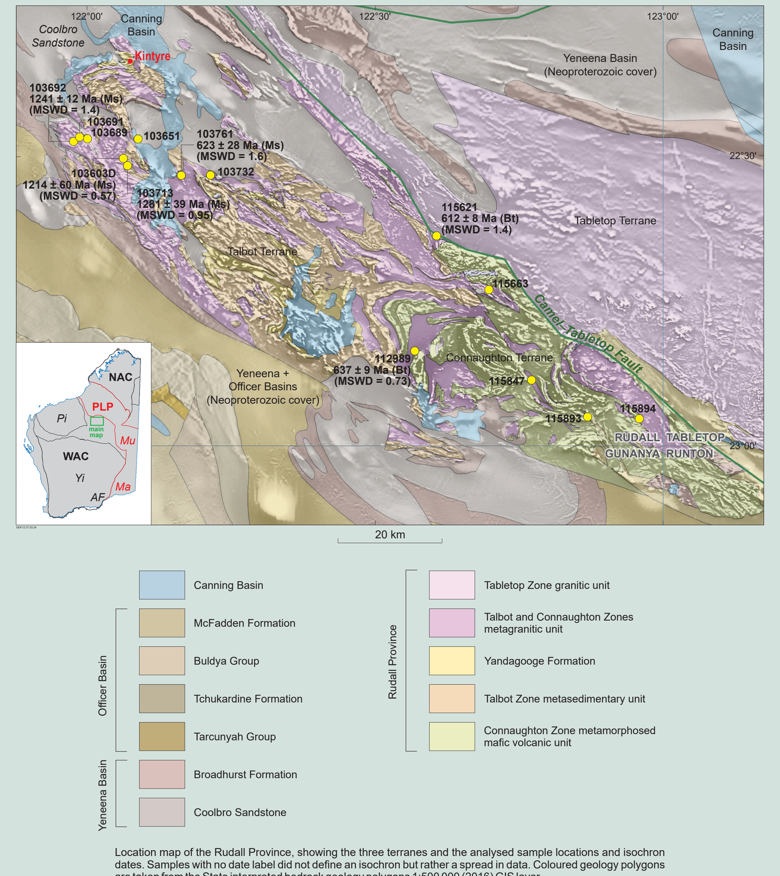
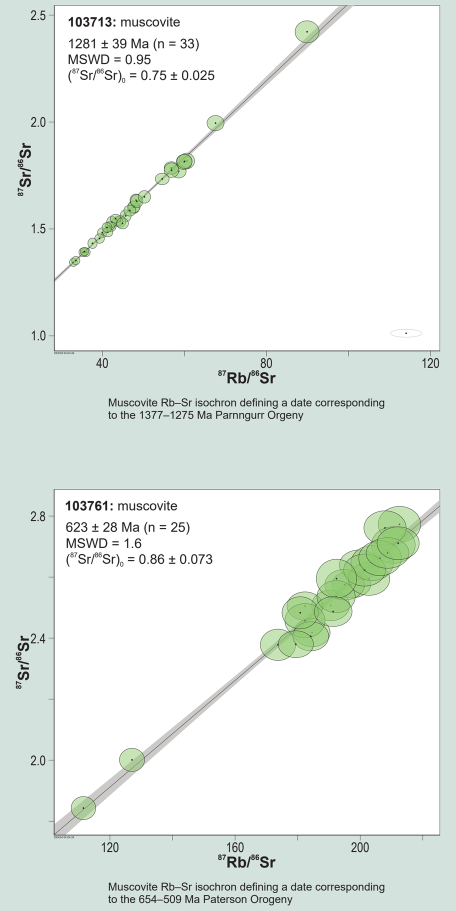
Department of Energy, Mines, Industry Regulation and Safety

Novel geochronology

Can't see for Miles: In situ mica Rb–Sr geochronology from the Rudall Province





A longstanding point of conjecture in the evolution of the Paterson Orogen in northern Western Australia is the age of the Neoproterozoic Miles Orogeny. The Miles Orogeny is thought to be characterised in outcrop by regional D3 and D4 structures that were subsequently overprinted by D5 and D6 structures during the 654–509 Ma Paterson Orogeny. However, existing quantitative age constraints for the Miles Orogeny have large uncertainties and define a time frame of approximately 840–750 Ma, all from low-temperature hydrothermal rocks at Nifty mine and Kintyre prospect.

We obtained in situ mica Rb–Sr geochronology from crystalline meta-igneous and metasedimentary rocks within the Rudall Province to try to constrain the age (and existence) of the Miles Orogeny.

Isochrons yielded three Paterson Orogeny ages (623 ± 28 Ma muscovite, 637 ± 9 Ma biotite and 612 ± 8 Ma biotite) and one Parngurr Orogeny age (1281 ± 40 Ma muscovite). The other two isochrons were 1214 ± 60 Ma (muscovite) and 1242 ± 12 Ma (muscovite). Strikingly, no isochron ages, nor definitive Rb–Sr model ages, were obtained for the Miles Orogeny. Therefore, it is likely that existing and new age data for the proposed Miles Orogeny represent either a hydrothermal fluid flow event, in which case 'Orogeny' is not appropriate terminology, or that it represents mixing of Paterson Orogeny and Mesoproterozoic age components.

