

RECORD 2021/8

GSWA 2021 EXTENDED ABSTRACTS

ADVANCING THE PROSPECTIVITY OF WESTERN AUSTRALIA



Government of Western Australia
Department of Mines, Industry Regulation
and Safety

Geological Survey of
Western Australia





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Advancing the prospectivity of
Western Australia

November 2021

Perth 2021



**Geological Survey of
Western Australia**

MINISTER FOR MINES AND PETROLEUM
Hon Bill Johnston MLA

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Based on consultation with the Western Desert Lands Aboriginal Corporation (WDLAC) on the cultural significance of the name, Waukarlycarly, it has been agreed to change the name of the well to Barnicarndy 1 and the tectonic subdivision to Barnicarndy Graben. This and all future publications will now refer to the Barnicarndy 1 stratigraphic drillhole (previously Waukarlycarly 1) and the Barnicarndy Graben (previously Waukarlycarly Embayment).

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Cover image: Wave and wind sculpted stromatolites at Flagpole Landing, Hamelin Pool in the world heritage site of Shark Bay, Western Australia (photo by Heidi Allen, DMIRS)



GSWA Open Day 2021 program

21 November 2021, Hyatt Regency Perth



08.30	REGISTRATION / doors open	
09.00	Introductory statement	Jeff Haworth
09.10	Welcome and opening remarks	The Hon Bill Johnston MLA Minister for Mines and Petroleum

SESSION 1 Strategic outlook, Chair: Michele Spencer

09.20	'This is GSWA' film screening	Michele Spencer
09.30	Where to next for GSWA?	Simon Johnson
09.50	Stimulating exploration – a case study from the Northern Territory combining research and drilling	Andrew Bailey, CEO, MinEX CRC



Morning tea 10.10 – 10.55

SESSION 2 Accelerated Geoscience Program, Chair: Charlotte Hall

10.55	Accelerated Geoscience Program: State GIS datasets	Warren Omsby
11.10	Geoscience data for critical mineral discovery in Western Australia	Trevor Beardsmore
11.25	Pre-Mesozoic interpreted bedrock geology of the southwest Yilgarn, 2021	Raphael Quentin de Gromard
11.50	Far East Yilgarn Geological Exploration Package: accelerating the uncovering of the eastern margin of the Yilgarn Craton	Richard Chopping
12.05	Energy Systems Atlas	Deidre Brooks

Lunch 12.20 – 13.30

SESSION 3 Ongoing technical research, Chair: Klaus Gessner

13.30	Natural hydrogen: a future energy resource?	Peter Haines
13.40	GSWA pilot petrophysics project	Lucy Brisbout
13.50	Alteration, Cu–Au mineralization and felsic magmatism at Obelisk, north Paterson Orogen	Paul Duuring
14.00	Assessing the heavy mineral cargo of regolith from the west Arunta	Erin Gray
14.10	Enhancing earthquake monitoring in Western Australia	Ruth Murdie
14.20	An update on regolith geology in Western Australia	Nadir de Souza Kovacs
14.30	Using apatite to characterize hydrothermal fluids in the west Arunta	Jennifer Porter



Afternoon tea 14.40 – 15.30

SESSION 4 Geoscience and the minerals and energy revolution: towards 2030, Chair: Simon Johnson

15.30	Panel discussion Panel members Jayne Baird, Woodside; Geoffrey Batt, MRIWA; Katy Evans, Curtin University; Klaus Gessner, DMIRS; David Giles, MinEx CRC; Steffen Hagemann, CET; Campbell McCuaig, BHP; Sandra Occhipinti, CSIRO	
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Sundowner 16.30 – 18.00



Government of Western Australia
Department of Mines, Industry Regulation and Safety

Contents

Strategic outlook



Where to next for GSWA?	1
<i>by SP Johnson, J Haworth, M Spencer, K Gessner, C Hall and D Purnomo</i>	



Stimulating exploration – a case study from the Northern Territory combining research and drilling.....	2
<i>by A Bailey and D Giles</i>	

Accelerated Geoscience Program

Accelerated Geoscience Program: State GIS datasets	6
<i>by WR Ormsby</i>	

Geoscience data for critical mineral discovery in Western Australia	9
<i>by TJ Beardsmore, P Duuring, JN Guilliamse, S Kenworthy, S Morin-Ka, J Hogen-Esch and D Then</i>	

Pre-Mesozoic interpreted bedrock geology of the southwest Yilgarn, 2021	11
<i>by R Quentin de Gromard, TJ Ivanic and I Zibra</i>	

Far East Yilgarn Geological Exploration Package: accelerating the uncovering of the eastern margin of the Yilgarn Craton	14
<i>by R Chopping</i>	

Energy Systems Atlas	16
<i>by D Brooks</i>	

Ongoing technical research

Natural hydrogen: a future energy resource?	18
<i>by PW Haines</i>	



GSWA pilot petrophysics project	19
<i>by L Brisbout, M Markoski, J Trunfull, B Bourne, D Howard, C Hall, J Sapkota and M de Paoli</i>	



Alteration, Cu–Au mineralization and felsic magmatism at Obelisk, north Paterson Orogen	20
<i>by P Duuring, J Guilliamse, D Kelsey, I Fielding and L Fonteneau</i>	

Assessing the heavy mineral cargo of regolith from the west Arunta	21
<i>by E Gray, A Walker, F Korhonen and BIA McInnes</i>	



Enhancing earthquake monitoring in Western Australia	22
<i>by R Murdie</i>	



An update on regolith geology in Western Australia	23
<i>by N de Souza Kovacs</i>	



Using apatite to characterize hydrothermal fluids in the west Arunta	24
<i>by JK Porter, E Finch and DE Kelsey</i>	

Panel discussion

Geoscience and the minerals and energy revolution: towards 2030	25
<i>by SP Johnson</i>	

Panel members: J Baird, Woodside; G Batt, MRIWA; K Evans, Curtin University; K Gessner, DMIRS;
D Giles, MinEx CRC; S Hagemann, CET; C McCuaig, BHP; S Occhipinti, CSIRO

Where to next for GSWA?

by

SP Johnson, J Haworth, M Spencer, K Gessner, C Hall and D Purnomo



The challenge ahead

The decade ahead will be pivotal as the State plays its role in mitigating climate change by reducing our dependency on fossil fuels and moving towards a net-zero emissions economy by 2050. 'Decarbonization' will require a massive addition of renewable energy capacity and the conversion of existing uses of fossil energy to low-carbon hydrogen, a significant move towards the use of electric vehicles, and an ability to capture, use and store carbon dioxide. To enable the net-zero carbon dioxide emission transition, there will be a need for an increasing range and quantity of raw materials, including those deemed 'critical' as their supply is at risk due to known low global abundances or geopolitical issues. Western Australia is well placed to meet this new demand, but it will require the continued discovery of new resources, most likely in remote areas of the State where the bedrock is covered by a significant blanket of regolith or shallow sedimentary basins. These demands will also generate an increase in perceived and actual land use conflicts. With these issues in mind, the Geological Survey of Western Australia (GSWA) has designed a series of strategic priorities to meet these challenges head on.

Meeting the challenge

GSWA has identified four high-level strategic priorities that will help it to address and meet the challenges across the next decade:

- **Garnering geoscientific knowledge:** building our geological understanding of the State by acquiring and synthesizing precompetitive data and utilizing collaborative research and strategic partnerships
- **Transforming our data:** modifying the way we store, analyse and deliver our data to ensure it can move fluidly with emerging technology and innovation
- **Strengthening our team:** building capacity for a high-performing workforce by attracting exceptionally skilled people, developing and enhancing their capabilities to ensure they have the resources to excel, and encouraging innovation
- **Providing trusted information:** delivering trusted geoscientific information and advice to Western Australia's government, community and resources industry.

The first two priorities have been addressed in significant detail with the development of long-term 'strategic plans' which have been, or will be, made publically available through the Department's website. The **Geoscience Strategy 2021–31** identifies the present and emerging geoscience challenges, particularly those associated with exploring under cover and the discovery of new energy resources, hydrogen and carbon reservoirs, and provides a decadal 'action plan' to address them. As part of this strategy,

GSWA has managed to secure additional State funding for the purchase of a new HyLogger 4 core scanning system for the Perth Core Library, \$7 million for the extension to the Joe Lord Core Library, and \$3.2 million to co-fund (with AuScope) the purchase, installation and running of a state-of-the-art CAMECA 1300HR3 ion-microprobe at the John de Laeter Centre at Curtin University. The State Government has also approved a permanent increase of an additional \$2.5 million per year, to \$12.5 million per year, to the Exploration Incentive Scheme, allowing for more government–industry co-funded projects and geoscience data acquisition.

GSWA is a data-rich organization which holds a wealth of high-quality, state-of-the-art geoscience data, including both legacy and current data that have been generated in-house and externally. The released **Geoscience Data Transformation Strategy 2021–25** recognizes that the majority of these data are not currently Findable, Accessible, Interoperable and Reusable (FAIR). The strategy outlines how we can deliver a streamlined, open and FAIR data delivery system that will transform, modernize and rationalize our data storage, management and delivery, keeping pace with modern, digitally enabled exploration demands. To enable this strategy, GSWA has successfully secured State funding of \$10.6 million to fast-track the delivery of this strategy over four years. The organization has appointed a new, permanent position of Chief Geoscience Information Officer to plan, execute and deliver this data transformation program.

Producing world-class science and data, requires us to continually renew, strengthen and develop our workforce to be at the leading edge of science, embrace new technologies as well as providing the correct balance of a broader range of skills and key specializations. This challenge will be met by strategic staffing, continuous learning and collaborating with universities, research institutions, other geological surveys, government agencies and industry.

The final piece of the decadal puzzle is the integration of these strategic priorities to continue to provide objective, authoritative and trusted advice on the responsible development of the resources industry as well as on a variety of land use planning issues, including land access. Key to this success will be the ability to communicate and engage with traditional owners and other stakeholders as well as strategically negotiating policy issues across government agencies. Ultimately GSWA hopes that over the next decade we can help stimulate mineral exploration investment, including in critical minerals, and to open up new mineral and energy-producing provinces. We will continue to provide geoscience information to support new mineral and energy exploration technologies and drive new discoveries that will help the State transform its energy systems to achieve a net-zero emissions economy by 2050.

Stimulating exploration — a case study from the Northern Territory combining research and drilling

by

A Bailey* and D Giles*



The Perth-based Mineral Exploration Cooperative Research Centre (MinEx CRC), with a 10-year program (2018–28) and \$220 million in resources, is the world's largest mineral exploration research centre. The MinEx CRC mission is to address the threat of declining mineral inventory.

Currently in its third year of research, MinEx CRC is developing a novel set of drilling and sensing tools to measure the subsurface, explore new ways to deploy those tools and seek new methods to assess the resultant data and inform mineral exploration decisions. In combination, these techniques and methods help kick off a virtuous cycle of exploration activity leading to discovery. MinEx CRC currently supports about 100 researchers across universities, CSIRO, geological surveys and industry partners. This research effort is augmented by 28 PhD and Masters' students.

MinEx CRC is combining a mineral systems approach to exploration geoscience with the development of technologies that are geared to the challenge of exploration and mine development. MinEx is applying these technologies in various states and territories as part of a National drilling Initiative (NDI). The results of the 2020 NDI in the Northern Territory have been a stunning success.

Drilling technologies

MinEx CRC is undertaking two projects to develop innovative drilling technologies. The first project is extending the capability and reach of Coil Tube (CT) drilling so that it can drill more deeply, is steerable and delivers the highest quality sampling. CT technology promises drilling at one-fifth the cost of diamond drilling and thus has the potential to drive a revolution in mineral exploration. Despite the potential for CT drilling, many drilling tasks are still best suited to existing techniques, and thus the second project is developing technologies for optimizing performance and increasing the productivity of diamond and RC drilling.

Data from drilling

Four separate projects are tackling technologies for capturing geochemical, petrophysical and seismic data:

- Real-time Downhole Assay which is developing a Laser Induced Breakdown Spectroscopy (LIBS) tool for measuring downhole geochemistry while the hole is being drilled in a narrow-diameter (~65 mm) setting

- Petrophysical Logging While Drilling which has two linked components: a) development of new sensors for real-time logging of multiple petrophysical properties while drilling; b) rapid, automated imaging of the volume around drillholes, including enabling steering towards targets during drilling
- Seismic in the Drilling Workflow, which combines low-cost fibre optic cables deployed as seismic sensors in drillholes with low-cost seismic sources to develop a seismically instrumented drillsite. The project is also testing Distributed Acoustic Sensing (DAS) methods for hard rock boreholes, and integration with surface seismic techniques
- Automated 3D modelling, which helps to develop software to significantly reduce the time taken from receiving drilling data to constructing a probabilistic and objective geological model, at both the mine scale and the regional scale.

