm/Nd and assuming a depleted mantle, Champion and Cassidy, 2008). Highest nickel sulphide endowment (Kalgoorlie Terrane) is associated with intermediate age crust (neodymium two-stage model ages of 3.02 to 2.87 Ga)

Model age surface (cell size 1 km) calculated using interpolating grid routine in ArcGIS. Interpolating method: Inverse Distance Weighted with a fixed search radius (number of neighbours is 12)

Sample locations for dating are not uniformly distributed across the Yilgarn Craton

Crustal Neodymium Model Ages



MAP LOCALITY

Compiled by D.M. Hoatson, S. Jaireth, A.J. Whitaker, D.C. Champion, and J.C. Claoué-Long
Cartography by G.A. Young

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Other maps in this series:
This map is part of a Geoscience Australia series showing the geographic extent and time-space relationships of Archean and Proterozoic mafic-ultramafic magmatism and associated mineral deposits across the Australian continent

Part 1: Western Australia was published in October 2006 and documents 15 Proterozoic mafic-ultramafic magmatic events
Part 2: Northern Territory–South Australia was published in July 2007 and documents 19 Proterozoic mafic-ultramafic magmatic events
The Australian Proterozoic map which comprises two sheets, was published in August 2008 and documents 30 Proterozoic mafic-ultramafic magmatic events across the continent

The geological and geochronological information accompanying the Proterozoic map series is summarised in Geoscience Australia Record 2008/15 (GeoCat Number: 66624) Guide to using the 1:5 000 000 map of Australian Proterozoic mafic-ultramafic magmatic events by Hoatson, Claoué-Long, and Jaireth. A Geoscience Australia Record summarising the Archean mafic-ultramafic magmatic events is planned for release in 2009. Two map sheets by Claoué-Long and Hoatson (GeoCat Number: 69213) showing the distribution of Proterozoic Large Igneous Provinces in Australia are also to be released in 2009
Copies of the maps (in pdf and jpg formats) and Geoscience Australia Record 2008/15 are available free online in a resource package at:
http://www.ga.gov.au/map/index.jsp#mum

References for digital geological and geophysical datasets:
- **Geological base maps and solid-geology rock polygons (Sheet 1)**

Western Australia
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- **Geological and tectonic province boundaries (Sheets 1 and 2)**

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- **Distribution of Archean dolerite dykes and sills in Western Australia (Sheet 1)**

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Composition of komatiitic rocks
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Lesher, C.M. and Keays, R.R., 2002. Komatiite-associated Ni-Cu-PGE deposits: geology, mineralogy, geochemistry, and genesis. *In*: Cabri, L.J. (editor), The Geology, Geochemistry, Mineralogy and Mineral Beneficiation of Platinum-Group Elements. Canadian Institute of Mining, Metallurgy and Petroleum, Special Volume 54, 579–617

Nickel sulphide resources for deposits and regional nickel endowment
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It is recommended that this map sheet be referred to as:
Hoatson, D.M., Jaireth, S., Whitaker, A.J., Champion, D.C. and Claoué-Long, J.C., 2009. *Australian Archean Mafic-Ultramafic Magmatic Events: Yilgarn Craton, Western Australia, Sheet 2 of 2* (1:3 000 000 and 1:6 000 000 scale maps), Geoscience Australia, Canberra

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Sheet 2 of 2
2009