Data and Software Centre

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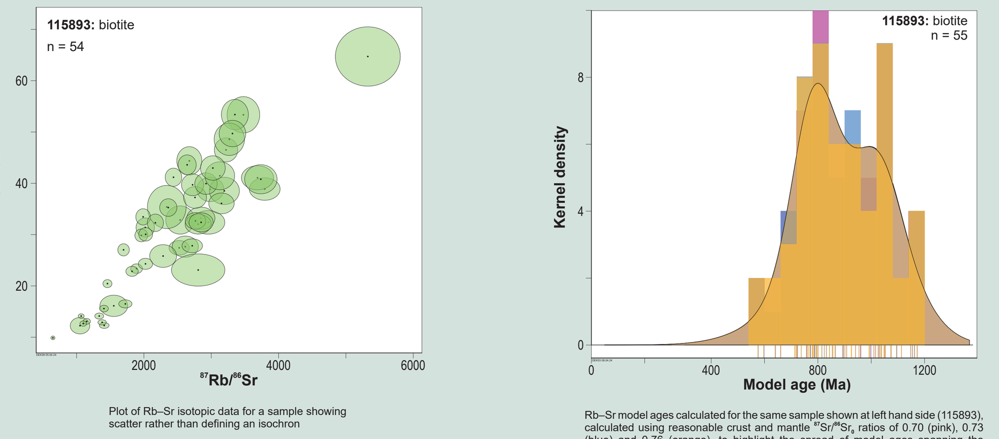
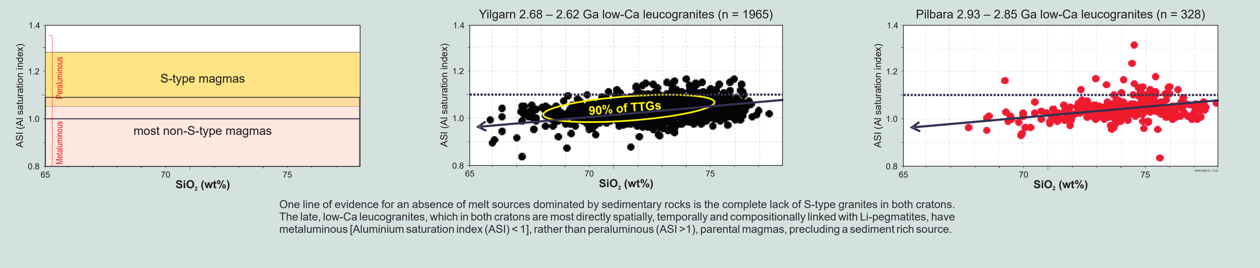


An Archean lithium pegmatite model

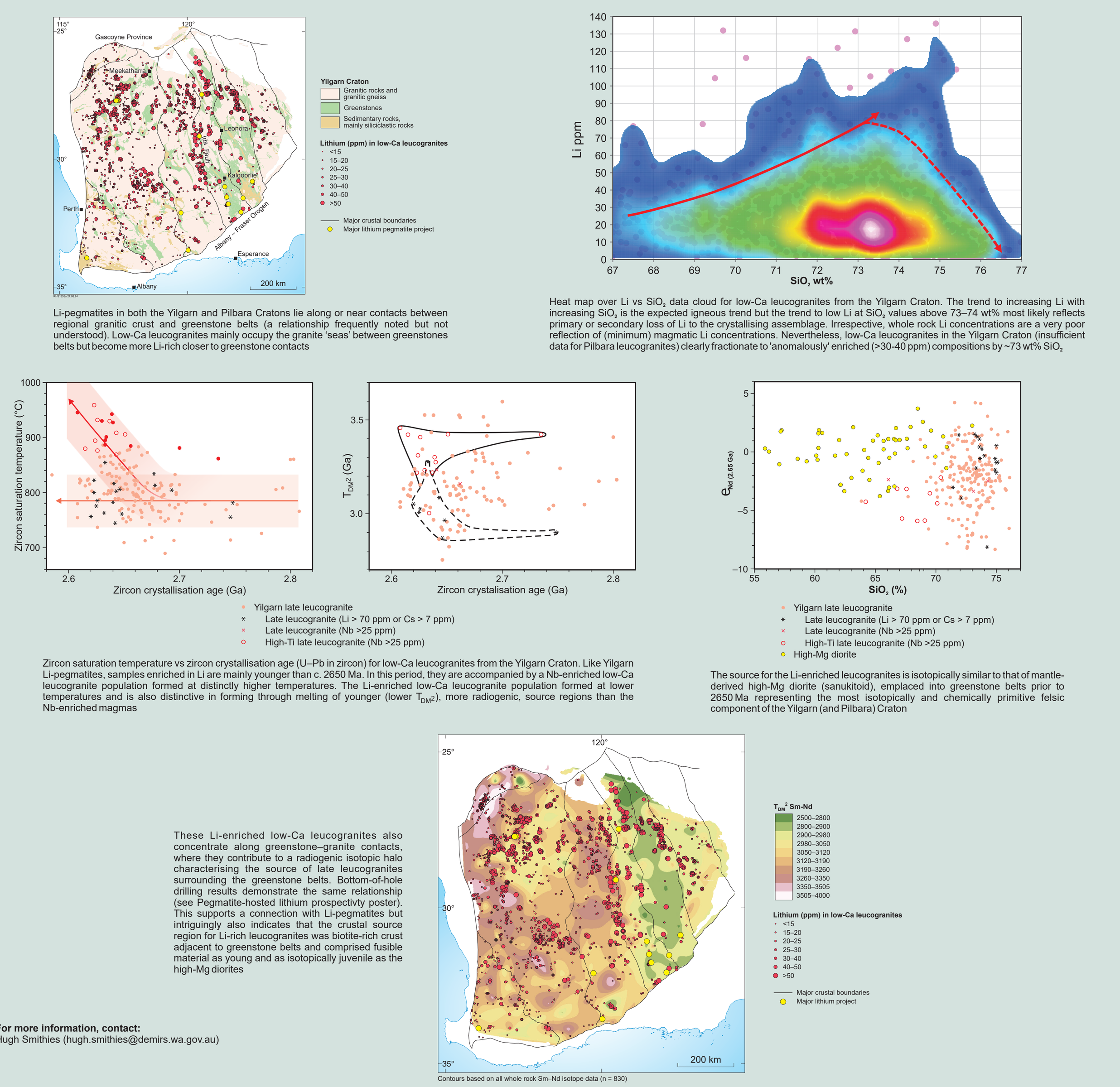
GSWA's Archean granite project has acquired a strong Li-bias with sampling now concentrating on the younger low-Ca leucogranite components of both the Yilgarn and Pilbara Cratons. In addition to providing a useful geochemical dataset to Industry, one of our aims is to reconcile field data with prevailing Li-pegmatite models.