National Drilling Initiative case study

The NDI is a world-first scientific drilling program conducted as a collaboration between geological survey organizations in every state and territory, Geoscience Australia, CSIRO and seven Australian universities brought together by MinEx CRC. The NDI is designed to understand the evolution of the continent, provide clues about where to search for new mineral deposits and bring forward the next generation of mineral exploration technology. NDI drilling programs are planned over the life of MinEx CRC, in multiple jurisdictions, targeting underexplored areas where prospective rocks occur beneath younger cover sediments. MinEx CRC is deploying both conventional and CT drilling technologies to undertake the NDI.

In December 2020, MinEx CRC successfully completed its first NDI campaign in the East Tennant area of the Northern Territory (Pitt and Manison, 2021). The program comprised 10 exploration drillholes for 3970 m of drilling. The East Tennant campaign focused on capturing precompetitive data using conventional drilling techniques augmented by in-field portable XRF data, novel drilling sensors, new-to-market core-yard geochemical scanning provided by MinEx CRC affiliate Minalyze and hyperspectral + high-resolution core imaging via the Northern Territory Geological Survey's HyLogger instrument.

Drilling was contracted by MinEx CRC to DDH1 Drilling and drillsite management was contracted to OMNI GeoX. Drilling data, geological logging and in-field analyses were communicated regularly from the drillsites allowing key decisions to be made remotely.

* MinEx CRC, 26 Dick Perry Avenue, Kensington WA 6151

The East Tennant drilling campaign was designed to test the hypothesis that the basement rocks east of Tennant Creek are comparable to those which host the Tennant Creek mineral field (similar rock types, age of rocks, geological structures and alteration) and thus have a high chance of hosting comparable mineral deposits, particularly Au and Cu.

The drillholes were targeted in an exhaustive process, beginning in 2018 and using regional gravity and magnetics, seismic, magnetotelluric and airborne electromagnetic data recently acquired and/or reprocessed by Geoscience Australia as part of the Exploring for the Future initiative. The final list of priority drill targets was chosen to enable characterization of the stratigraphy, prominent igneous rock types and various structural domains within an approximately northeast–southwest corridor where the inferred depth to basement (typically <500 m) would allow economic mining if exploration is ultimately successful.

An early result of the drilling was to constrain the cover materials and their thickness, with prospective basement beneath less than 200 m of Georgina Basin sediments and 30 m of Cambrian basalt. Beneath these rocks, the drilling program has uncovered a range of igneous and metasedimentary rocks with heterogeneous structural and metamorphic overprint, and variable degrees of hydrothermal alteration. Detailed analyses of these rocks are ongoing while preliminary data collected at the drillsite and core yard within weeks of drilling were released to the public via the MinEx CRC NDI portal in February 2021 (www.minexcrc.com.au). These data have already contributed to a greater understanding of the structure, stratigraphy and magmatic history of the area and helped to support and refine pre-drilling interpretations of the region's prospectivity.

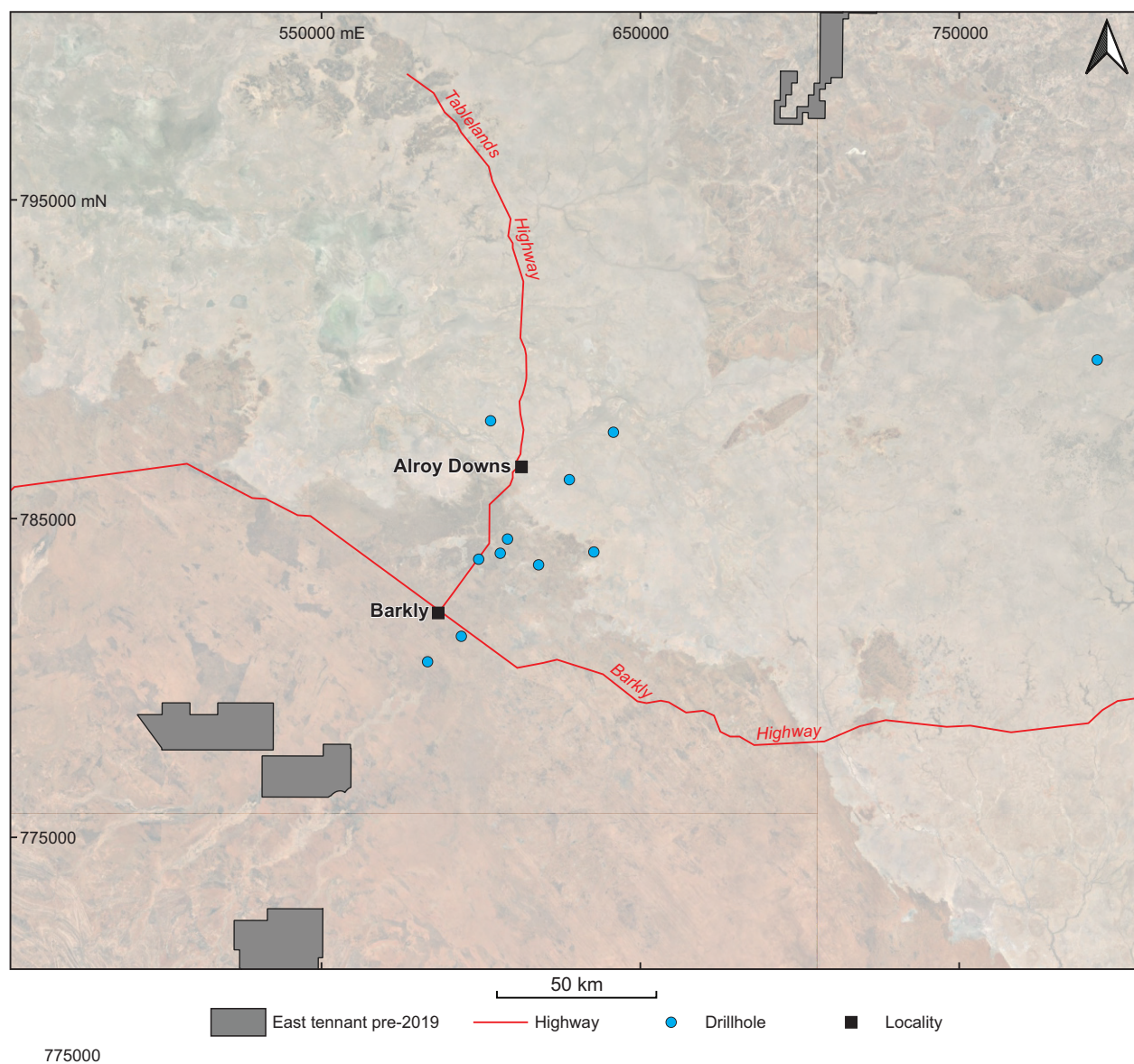


Figure 1. Tenements in the East Tennant area, pre-2019

Key outcomes include:

- The East Tennant area contains metasedimentary rocks of the same type and age as the rocks which host Au–Cu mineralization in the Tennant Creek mineral field
- Felsic igneous rocks are comparable in age and chemistry to felsic igneous rocks in the Tennant Creek mineral field and show evidence of potassium and iron oxide alteration characteristic of the Tennant Creek mineralization
- Sulfide minerals, including chalcopyrite, occur at percentage concentrations in association with veining and wall-rock alteration in one drillhole, confirming the presence of a copper-bearing mineral system.

A significant measure of the impact of the NDI is the exploration interest and investment that has been triggered by the MinEx CRC East Tennant NDI campaign. In 2019, prior to the East Tennant drilling campaign, there was minimal tenement coverage in the East Tennant campaign area (Fig. 1). Following the East Tennant campaign,

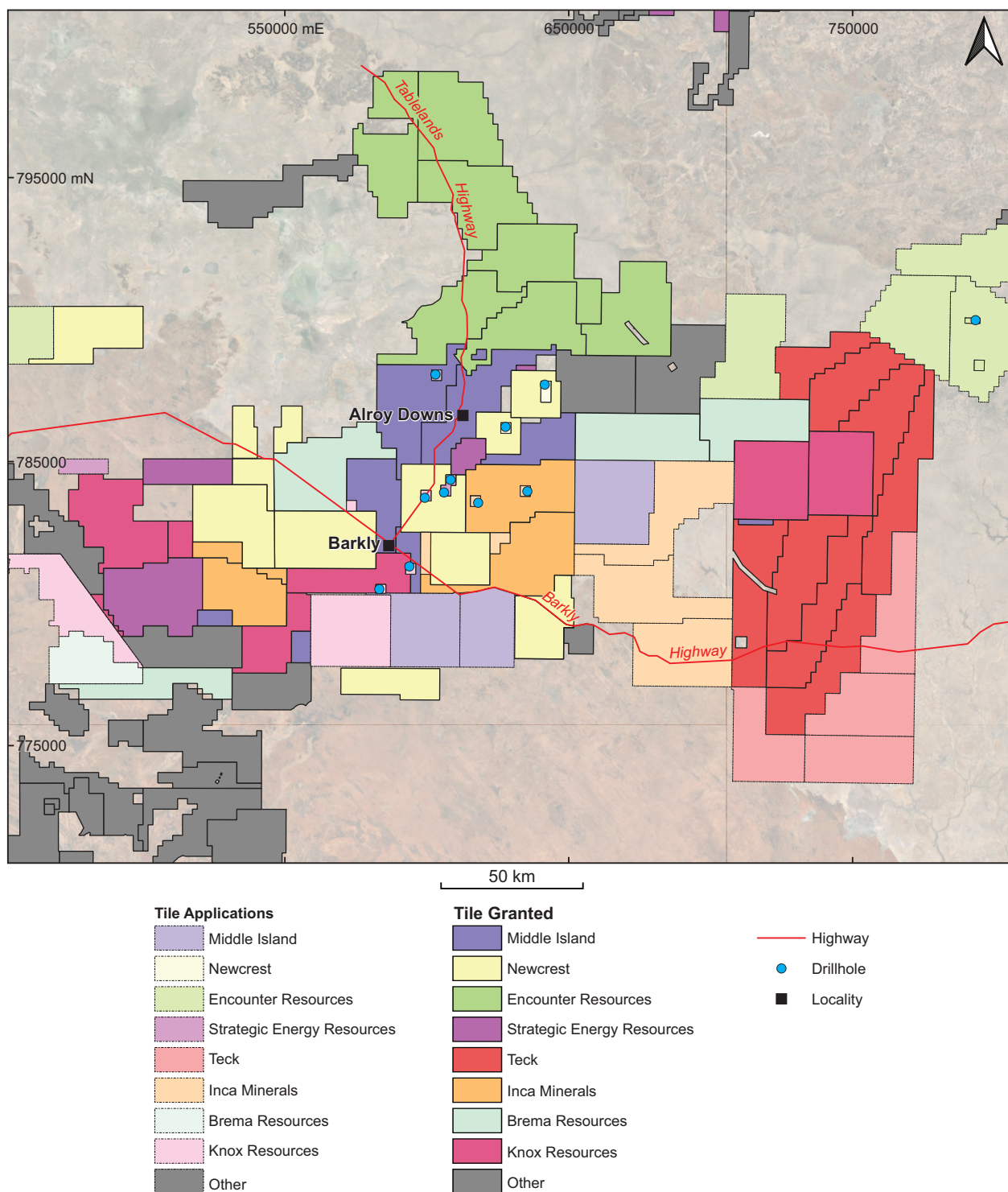


Figure 2. Tenements in the East Tennant area, June 2021

tenement coverage of the priority corridor incorporating the MinEx NDI drillholes was complete (Fig. 2) with new tenements granted to major mining companies and junior explorers. Four of these junior explorers (Encounter Resources, Inca Minerals, Middle Island Resources and Strategic Energy Resources) have become affiliate members of MinEx CRC and have formed a consortium to support a PhD project focused on East Tennant which commenced in August 2021.

Acknowledgements

This work has been supported by MinEx CRC whose activities are funded by the Australian Government's Cooperative Research Centre Program. This is MinEx CRC Document 2021/50.