Lithium-pegmatites are thought to form either through direct anatexis of Li-rich crust or through extreme fractionation of granitic melts. Geochemical and isotopic data (Kendall-Langley et al., 2020; Lithos, 352–353) strongly favour the latter model for Li-pegmatites in the Archean of Western Australia.

Phanerozoic studies have strongly influenced Li-exploration models which, in the case of granite fractionation models, posit that Li-pegmatite are extracted from granites formed through melting sedimentary-rock dominated crustal source (i.e. S-type granites). Such models are applied to Archean terranes — but the Yilgarn and Pilbara Cratons, which contribute most of the world's hard-rock Li, contain no sedimentary sequences that represent a viable melt source.



The Li-carrying capacity of any crustal melt source is linked to its mica content. With than in mind we look at leucogranite compositions in an attempt to identify mica-rich crustal components, other than metasediments, that might form a crustal melt source.



Contours based on all whole rock Sm–Nd isotope data (n = 830)

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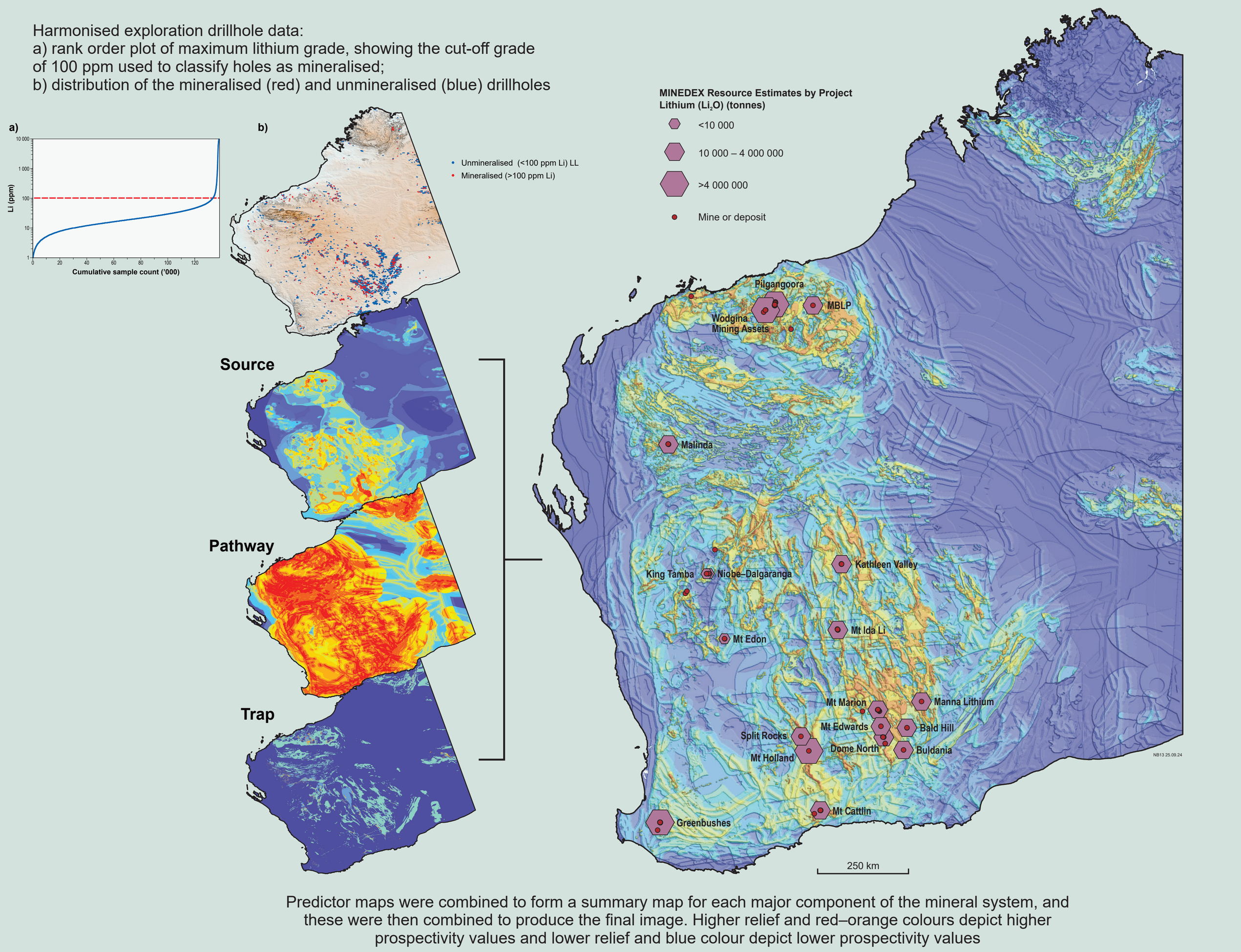
The radiogenic halo surrounding greenstone belts is primarily a result of infusion of greenstone root zones and adjacent crust by strongly hydrated mantle-derived magmas late in greenstone evolution — but before Li-pegmatite and low-Ca leucogranite formation. This hybridised crust reflects one of the most voluminous components of the sub-greenstone crust. Where these mantle-derived intrusions are exposed, they form biotite-rich country rock alteration zones containing up to 300 ppm Li. Potential sources of this Li include sanukitoid-related magmatic fluids (i.e. derived from enriched lithospheric mantle) and Li sequestered from country rock, including seawater altered greenstone.

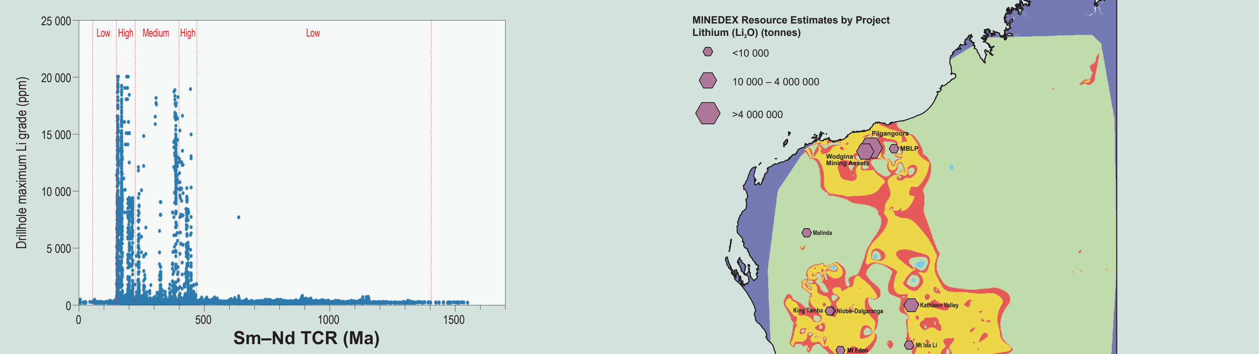
If no viable 'traditional' source exists for the leucogranites and assocciated Li-pegmatites in the Yilgarn or Pilbara Cratons, we must look at alternative sources. We are currently investigating the possibility that the required biotite-altered crustal source formed as juvenile, mantle-derived, dioritic magmas (sanukitoid) invaded the root zones of greenstone belts late in greenstone evolution. Melting of this source to produce low-Ca leucogranite, and subsequent fractionation to form pegmatite, explains the empirical spatial link between Li-pegmatite and greenstone–granite contacts as well as the unusually juvenile isotopic signature of Li-enriched Yilgarn leucogranites.

Mineral Systems Atlas

Pegmatite-hosted lithium prospectivity (in prep)

A mineral system-based hybrid *data-rich, knowledge-driven* approach was used to produce a series of predictor maps thought to represent critical components of pegmatite-hosted lithium mineralisation. Predictor maps were calibrated using a dataset of 138 310 exploration drillholes with harmonised maximum lithium grades. Fuzzy logic was employed to combine predictor maps into a final prospectivity map. The results of this map correlate well with known Li resources in Western Australia, and highlight areas for further exploration, which considerably reducing the search area of the State.





Input datasets were assigned a relative prospectivity value based on their correlation with harmonised drillhole data. This example shows the correlation between Sm–Nd Total Crustal Residence (TCR) times and the maximum lithium grade in drillholes and their relative prospectivity ratings

The Mineral Systems Atlas (MSA) seeks to help anyone who wants to find exploration-relevant spatial data and information presented in a logical mineral systems-based framework. Each system is accompanied by an online MSA Guide and GSWA Record. The online guide presents information on each spatial layer, the primary data from where it was derived, and any filters or query models used. The Li prospectivity map, intermediate predictor maps and input datasets will be published on the MSA and the Data and Software Centre as part of the Rare-element pegmatite system along with an explanatory note Record, allowing the end-user to recreate the map or combine this approach with their own datasets.