References

Pitt, K and Manison, N 2021, A joint ministerial release from The Hon Keith Pitt MP, Minister for Resources, Water and Northern Australia and The Hon Nicole Manison MLA, Northern Territory Minister for Mining and Industry, <www.minister.industry.gov.au/ministers/pitt/media-releases/national-drilling-initiative-reveals-golden-opportunity-northern>.

Accelerated Geoscience Program: State GIS datasets

by

WR Ormsby

Introduction

This project collated previously non-digital data as new spatial datasets, enhanced the utility of existing digital data and included a new interpretation of crustal architecture.

These datasets provide key information to investigate the relationship between crustal architecture, regolith geology, geochemical, geophysical and isotopic signatures with known mineralization and thus provide insights to the potential for new discoveries at the statewide, regional and district scale.

Further details on all datasets, including availability, can be found in GSWA (2021a) and Ormsby et al. (2021). The complete package of datasets along with many other selected State layers are also available in GSWA (2021b).

Geochronology and isotopes

Mapping of zircon isotopes for samarium–neodymium, lutetium–hafnium and oxygen, and the associated digital data assist with characterizing lithospheric architecture and understanding crustal evolution. Geochronology sample locations and associated digital information have also been made available through the McNaughton Legacy SHRIMP Mount Collection, thus facilitating access for further studies.

Geophysical images

An isostatic correction was subtracted from the Bouguer gravity anomaly data to create a new isostatic residual gravity image for the State. A selection of aeromagnetic images was also compiled and multiscale edges (worms) were generated from Bouguer gravity and reduced-to-pole magnetic data.

The Moho, 2021 image is a depth contour map of the Mohorovičić (Moho) discontinuity between the crust and mantle as determined from seismological methods.

Major crustal boundaries

The major crustal boundaries map integrates the most recent geophysical data with current understanding of the geological evolution of the State at a significantly improved level of detail (Fig. 1). The primary data sources for identifying these structures are the State tectonic units map and a network of 25 deep seismic reflection profiles. These were integrated with other geophysical, isotopic and geological datasets and modelled in 3D to validate the crustal architecture and to ensure internal consistency.

Regolith regimes

Existing Geological Survey of Western Australia (GSWA) regolith and surface geology maps were compiled and integrated with new regolith interpretation using radiometric imagery to create a seamless digital regolith coverage with the best available information and a revised regolith classification scheme.

Selected mineralization sites

Many mineralized sites contain multiple commodities. These layers highlight where mineralization sites are known for specific commodities, even if they are a relatively minor component of the mineralization. Derived from the Mines and Mineral Deposits (MINEDEX) database, these sites were selected to exclude exploration targets and infrastructure not directly related to known mineralization.

Abandoned gold mines

Selectively extracted data and images derived from the inventory of abandoned mine features have been provided to assist with the understanding of spatial patterns for bedrock and alluvial gold mineralization. This information covers about half of the known abandoned mine sites in the State.

WAMEX geochemistry

Improving the utility of the Western Australian Mineral Exploration (WAMEX) industry geochemistry database was an important outcome. Analytes were extracted from the many disparate submission names and units in WAMEX into flat tables using a common set of units.

Images and processed maximum grade in-hole data and mean soil geochemical data are provided for the most commonly analysed elements, thus facilitating a spatial overview of mineralization trends and patterns at different scales (Fig. 2).

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- Geological Survey of Western Australia 2021a, Accelerated Geoscience Program extended abstracts: Geological Survey of Western Australia, Record 2021/4, 217p.
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- Ormsby WR, Jefferys SDM, and Tapping, BR 2021, Gold mineralization trends from abandoned mine features in Western Australia: Geological Survey of Western Australia, digital dataset.

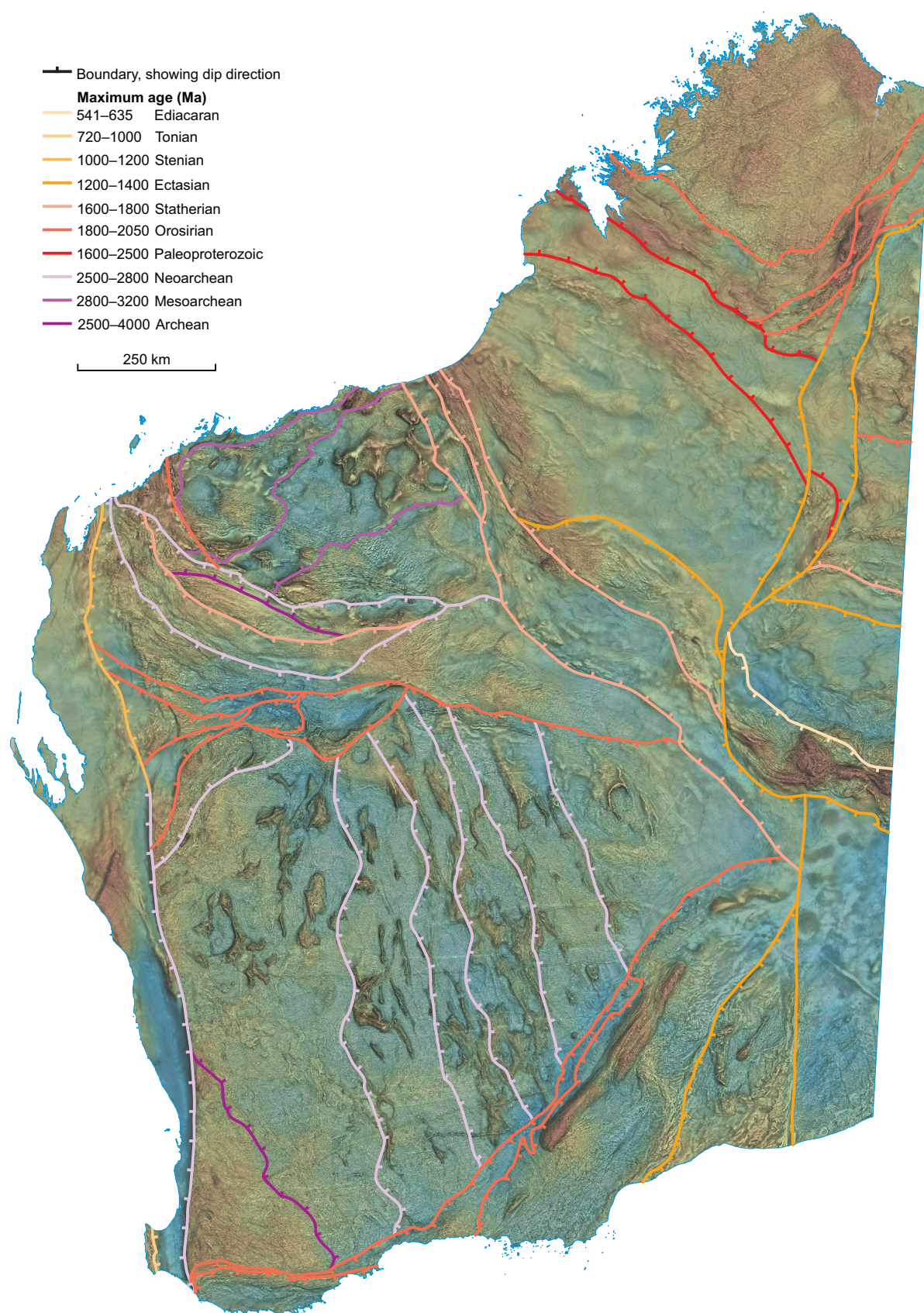


Figure 1. Major crustal boundaries of Western Australia overlain on composite potential field data consisting of isostatic residual gravity (colour) and first vertical derivative, reduced to pole aeromagnetics (texture). Boundaries are symbolized and coloured according to dip direction and maximum age, respectively

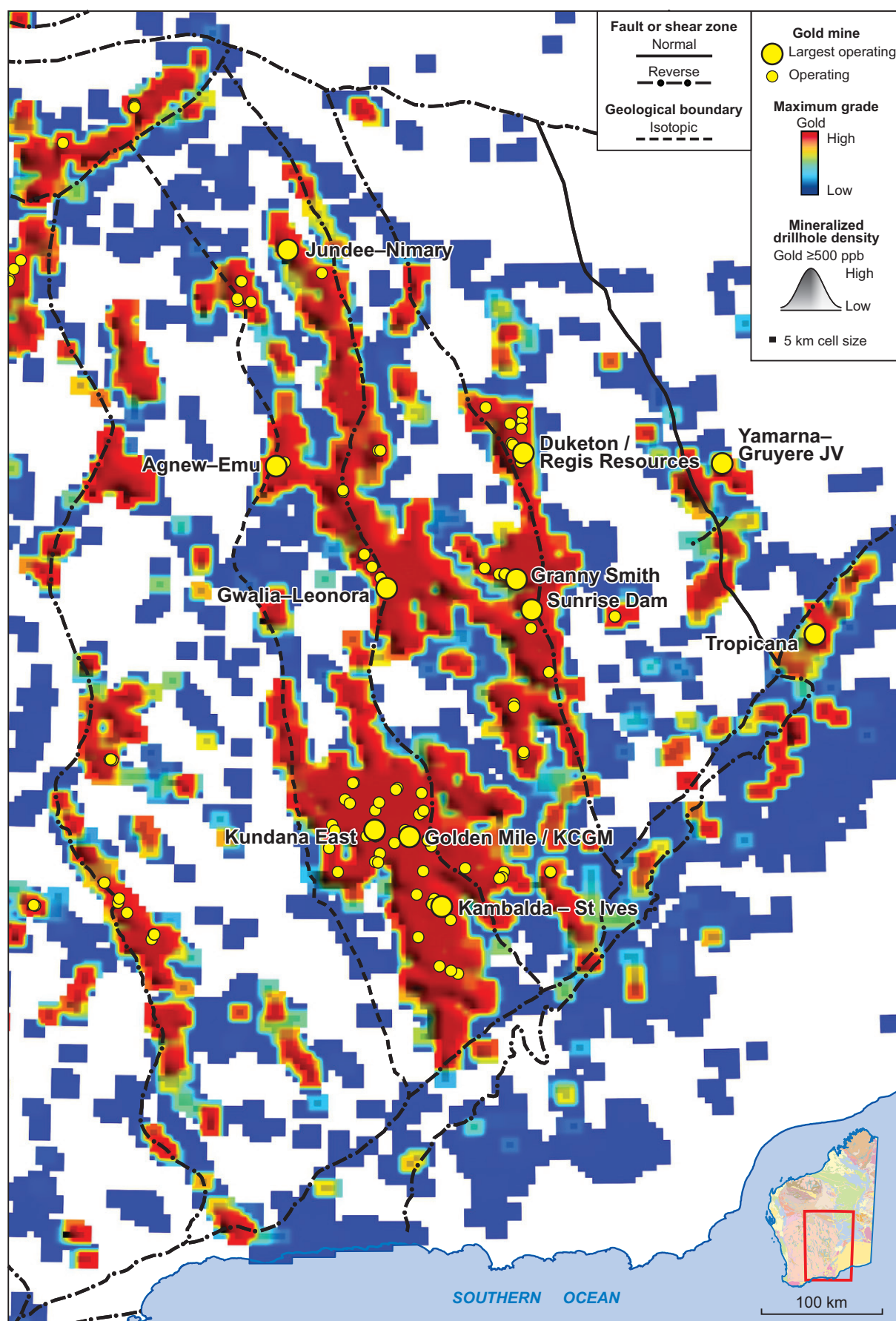


Figure 2. Maximum grade (colour stretched and smoothed) for gold for drillholes collared within the search area (one cell to either side, i.e. over nine cells in total) for a cell size of 5 km, draped over a grey scale hill-shaded layer depicting the number of drillholes with maximum grade ≥ 500 ppb gold. Note the common coincidence of the major crustal boundaries with proximity to known gold mineralization

Geoscience data for critical mineral discovery in Western Australia

by

TJ Beardsmore, P Duuring, JN Guilliamse, S Kenworthy, S Morin-Ka, J Hogen-Esch and D Then

Critical minerals are non-fuel commodities deemed essential for primary or manufacturing industries, for which substitutes are not readily available and supply chains are vulnerable to disruption (e.g. USA – Petty, 2018; EU – European Commission, 2020; India – Gupta et al., 2016). The Australian Commonwealth Government identifies 24 'priority' critical minerals or mineral groups that are, or might be, locally mined for use in domestic or international manufacturing of technologies for a 'low-carbon' world (Austrade-DIIS, 2019; see Fig. 1).

Western Australia is already a significant producer of cobalt, lithium, manganese, rare earth elements (REE), tantalum, titanium and zirconium. It also has known – but undeveloped – resources of antimony, chromium, gallium, graphite, hafnium, magnesium, niobium, platinum group elements (PGE), potash, silica and vanadium. Western Australia presently has no defined resources of other critical minerals such as beryllium, bismuth, germanium, helium, indium, rhenium and scandium, but is considered prospective for the types of mineral deposits likely to contain them, either as primary or significant accessory components of mineralization (Fig. 1).

The State's long-term economic benefit from critical minerals depends on continuing discovery and development of additional resources. These will most likely be found in challenging geological environments – for instance as minor components in known deposits, or in undiscovered, deeply buried ores, or even in mining and processing residues. The Geological Survey of Western Australia (GSWA) therefore expedited the delivery of relevant, novel geoscience data as part of its 2020–21 Accelerated Geoscience Program (AGP), to stimulate exploration activity and related economic development (particularly in the wake of the COVID-19 pandemic).

A mineral systems analysis was applied to selected prominent critical minerals and prospective mineralized environments to identify specific geological features that might indicate fertility of a region for these minerals (Table 1). These geological features were then extracted into digital, GIS-based 'occurrence' maps from GSWA and third-party databases. The goals were to generate a sufficiently comprehensive data package that will be of use to critical (or other) mineral explorers, and to demonstrate the types of information that can be extracted from GSWA geoscience data, and the methodology for achieving this.

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Figure 1. Mined and prospective mineral commodities in Western Australia, with critical minerals highlighted

Table 1. Selected critical minerals and mineralized environments

Critical Mineral Group	Mineralized environment
bismuth, germanium, indium	VMS systems (associated with zinc and lead)
graphite	carbonaceous metasediments
lithium (\pm tin, tantalum, beryllium)	rare-element pegmatites
manganese	sedimentary basins
REE (+ tantalum, tungsten, niobium)	carbonatites, kimberlites and lamproites
vanadium, PGE	mafic igneous intrusions
potash	brines in paleochannels and playa lakes
silica	quartz veins

More than 250 individual critical mineral 'fertility indicator' maps were produced during the AGP, reflecting five broad categories of information – known mineral occurrences, prospective rock types, indicator minerals, geochemical signals, and climate. The maps and associated geoscience data and documents have been compiled into a Geological Exploration Package available via the DMIRS eBookshop or the Data and Software Centre (www.dmirs.wa.gov.au/datacentre). The various components of the product are briefly reviewed here, but are described in more detail in a series of extended abstracts published in GSWA (2021).

The locations of known critical mineral occurrences have been extracted from GSWA's MINEDEX database.

Maps showing the locations of prospective rock types – either hosts for critical minerals, or indicating geological environments favourable for critical mineral-bearing mineralization – were derived from several primary sources. Prospective lithostratigraphic units were extracted from GSWA's interpreted bedrock geology (IBG) maps (Martin et al., 2016). The locations of quartz veins, granitic pegmatites and other igneous intrusions too small to appear in the GSWA IBG were digitized from georegistered images of GSWA or third-party fact geology maps, or garnered from the GSWA diamond exploration database (Hutchison, 2018a,b). The distributions of Western Australian lakes, paleovalleys and drainage catchments were sourced from Geoscience Australia and the WA Department of Water and Environment. Maps showing observed (point) locations of outcrops of prospective rock types were derived from GSWA's WAROX database (Riganti et al., 2015).

The WAROX database also supplied maps showing observed occurrences of 'indicator' minerals that are potentially diagnostic either of prospective rock types, or of critical mineral-bearing mineralization or associated alteration (including metamorphosed assemblages).

A Western Australian 'near surface' whole-rock litho-geochemical database was created by combining the GSWA WACHEM, Geoscience Australia OzCHEM, CRC-LEME 'Laterite' and WAMEX Mineral Exploration 'surface' (soil, stream, rock chip, shallow auger and 'maximum grade in drillhole') datasets. Specific litho-geochemical fertility indicator maps were also derived for rare-element pegmatites and the granites from which they are sourced; for mafic intrusion-hosted vanadium; for basin-hosted manganese; and for VMS systems.

Three discrete Western Australian well- and bore-water chemistry datasets created by CSIRO were combined, and maps produced to show concentrations of a suite of critical

minerals and other analytes. Maps showing gridded, time-averaged rainfall, evaporation, and evapotranspiration data, obtained from the Bureau of Meteorology permit evaluation of the influence of long-term climate on the concentration of commodities dissolved in groundwaters.

The Critical Minerals data package also compiles many of these maps into four 'mineral system' types having significant potential to host critical minerals – basin-hosted manganese, rare-element pegmatites, volcanogenic massive sulfides and mafic intrusion-hosted vanadium. The thematic map layers for the 'rare-element pegmatite' and 'mafic intrusion-hosted vanadium' mineral systems are also available via GSWA's Mineral Systems Atlas (www.dmirs.wa.gov.au/mineralsystems atlas; Morin-Ka et al., 2019).

The Critical Minerals data package contains other statewide geoscience maps, some created during the AGP ('merged' IBG; 'outcrop geology' – see also Jakica et al., 2020; 1:100 000 regolith regimes; 2.5 million-scale major crustal structures; radiogenic [Sm–Nd and zircon Lu–Hf] and stable [zircon O] isotope; gravity and magnetic multiscale edges ['worms']; depth to Moho), and some previously created standard base layers (1:100 000 and 1:500 000 IBG, 1:10 million tectonic units, 1st vertical derivative of total magnetic intensity, radiometrics, and Bouguer and isostatic residual gravity).

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Pre-Mesozoic interpreted bedrock geology of the southwest Yilgarn, 2021

by

R Quentin de Gromard, TJ Ivanic and I Zibra

Even though the Yilgarn Craton is highly mineralized and represents one of the largest portions of Archean crust on Earth, the southwest Yilgarn is largely underexplored and interpretations of bedrock geology mostly pre-date seamless high-resolution aeromagnetic coverage. Released in July 2021, the pre-Mesozoic interpreted bedrock geology (IBG) map of the southwest Yilgarn (Fig. 1) now integrates legacy data with a substantial volume of multiple, diverse datasets acquired under the Accelerated Geoscience Program into a holistic interpretation that provides a fundamental update on our understanding of the geology of the Youanmi and South West Terranes (GSWA, 2021; Quentin de Gromard et al., 2021). The updated interpretation provides context for known mineral deposits in the region, and aims to open new search spaces in this underexplored and highly prospective portion of the Yilgarn Craton.

The southwest Yilgarn IBG forms an area approximately 450 x 380 km wide that is bounded in the west by the Darling Fault, and in the east by the Southern Cross – Forresteria – Ravensthorpe greenstone belts. It includes the Wongan Hills and Westonia greenstone belts in the north, and extends into the Albany–Fraser Orogen in the south. The IBG consists of four interpretative digital layers including 7864 aeromagnetic form lines, 5922 geolines, 3868 structure lines and 1581 geopolygons.

The aeromagnetic form lines should be regarded as a representation of the ductile architecture of the crust subsurface. They are particularly useful to estimate strain intensity, to interpret faults and shear zones and their kinematics, and to identify domains of differing geometries possibly reflecting differing geological histories.

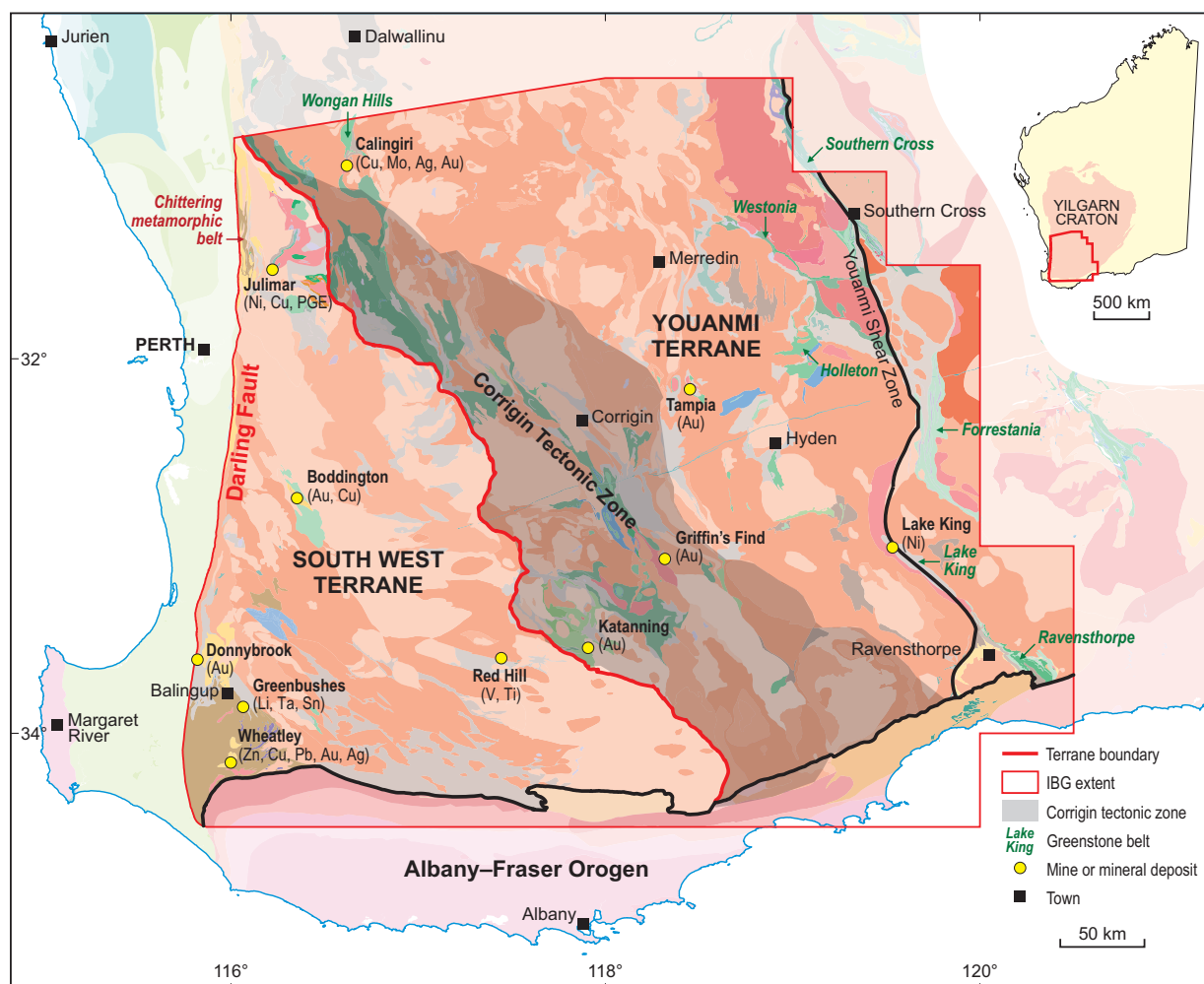


Figure 1. Simplified pre-Mesozoic interpreted bedrock geology of the southwest Yilgarn, showing the new mapping overlain on the 1:500 000-scale state IBG polygon layer. The thick red line shows the location of the redefined terrane boundary between the Youanmi and South West Terranes, the yellow dots show the location of the main mines and mineral deposits west of the Youanmi Shear Zone; the main commodities are shown in brackets. To view all layers of the southwest interpreted bedrock geology, see the Southwest Yilgarn, 2021 Geological Exploration Package (GSWA, 2021) or visit GeoVIEW.WA <www.dmirs.wa.gov.au/geoview>