Each predictor map was rasterised using a standard 1 km cell size, with each cell being assigned a relative prospectivity value. This example used the relative prospectivity rating for Sm–Nd Total Crustal Residence times. Red represents the highest rating, orange a medium rating, with green representing the lowest. Blue denotes insufficient data

Mineral Systems Atlas

Scan to go to latest release

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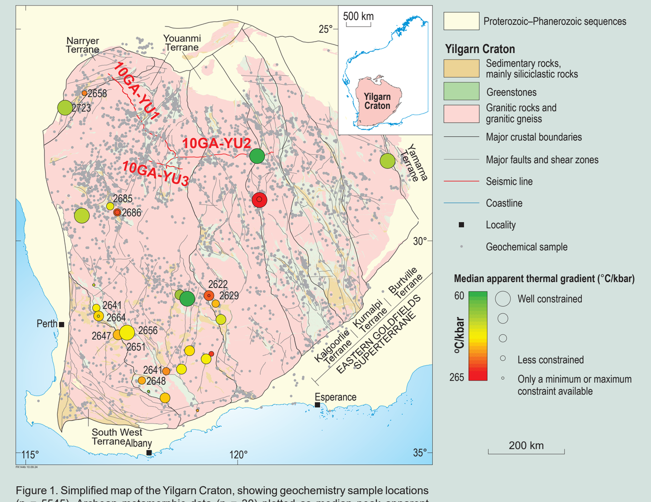
Yilgarn Craton

Radiogenic heat production provides a thermal threshold for cratonisation of the Yilgarn Craton



The magnitude of radiogenic heat production in the Yilgarn Craton has been underestimated in previous studies, resulting in an underappreciation of its role in crustal evolution and mineralisation (Au ± Ni) processes. It may also play a critical role in promoting the melting of Li-bearing source regions.

A striking feature of the Yilgarn Craton (Fig. 1) at the current erosional level is an abundance of high-K (low-Ca) granites with radiogenic heat production elevated far above global crustal averages (Fig. 2). Extrapolated back in time, the total thickness and contribution to crustal heat production and heat flow from these granites was greater, implying that the deeper crustal sources must also have been elevated in radiogenic heat production.

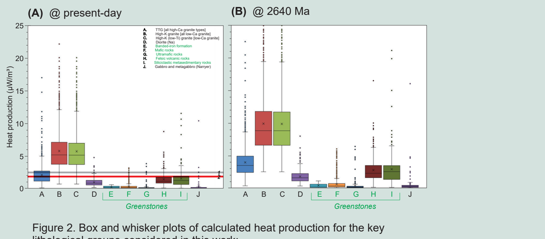


Figure 2. Box and whisker plots of calculated heat production for the key lithological groups considered in this work:

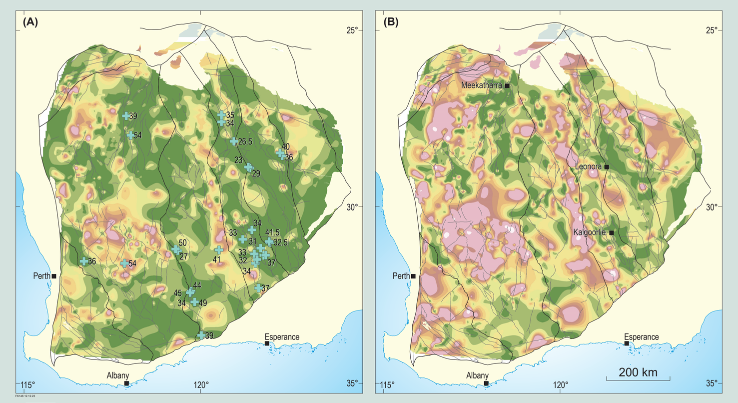
(A) Present-day

(B) 2640 Ma

(1) Grey line is average granite (= 2.5 μW/m^3; Haenel et al., 1988)

(2) Red line is mean felsic value for the Yilgarn Craton (= 1.88 μW/m^3; Hawkesworth and Jaupart, 2021).