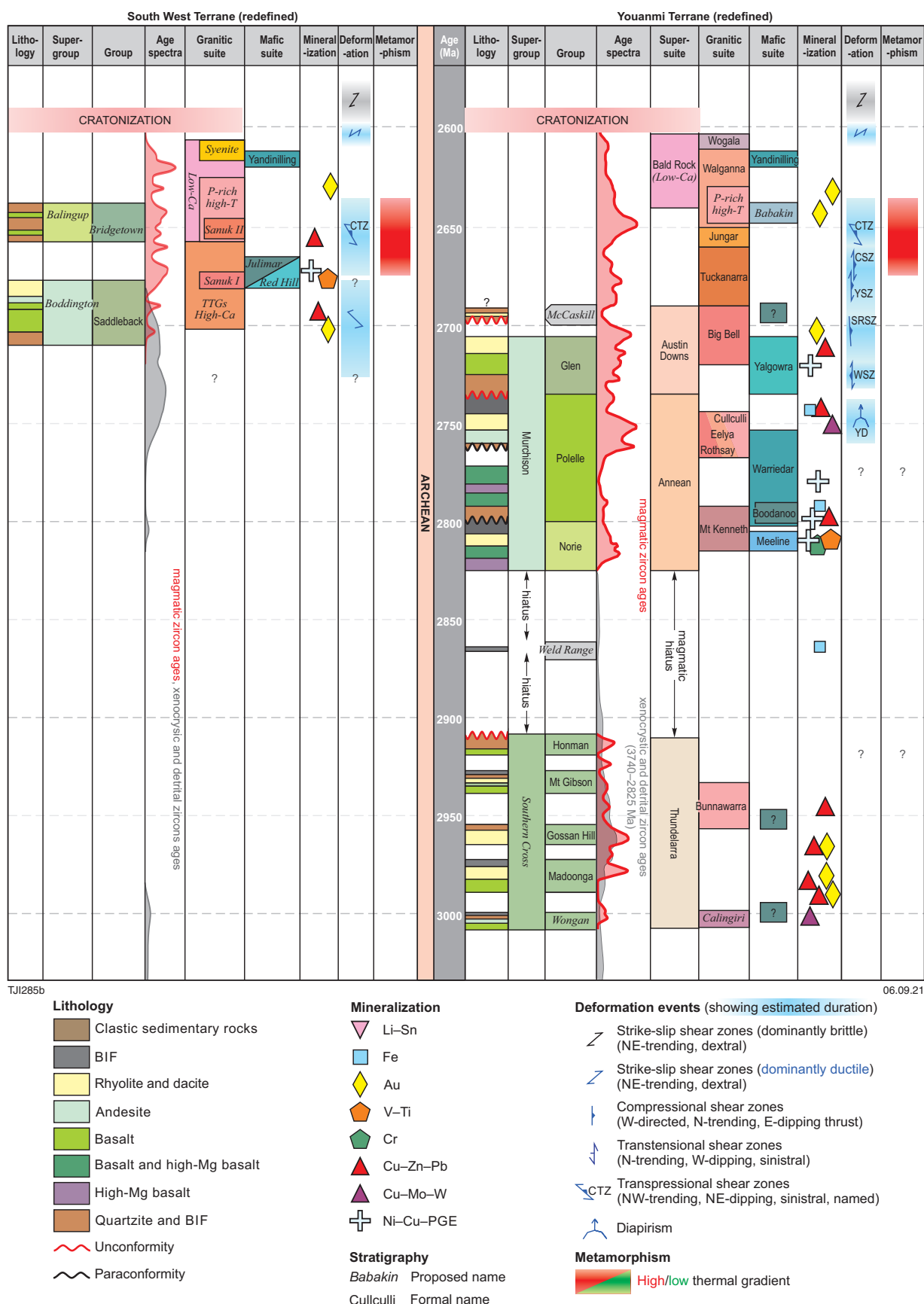


Figure 2. Simplified time-space event diagram and stratigraphic framework comparing datasets between the revised extents of the South West and Youanmi Terranes of the Yilgarn Craton for the Archean time slice. Note that published stratigraphic and magmatic nomenclature is shown along with proposed nomenclature (italicized text). Age spectra include geochronology data by GSWA and from published sources. Significant mineralization events are shown alongside deformation and metamorphic events with inferred event duration where estimates are possible. Question marks denote features or events with high uncertainty or where data is lacking. Abbreviations: CSZ, Cundimurra Shear Zone and related shear zones; CTZ, Corrigin Tectonic Zone; YSZ, Youanmi Shear Zone and related shear zones; SGSZ, Swan Gorge Shear Zone; LSSZ, Lady Springs Shear Zone; CSZ, Cundimurra Shear Zone and related shear zones; SGSZ, Swan Gorge Shear Zone; SRSZ, Salt River Shear Zone; WSZ, Waroonga Shear Zone; YD, Yalgoo Dome and related domes; YSZ, Youanmi Shear Zone and related shear zones

The geolines layer largely consists of interpreted mafic dyke segments assigned to 12 different dyke suites, ranging in age from 2615 to 733 Ma. Each geoline is attributed with a code, a unit name, a description and, where available, an age and a magnetic polarization (either positive or negative). The structural lines provide the structural framework of the IBG, and were attributed as either 'fault' (i.e. brittle) or 'shear zone' (i.e. ductile) and where constraints are known, faults and shear zones are also attributed with dip estimates, dip direction, kinematics, and maximum and minimum ages. The structure age constraints were interpreted from crosscutting relationships of dated geological features, and as a result, 13 sets of aged-constrained structures are identified. Each geopolygon is attributed with a code, a unit name, a description, and where available, maximum and minimum ages and granite geochemistry classification.

In our interpretation, the terrane boundary between the South West and the Youanmi Terranes has been shifted approximately 200 km southwestwards and is interpreted to lie along the southwestern deformation front of the northwest-trending, southwest-verging Corrigin Tectonic Zone (Fig. 1). Our interpretation is based on major variations

in granite geochemistry and crystallization ages, the age and nature of supracrustal packages, structural patterns and deformation and metamorphic history, geophysical data, and Nd and O isotopes data across the redefined terrane boundary (Fig. 2). The revised terrane boundary between the South West Terrane and the Youanmi Terrane represents one of the major divisions within the Yilgarn Craton. A feature of this scale and tectonic significance has the potential to be mantle-tapping, which is of significance to mineral explorers that target mineral systems within or near lithosphere-scale structural corridors.

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Far East Yilgarn Geological Exploration Package: accelerating the uncovering of the eastern margin of the Yilgarn Craton

by

R Chopping

Although the economic importance of the Yilgarn Craton is well understood, the eastern margin of the Craton is under cover, misunderstood and consequently remains underexplored. Within the Accelerated Geoscience Program (AGP), efforts were focused on compiling the latest information to assist in uncovering this region of the State. The cover sequences of multiple basins and extensive regolith are, however, not simply impediments to exploration but also host important resources in their own right. Providing data to map these multiple layers in the region is the primary rationale for the Far East Yilgarn Geological Exploration Package (FEY GEP: area of interest shown in Figure 1a). Many new statewide data from the AGP, and also targeted products designed for the region, are included in this package.

New views of geophysical imagery

With the complexity of cover sequences obscuring basement geology, the FEY GEP provides not just the latest

geophysical compilations but also new image products to help see through this cover. An example of this is the magnetic integral (Fig. 1b), which is more sensitive to depths comparable to gravity data rather than traditional magnetic intensity images which are sensitive to shallower features. Such data are more useful for those working in areas of deeper cover.

New insights to basin, basement and regolith geology

Alongside the new geophysical imagery, the basement geology was reinterpreted to utilize the new insights from these data. Rather than simply removing all basin cover, the basin geology was interpreted in multiple phases and provided as individual layers, allowing users of the package to strip away different basin sequences. Rather than one-size-fits-all, this approach allows for zeroing in for a particular sequence of interest, either in the basement or in the basins themselves.

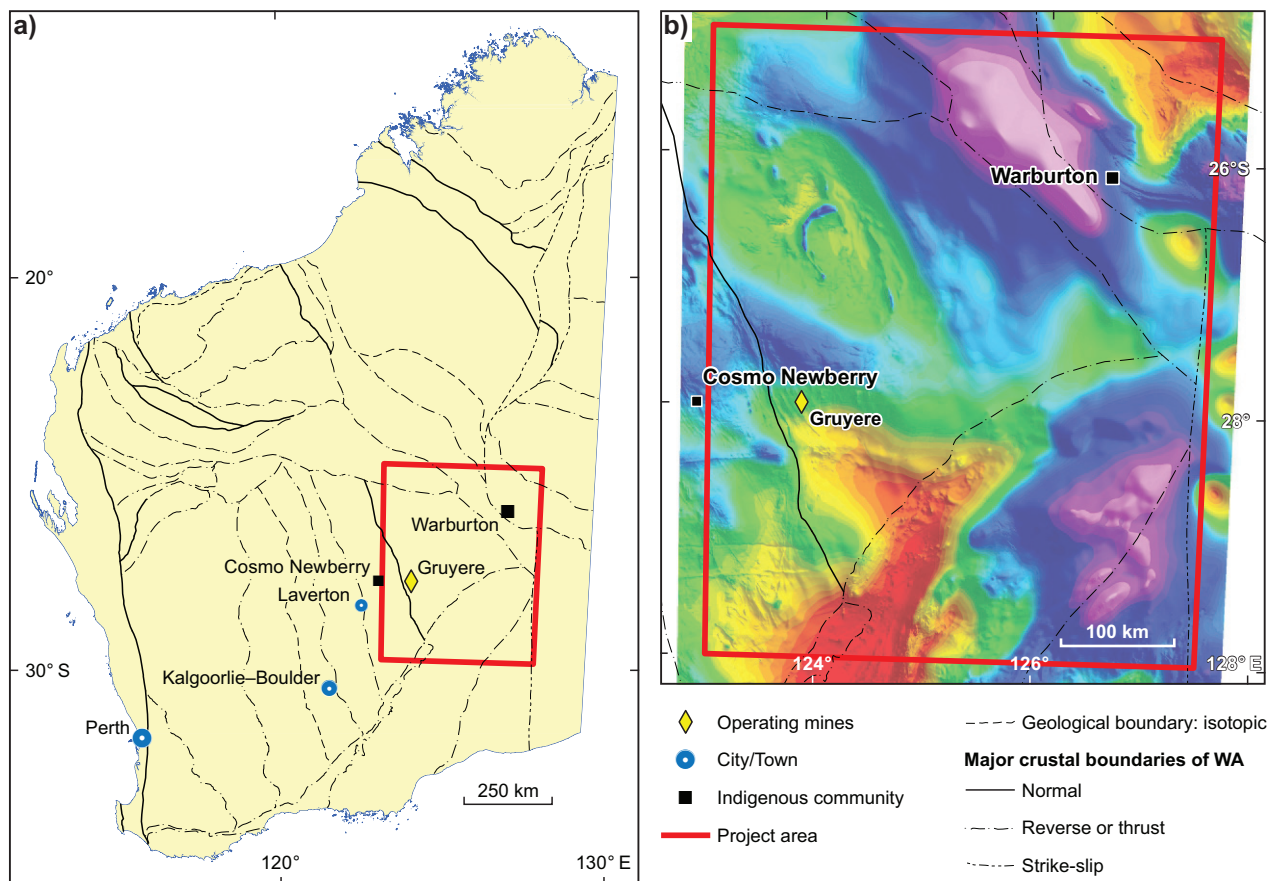


Figure 1. a) Statewide context of the Far East Yilgarn Geological Exploration Package; b) magnetic integral of the region, with linework from the Western Australian Major Crustal Boundaries (Martin et al., 2021)

Another area of effort for the FEY GEP was in the regolith geology regimes (see de Souza Kovacs, 2021; Fig. 2), a new dataset created statewide for the AGP. While created as a statewide layer, further refinement based on original 1:100 000 regolith mapping over the Yilgarn Craton was incorporated to refine boundaries over the 1:500 000 state regolith geology (Jakica et al., 2020). By separating regolith units into fundamental classes of residual, exposed or deposition, GEP users can understand the regolith regime they are in, influencing geochemical surveying parameters. These regolith regimes have often arisen from geological processes influenced by subsurface geology and thus can represent another proxy for this buried basement geology.