Note some extreme outliers plot beyond the range shown

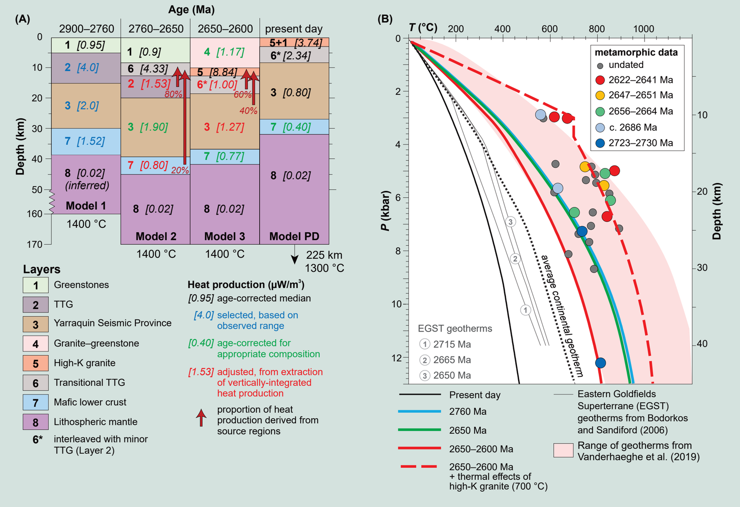


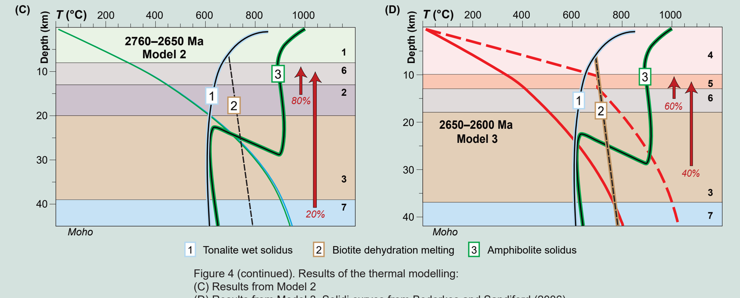
A heat production map (Fig. 3A) shows that vast tracts of the exposed surface have heat production that is significantly higher than global average granite (grey line on Fig. 2A). High-heat production at the surface coupled with low- to moderate surface heat flow (Fig. 3A) implies that modern day heat production at depth must be lower, consistent with extraction of heat-producing elements (K, Th, U) from deeper sources to produce these upper crustal radiogenic granites. The median heat production at 2640 Ma for the felsic groups ranges from 3.5 to 8.8 μW/m^3 (Fig. 2B), and the heat production map for 2640 Ma (Fig. 3B) shows that the lithologies at the exposed surface would have had considerable heat production in the past.

Figure 3. Heat production maps of the Yilgarn Craton, based on whole-rock geochemistry of all least-altered samples shown in Figure 1:

(A) Present-day, with surface heat flow

(B) Heat production calculated at 2640 Ma. Maps generated with natural neighbor interpolation using natural breaks in data values