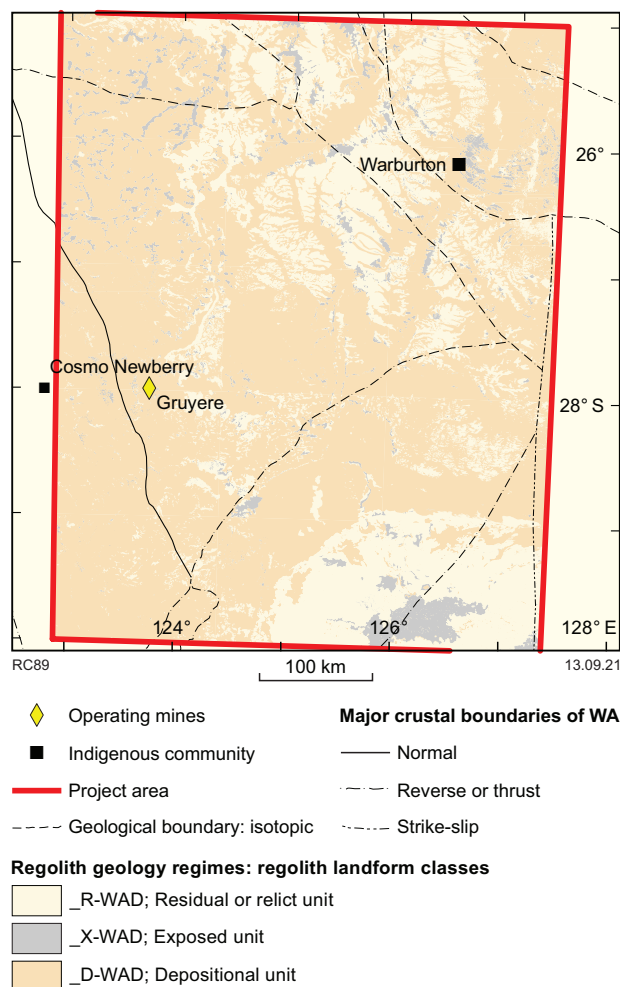


Figure 2. Far East Yilgarn regolith regimes (de Souza Kovacs et al., 2021) for the Far East Yilgarn Geological Exploration Package. These are extracted from the statewide dataset produced under the AGP

Stepping forwards in time and eastwards in space

The FEY GEP is a 'state of play' for the current data for the region and represents a first phase in investigating the eastern margin of the Yilgarn Craton. Insights from new or soon-to-be-acquired geophysics, and coordination with the MinEx CRC National Drilling Initiative (Bailey and Giles, 2021) will provide further data to build upon this package.

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Energy Systems Atlas

by

D Brooks

The Energy Systems Atlas is a collection of new geological map layers to help explorers of Western Australia's Phanerozoic and Neoproterozoic sedimentary basins identify regional geological frameworks. These frameworks include structure and stratigraphy, and essential elements and processes of petroleum, geothermal and subsurface storage systems such as source, reservoir and seal (GSWA, 2021). Data is captured from legacy Geological Survey of Western Australia (GSWA) Reports, well completion reports and other industry reports.

These layers will be updated periodically as new well and survey data is submitted, and interpretation and mapping projects are concluded.

The Energy Systems Atlas is accessed using the mapping tool within the Western Australian Petroleum and Geothermal Information Management System (WAPIMS). To access the Energy Systems Atlas, visit <wapims.dmp.wa.gov.au/WAPIMS/GISMap/Map>.

Completed layers

The layers released during 2021 include the following:

Structure

Subsurface Structure maps

The subsurface structure maps are derived from seismic interpretation and sourced from many GSWA publications. Each map has been digitized and georeferenced prior to inclusion in the Energy Systems Atlas. The maps are available as free downloads from the Data and Software Centre via Datasets as ESRI shapefiles, MapInfo TAB files and raster grid (.BIL) files.

SEEBASE maps

These layers include all maps produced as part of the Canning and Carnarvon Basins SEEBASE projects funded by the Exploration Incentive Scheme (EIS), including depth-to-basement and basement composition (Frogtech Geoscience 2017, 2019).

Seal

Salt

Regional depth and isopach maps delineate the lateral extents of subsurface salt formations that have potential sealing capacity to trap hydrocarbons, helium and natural hydrogen and for storage of manufactured hydrogen and as a seal for carbon dioxide sequestration. The current GSWA maps are based on well intersections and reflection seismic data and cover the southern Canning and Officer Basins.

Well information

Scanned composite well logs, mud logs and core photographs from well completion reports and GSWA Reports show essential well information and have been released in separate layers.

Stratigraphy

Two stratigraphy related layers have been created: Biostratigraphy and Well Correlations. Well Correlations are original GSWA interpretations of wireline logs, lithology and biostratigraphy from petroleum and mineral wells and outcrop. Legacy correlations do not show updates since the year of publication. The biostratigraphy layer provides details on the age and depositional environments of strata within the Phanerozoic and some Proterozoic basins of Western Australia.

Reservoir

Routine Core Analysis (RCA) data including porosity, permeability, and other reservoir quality-related measurements are from new and legacy data submitted to, or generated by, GSWA.

Source

To help assess the hydrocarbon source rock potential, organic geochemistry data from Rock-Eval pyrolysis, Total Organic Carbon (TOC) and vitrinite reflectance measurements (Vr) have been gathered from a variety of reports.

Hydrocarbon distribution

The known distribution of hydrocarbons from petroleum wells are presented in three layers: hydrocarbon shows, oil and gas fields, and composition. The hydrocarbon shows include descriptions of fluorescence oil shows and mud log gas measurements. The oil and gas fields layer describes the reservoir, seal, source, trap and hydrocarbons. Petroleum composition lists the percentage of petroleum and other components analysed from fluid and gas samples.

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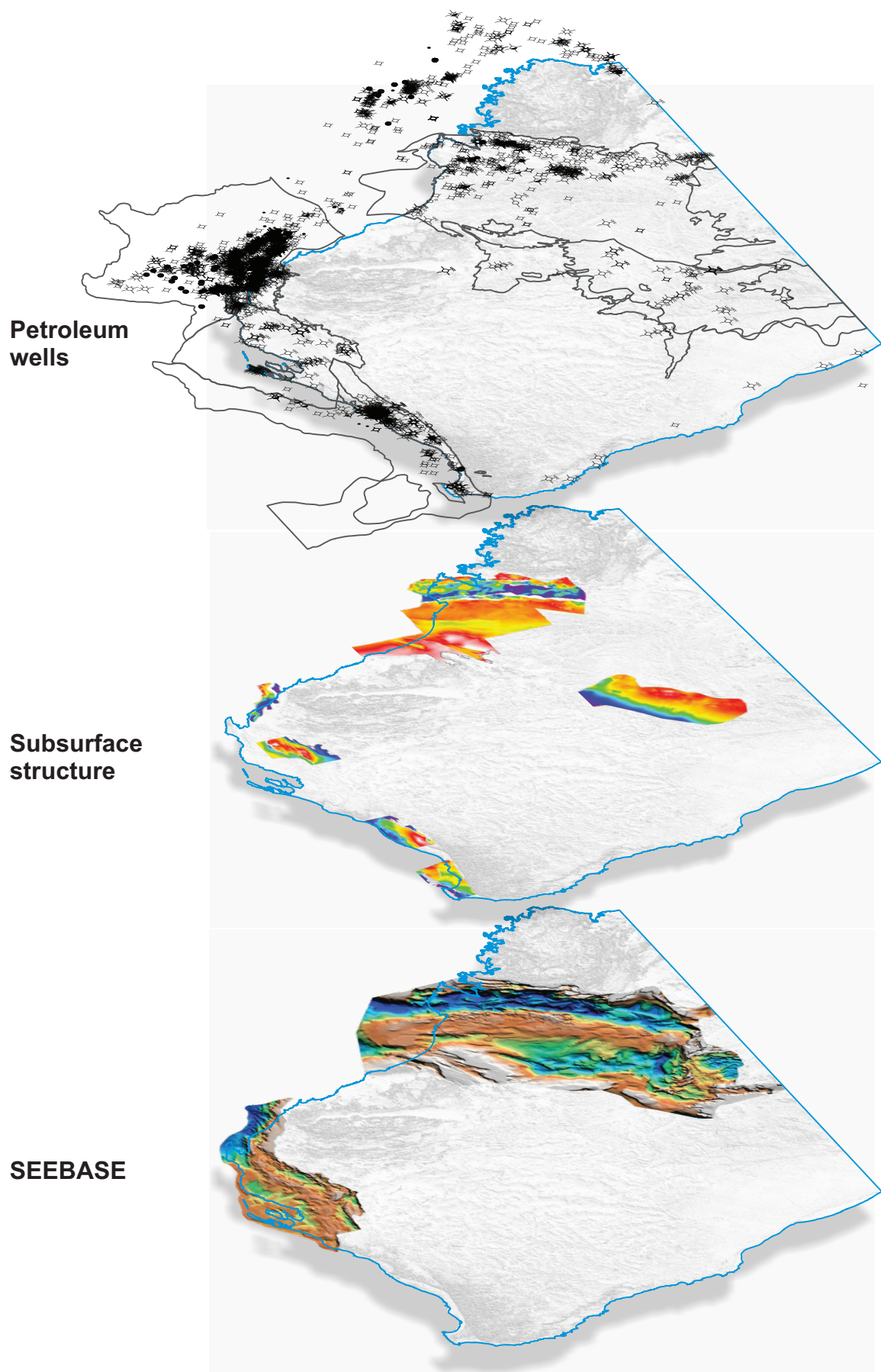


Figure 1. Three maps from the Energy Systems Atlas showing petroleum well locations, examples of Subsurface Structure maps and SEEBASE Depth to Basement maps over the Canning and Carnarvon Basins

Natural hydrogen: a future energy resource?

by

PW Haines

Hydrogen is frequently in the news as the clean fuel of the future, with most debate centred on so called 'green hydrogen', created by electrolysis using renewable energy sources, or 'blue hydrogen', created from methane with waste carbon dioxide captured and stored. But could we explore for economic accumulations of natural hydrogen in the Earth's crust? Hydrogen can be naturally generated in a variety of geological environments by a number of mechanisms, the most significant being the oxidation of iron-rich rocks by water contact and radiolysis of water. Significant 'hydrogen kitchens' are likely to be situated deep within cratonic basement, but the hydrogen thus generated could migrate upwards via faults and fractures with the potential to temporally accumulate near the surface in porous reservoirs within overlying basins.

Accidental discoveries of hydrogen while drilling for other commodities have been reported worldwide, as have surface hydrogen seeps. The recent discovery of the Bourakebougou field in Mali, Africa, where shallow wells are flowing 98% pure hydrogen, is very encouraging. Here in Western Australia, hydrogen has been reported in gas analyses from some onshore hydrocarbon exploration wells in the Canning and Perth Basins, other shallow drilling in the Perth Basin, and mineral drillholes on the Yilgarn Craton. Concentrations vary widely, and it is possible that some hydrogen is an artefact of drilling operations (e.g. resulting from well acidization). It should be noted that analysis for hydrogen is rarely undertaken during exploration, so more occurrences may have been missed. The Geological Survey of Western Australia is currently investigating some of these historic reports.

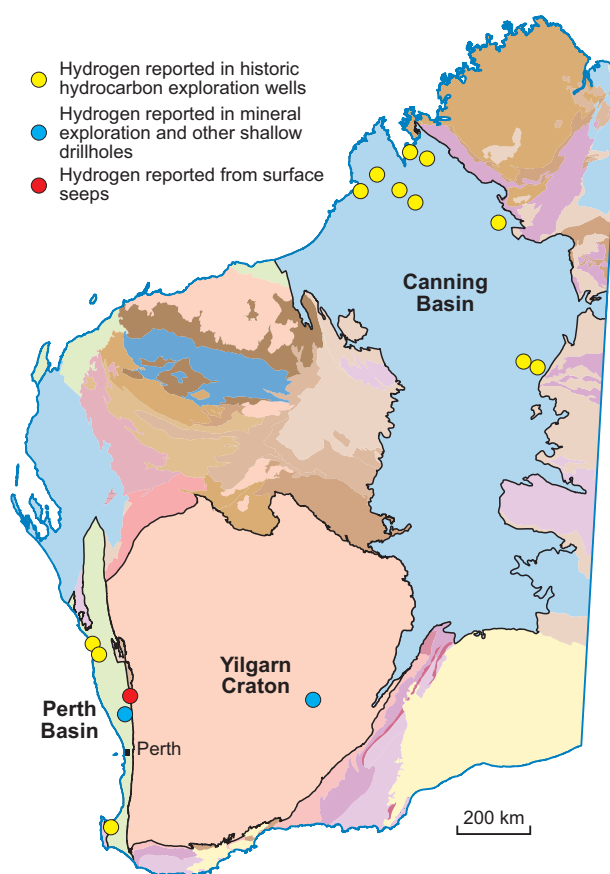


Figure 1. Simplified geological map of Western Australia showing reports of hydrogen from drilling and seeps

GSWA pilot petrophysics project

by

L Brisboud, M Markoski*, J Trunfull*, B Bourne*, D Howard, C Hall, J Sapkota and M de Paoli



In 2020–21, the Geological Survey of Western Australia (GSWA) undertook a pilot petrophysics project, in collaboration with Terra Petrophysics and funded by the Exploration Incentive Scheme (EIS). The project aims to collect petrophysical data from State and company drillcore, from significant mineral deposits and poorly exposed regions, to assist with the interpretation of geophysical data. This includes characterizing the physical properties of the sampled stratigraphic units, alteration and mineralization styles, and constraining geophysical models of the subsurface.