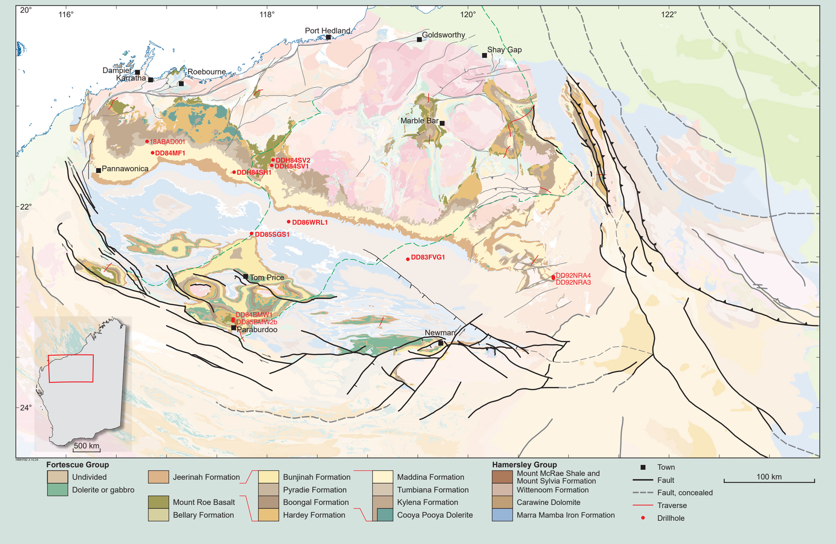




Fortescue Group

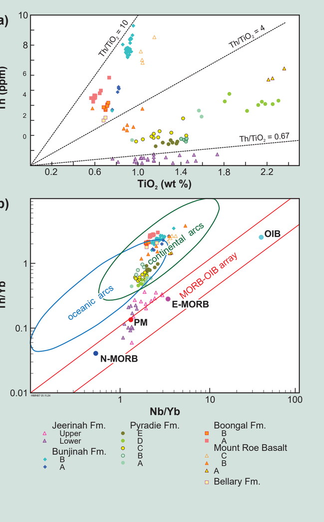
Geochemical barcoding

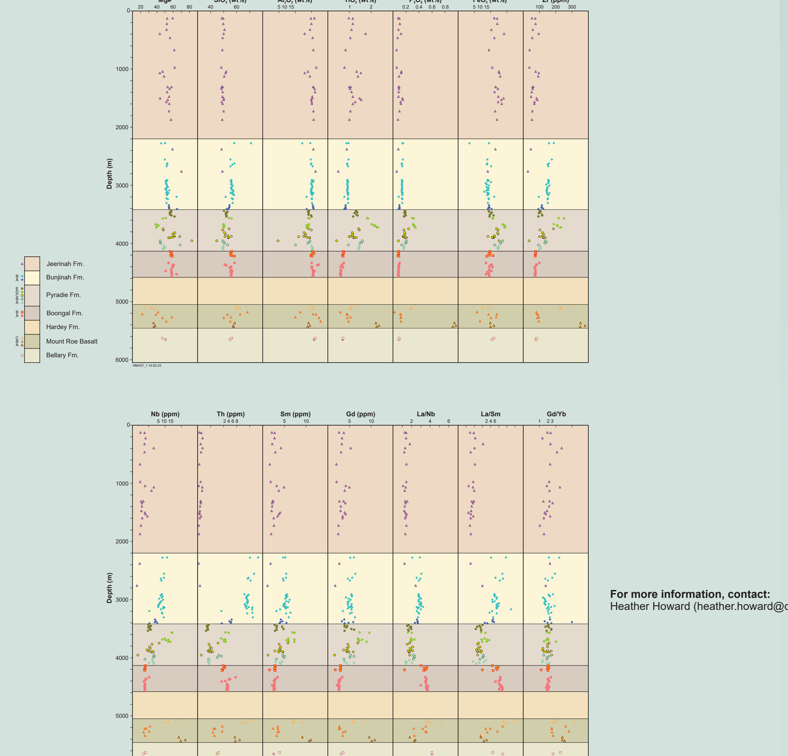
The 2780–2630 Ma Fortescue Basin of the Pilbara provides an opportunity to look at a nearly pristine and continuous Archean volcanic succession, equivalent in age to the greenstone belts of the Eastern Goldfields. This project uses high-quality whole rock major and trace element data from a number of drillholes and detailed outcrop traverses through the igneous rocks of the Fortescue Group, to provide a geochemical barcode for the succession. The geochemical data aids the correlation of the stratigraphy across the whole Fortescue Basin, previously established in several smaller mapping projects. The distribution and petrogenetic interpretations of the data help to uncover the ancient topography to the volcanic eruptions and identify major rift zones and fissures.

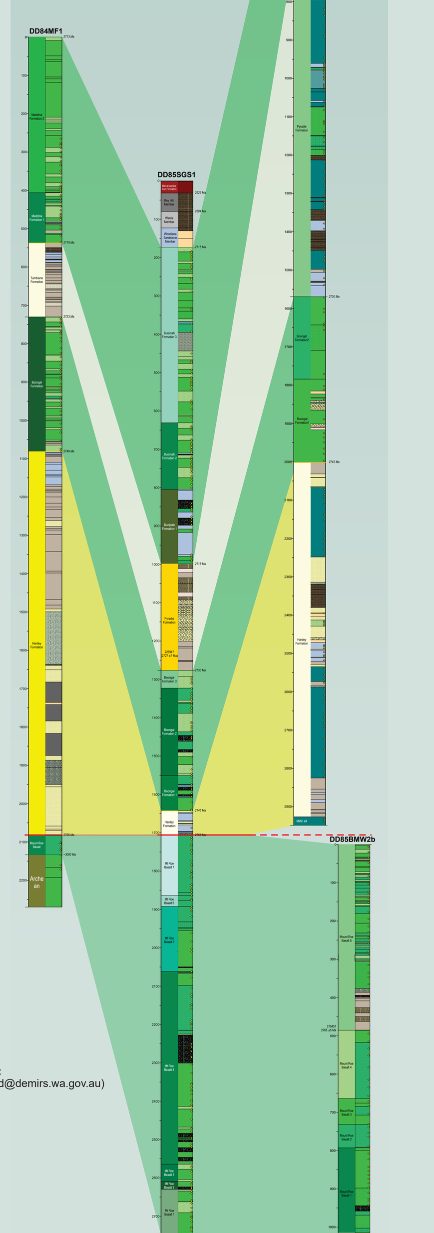


An example of correlated stratigraphic logs of drillcores from DD84MF1, DD86WRL1, DD86BMW1 and DD86BMW2b.

Using the previous mapping and drillcore logging as a basis for the broad stratigraphy, the geochemical sampling throughout the stratigraphy has identified several geochemical groups within each formation