The project took place in two stages; in both, the following suite of measurements were made: magnetic susceptibility, remanent magnetization, dry bulk density, apparent porosity, galvanic resistivity, induced polarization (chargeability), inductive conductivity and P-wave sonic velocity. In the first stage, petrophysical data were collected from samples from

the Paterson Orogen (n = 274), West Arunta (n = 975) and Eucla basement (n = 93) (Fig. 1a). Data from the Paterson Orogen showed promising results, including elevated magnetic susceptibility and chargeability in mineralized samples (Fig. 1b).

In the second stage, petrophysical data were collected from 1999 samples from the Kalgoorlie Terrane (n = 1651) and Yamarna Terrane (n = 348) of the Eastern Goldfields Superterrane (Fig. 1a). The Kalgoorlie Terrane petrophysical dataset includes mineralized and unmineralized samples, and an almost complete section through the Kalgoorlie Group stratigraphy.

Petrophysical data and reports are available from GSWA's MAGIX geophysical data repository.

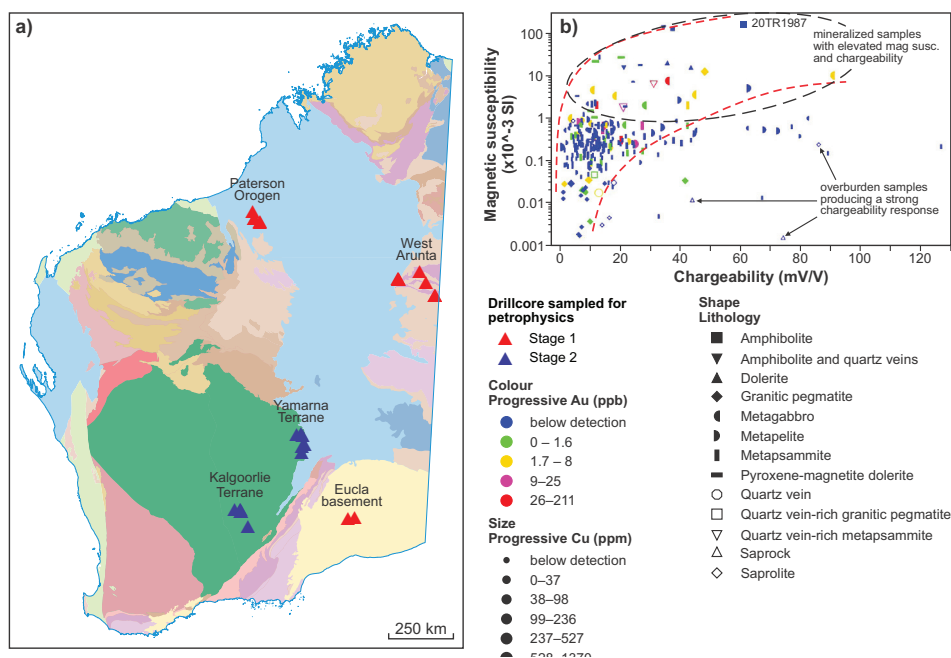


Figure 1. 2020–21 petrophysical data acquisition: a) location of drillcores sampled for petrophysics shown on the 1:10 000 000-scale tectonic units map; b) magnetic susceptibility vs chargeability data from the Paterson Orogen showing the elevated magnetic susceptibilities and chargeabilities of mineralized samples (from Terra report, MAGIX Registration Number 72014)

* Terra Petrophysics, Unit 5/51 Forsyth Street, O'Connor WA 6163

Alteration, Cu–Au mineralization and felsic magmatism at Obelisk, north Paterson Orogen

by

P Duuring, J Guiliamse, D Kelsey, I Fielding and L Fonteneau*



Recent mineral discoveries in the northern Paterson Orogen highlight its exploration potential. One such discovery, the Obelisk Cu–Au prospect, is located about 300 km east of Port Hedland in amphibolite-facies metamorphosed, Proterozoic basement rocks that are unconformably overlain by Phanerozoic sedimentary and volcanic rocks of the Canning Basin. Mineralization at Obelisk occurs along the folded and sheared northwesterly trending contact between metasedimentary rocks and amphibolite.

A multistage hydrothermal history is proposed, including (i) an early high-temperature fluid event characterized by plagioclase–hornblende alteration in metapsammite, (ii) a main-stage Cu–Au–W–Bi fluid event defined by widespread biotite–muscovite–anorthite–titanite–rutile–pyrrhotite–pyrite–chalcopyrite alteration in metasedimentary rocks and amphibolite, and (iii) a later-stage, lower-temperature fluid event, producing semimassive pyrrhotite–chalcopyrite–pyrite±molybdenite veins, quartz–muscovite±molybdenite veins, and chlorite-rich alteration assemblages in both rock types.

Magnetite-bearing dolerite dykes cut the main-stage alteration zones, but these dykes are in turn cut by granitic pegmatite dykes. Molybdenite in a quartz–muscovite vein cutting granitic pegmatite and associated with the later fluid stage returned a model Re–Os age of 651.6 ± 1.9 Ma (2σ , MSWD = 0.13) (Wingate et al., 2021) – overlapping a published age constraint for felsic magmatism in the nearby Venus Citadel T3 project (e.g. 649 ± 5 Ma; Wingate et al., 2019). Thus, granitic pegmatite clearly overlaps the later mineralization event but post-dates the main mineralization stage. Future work will focus on constraining the absolute timing and source of main-stage fluids.

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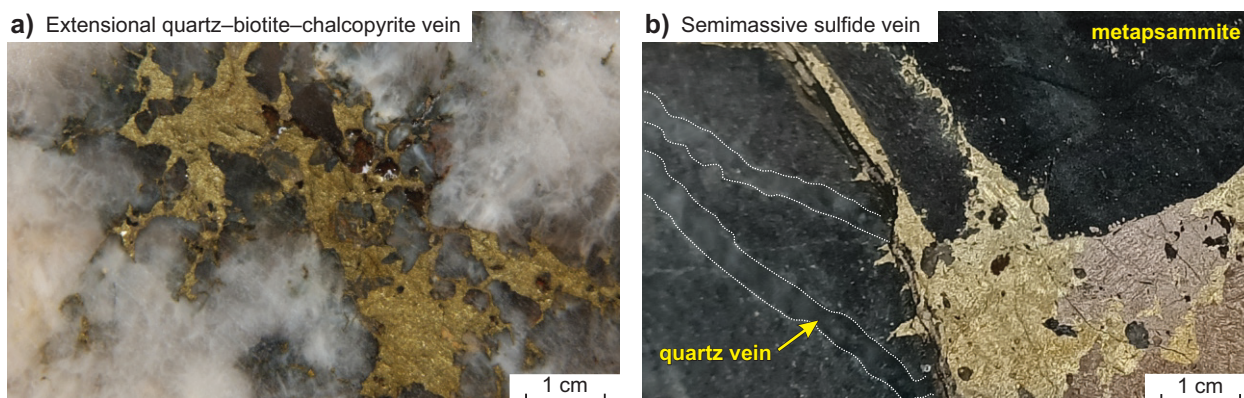


Figure 1. Main- and later-stage alteration at Obelisk: a) main-stage, quartz–biotite–chalcopyrite extensional vein that cuts metapsammite (sample 224227 from PND004 at 240 m); b) a later-stage semimassive sulfide vein comprising chalcopyrite–pyrrhotite (with minor amphibole mineral inclusions) that cuts two main-stage quartz±biotite±pyrite extensional veins (PND002 at 422 m)

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Assessing the heavy mineral cargo of regolith from the west Arunta

by

E Gray, A Walker*, F Korhonen and BIA McInnes*

The west Arunta region, near the Western Australia – Northern Territory border, forms part of ‘The Gap’, a region of Western Australia where geological knowledge and resource exploration is hampered by the depth and extent of cover. The west Arunta is geologically complex; Paleoproterozoic rocks of the Arunta Orogen are overlain by the Neoproterozoic Murraba Basin, Neoproterozoic to Cambrian Amadeus Basin, the Early Ordovician to Early Cretaceous Canning Basin and then by Cenozoic cover. In areas such as this, with limited or no outcrop, examining the cover itself can provide valuable clues about the underlying geology. The heavy mineral component ($>2.9 \text{ g/cm}^3$) of regolith includes authigenic and detrital resistate minerals such as zircon, monazite, iron oxides, ilmenite and rutile. Many of these minerals are useful for provenance studies, and some may also be indicator minerals that can be used to determine proximity to specific mineralization types.

Indicator minerals are widely used for diamond, gold and base metal exploration internationally, particularly in glaciated terrains, but are less routinely used in Australia.

The initial phase of this study will analyse heavy minerals separated from the fine fraction (75–425 μm) of soil samples from different regolith–landforms across the west Arunta region using Tescan Integrated Mineral Analysis (TIMA). This study aims to clarify the relationship between underlying geology and heavy mineral abundance, distribution and mineralogy in the fine fraction of transported and in situ cover, and therefore whether heavy mineral analysis of soil samples has the potential to aid exploration in this region.

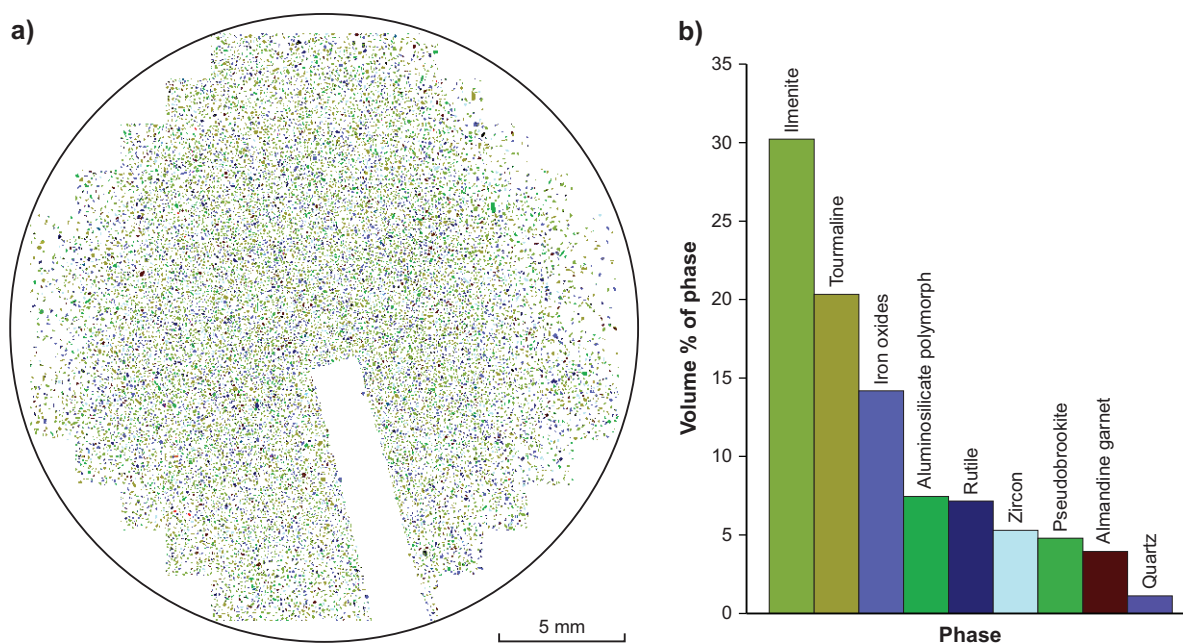


Figure 1. Example of TIMA mineral liberation analysis of heavy mineral separates from a soil sample from the west Arunta: a) mineral phase map, colours shown in b); b) graph showing nine most abundant minerals (94.5% of the sample)

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Enhancing earthquake monitoring in Western Australia

by

R Murdie

EXPLORATION
INCENTIVE
SCHEME

The Geological Survey of Western Australia (GSWA) is collaborating with Geoscience Australia to increase the capabilities of the Australian National Seismograph Network (ANSN) within Western Australia by installing several new monitoring stations in key locations.

The southwest Yilgarn Craton is one of the most seismically active areas of Australia, experiencing many small events on a regular basis and the occasional large earthquake. The possible level of damage became evident after the 1968 magnitude 6.5 earthquake in Meckering that caused extensive damage, dramatically bent the railway line, and produced a 37 km long and 2 m high fault scarp.