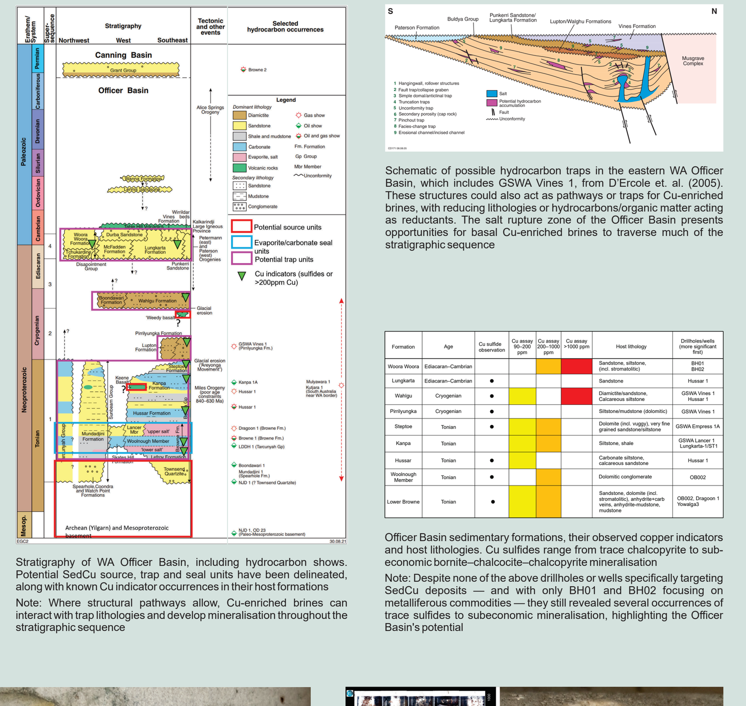


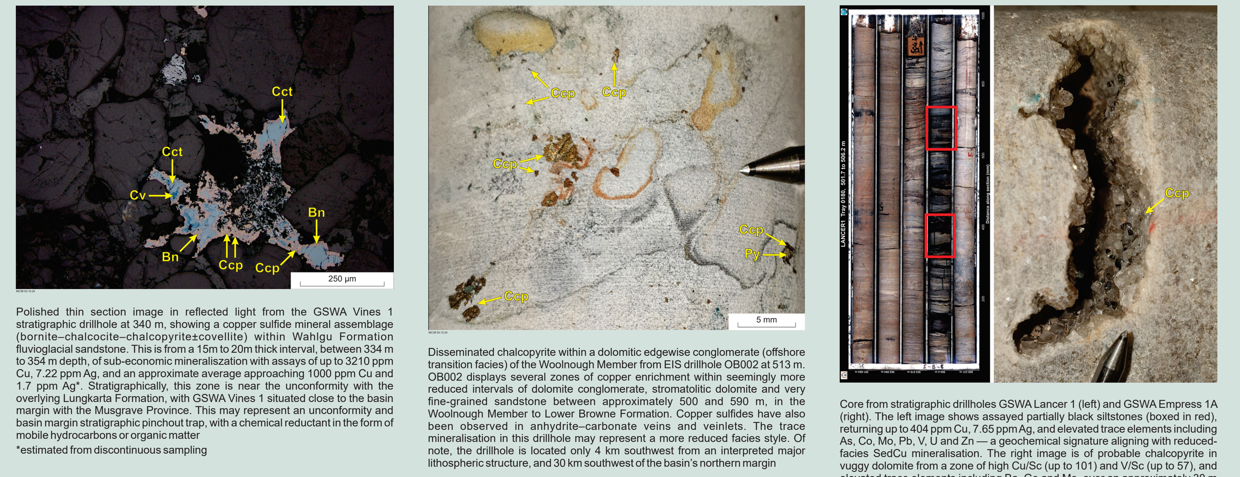
Officer Basin

Sediment-hosted copper shows

As nations embrace renewable energy transitions and the expansion of digital technologies, the demand for copper is poised for significant growth. Covering roughly 12% of Western Australia (WA), the Officer Basin has the potential to contain economic sediment-hosted copper (SedCu) deposits but remains mostly underexplored. Initial Geological Survey of Western Australia (GSWA) investigations into Officer Basin legacy data and material have yielded significant shows of subeconomic copper mineralisation or enrichment with SedCu signatures.

- The intracratonic Officer Basin is predominantly Neoproterozoic, overlying older Mesoproterozoic to Archean sedimentary, igneous and metamorphic rocks.
- An initial review of the basin's stratigraphy and characteristics showed a conceptual fit for the SedCu mineral system.
- A review of legacy data and reports, including from petroleum exploration, found several occurrences of SedCu indicators.
- GSWA core library drill core with SedCu indicators or potential trap lithologies were selectively sampled, with results further supporting the hypothesis.
- These initial investigations focused on the lesser explored central and eastern areas of the WA Officer Basin.
- More work to follow, including further sampling of legacy material and basin analysis.





Woolnough Member to Lower Browne Formation. Copper sulfides have also been observed in anhydrite–carbonate veins and veinlets. The trace mineralisation in this drillhole may represent a more reduced facies style. Of note, the drillhole is located only 4 km southwest from an interpreted major lithospheric structure, and 30 km southwest of the basin's northern margin

(right). The left image shows assayed partially black siltstones (boxed in red), returning up to 404 ppm Cu, 7.65 ppm Ag, and elevated trace elements including As, Co, Mo, Pb, V, U and Zn — a geochemical signature aligning with reduced-facies SedCu mineralisation. The right image is of probable chalcopyrite in vuggy dolomite from a zone of high Cu/Sc (up to 101) and V/Sc (up to 57), and elevated trace elements including Ba, Ge and Mo, over an approximately 30 m thick interval. These two examples are from drillholes over 250 km apart yet show copper enrichment at similar depths (approximately 500 m) and at a similar stratigraphic position — near the unconformity with the overlying Wahlgu Formation

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Minerals geoscience

GSWA has identified several new occurrences of trace to subeconomic copper mineralisation in the central and eastern WA Officer Basin. These, along with legacy data and recent modelling by Geoscience Australia (Cloutier et al., 2023), support the potential for SedCu deposits in the Officer Basin. Ongoing work, along with other GSWA initiatives, such as WA Array, could help narrow the search space for SedCu deposits in the Officer Basin.

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Geological Survey of Western Australia