Apart from increasing the reliability of all earthquake detections across the State, these new stations have been located to target the smaller earthquakes within particular areas to better characterize the seismic hazard of these regions.

Three stations in the northeast Wheatbelt, deployed in 2020, have already been useful in increasing the earthquake location precision and have been critical for defining the clustering of the Koorda and Beacon earthquake swarms of this year. A new network will be spread across the Eastern Goldfields, an area currently served by only one ANSN station, with the aim of documenting variations in seismicity in relation to active mining areas. A new network in the Kimberley has been deployed to image crustal structure and to investigate the baseline seismic activity in an area under consideration for unconventional hydrocarbon exploration.

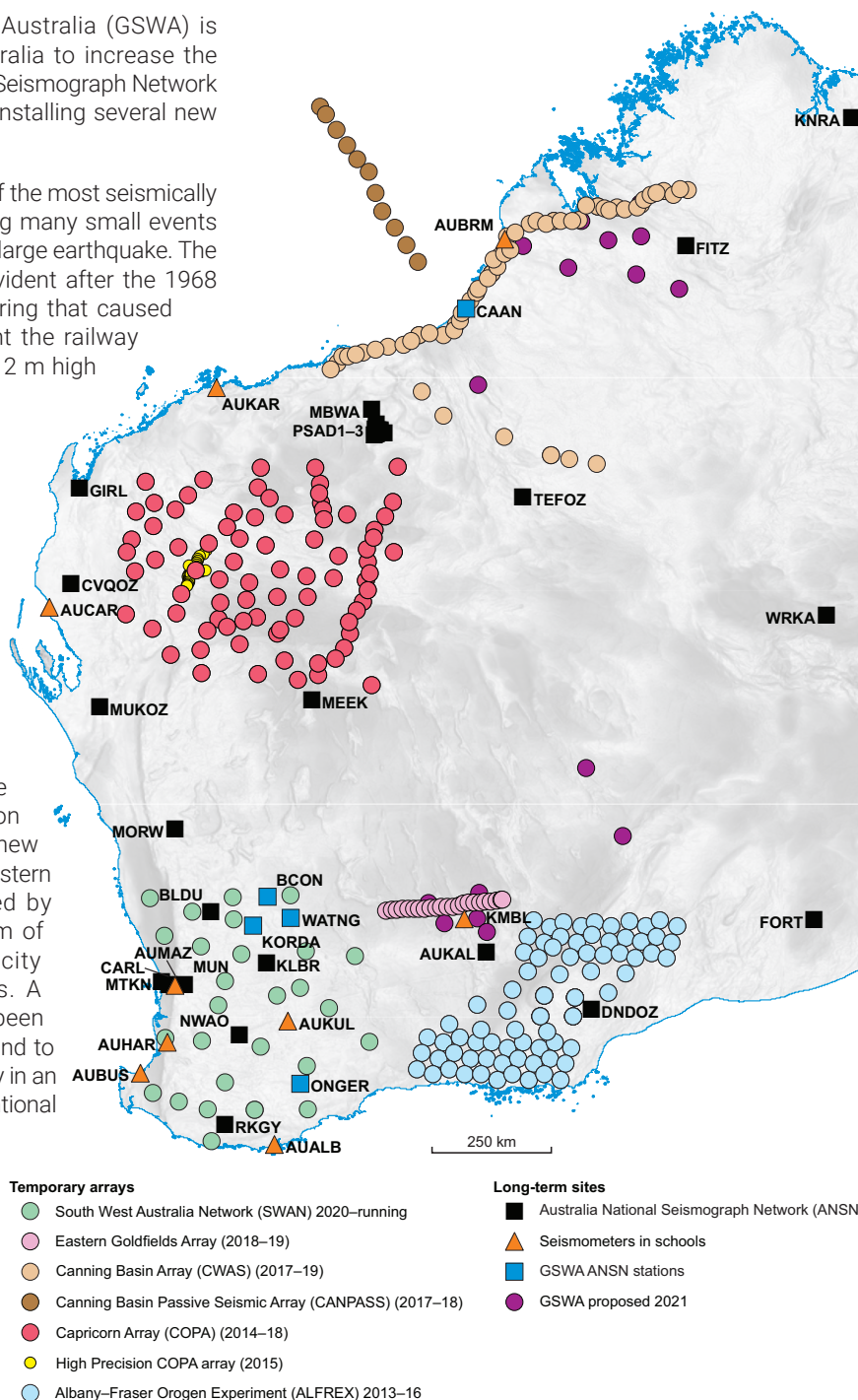


Figure 1. Map of the locations of the ANSN (black squares), Seismometers in Schools stations (orange triangles), the new GSWA stations (dark pink circles), and temporary arrays (labelled and various colours)

An update on regolith geology in Western Australia

by

N de Souza Kovacs

EXPLORATION
INCENTIVE
SCHEME

MinEx CRC

The 1:100 000 regolith geology regimes of Western Australia is a compilation of existing Geological Survey of Western Australia (GSWA) regolith and surface geology maps and new regolith interpretation from radiometric ternary potassium, thorium and uranium (KThU) imagery. This map incorporates all regolith coverage, providing a seamless 1:100 000-scale digital regolith coverage (Fig. 1).

The map comprises three simple regolith–landform units: residual–relict (R-WAD), exposed bedrock outcrops (X-WAD) and depositional transported regolith (D-WAD). Residual or relict materials include deposits derived from in situ weathering of underlying rocks, deposits of uncertain origin and relict reworked regolith deposits. Areas of transported depositional regolith comprise sediments derived from residual or erosional landforms including colluvial, sheetwash, alluvial, lacustrine, sandplain, eolian and marine deposits. Exposed bedrock is reserved for directly exposed underlying geological units.

A more comprehensive representation and understanding of regolith–landform and sediments dispersion in an area can be accomplished by combining any of GSWA's existing State regolith layers (1:100 000 regolith geology regimes or the 1:500 000 State regolith geology) with GSWA's bedrock geology layers available from GeoVIEW.WA <www.dmirs.wa.gov.au/geoview> or from the DMIRS Data and Software Centre <www.dmirs.wa.gov.au/datacentre>. Similarly, soil geochemistry can be combined with the regolith maps to show geochemical patterns in the surface and fingerprinting the most prospective areas accordingly. In addition to the new regolith regimes map, the distribution of regolith regimes has been mapped using the HyLogger to examine the spectral response of chips from water bores for the southwest Yilgarn.

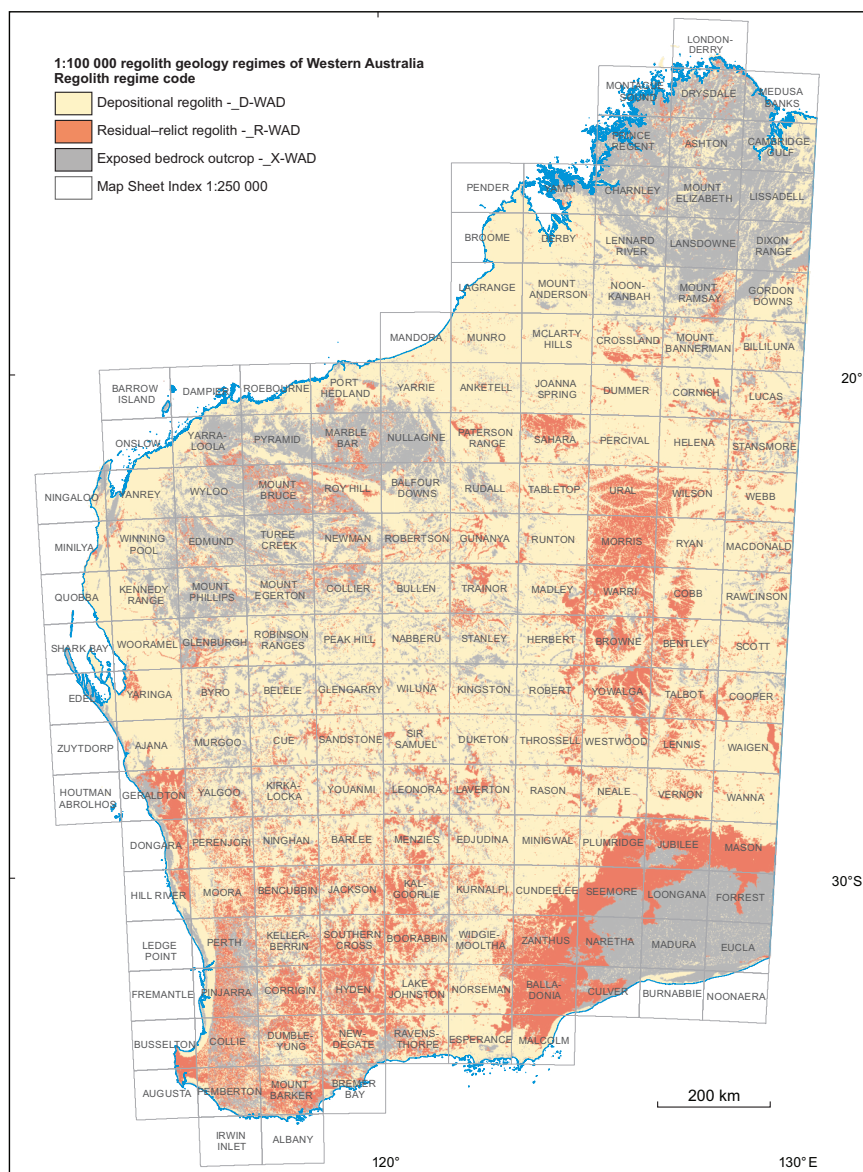


Figure 1. 1:100 000 regolith geology regimes of Western Australia digital map layer

Using apatite to characterize hydrothermal fluids in the west Arunta

by

JK Porter, E Finch and DE Kelsey



The west Arunta Orogen of Western Australia is largely unstudied due to its remote location and recent cover. Basement rock within a few sparse drillholes commonly features Fe-oxide–epidote-bearing alteration and sulfide mineralization, highlighting the potential for economic mineralization. However, the origin, source and chemistry of fluids of this terrane and its potential to host mineralization remain mostly unknown. In order to investigate the source and composition of hydrothermal fluids causing alteration and mineralization, apatite was chosen due to its incorporation of a variety of geochemical tracers, including halogens. Trace element concentrations and geochronology using different isotopic systems within apatite can also be utilized and may shed light on the types of mineralizing systems that fluids produce within a temporal framework.

Samples from ten drillholes in the West Arunta were investigated that show evidence of extensive hydrothermal alteration. Apatite grains were selected across changes in lithology, alteration and veining associated with sulfides in order to observe changes in fluid compositions across hydrothermal events, as well as establish baseline chemistry from unaltered rocks. Preliminary data show no systematic change in halogen (F and Cl) contents across centimetre- to metre-sized carbonate veining. However, changes in halogen contents between drillholes suggest variation in fluid chemistry and, potentially, source on a local to regional scale. Further collection of halogen, trace element, and stable and radiogenic isotope data will be undertaken as part of this ongoing project to provide additional constraints on fluid chemistry, source and timing of this understudied package of rocks.



With the nation's challenge of moving towards net-zero emissions by 2050, significant change will be required throughout the minerals and energy sectors. Those changes will mostly be driven by advances in geoscience, and closer union between geoscience institutions, government and industry. To reach the 2050 net-zero goal, the foundation for those changes will have to be implemented across the next decade. Western Australia has arguably the finest and most complete geoscience research and technology hub in the world, and when combined with the exceptional mineral and energy potential of the State, places Western Australia at the forefront of the nation's net-zero emissions revolution.

The aim of this panel discussion is to examine closely the relationship and synergies between academic and government geoscience organizations, the data they generate, and their role in the future minerals and energy revolution. Key to understanding these synergies is first, the recognition of the challenges that the minerals and energy sectors will face over the next decade, and second, to determine what types of geoscience data and collaborations are required to provide that foundation for long-term change.

The panel discussion will consist of:

1. Introduction (panel chair: 5 mins)
2. Minerals and energy sectors challenges for the next decade (minerals and energy sector representatives: 10 mins)
3. State and academic geoscience strategic visions (academic/government geoscience institution representatives: 30 mins)
4. Questions and answers via our online event platform (30 mins)

Although, we do not expect to reach a consensus on how to achieve a net-zero goal, we hope that this discussion can bring together Western Australian geoscientists, exploration and mining geologists, and technology specialists to help identify gaps in geoscience research and to inform collaborative partnerships that will help lay the foundations for the net-zero challenge ahead.

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