A Geological Survey of Western Australia Newsletter

JULY 2023 NUMBER 107

Fieldnotes

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

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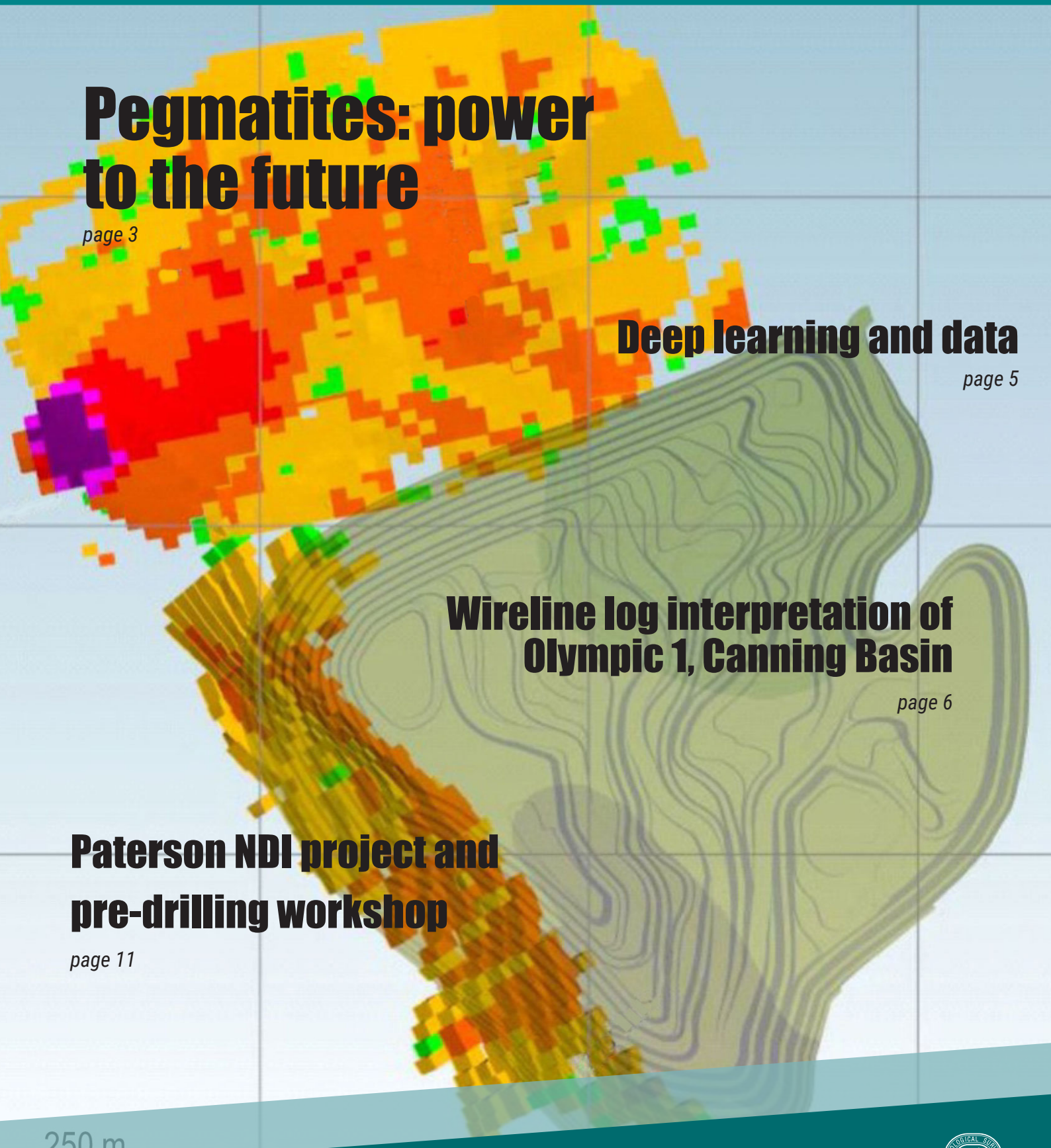

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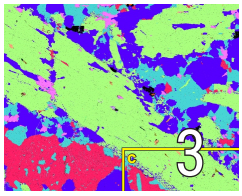

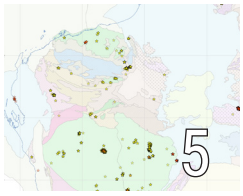

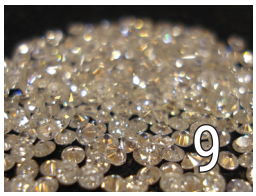

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Acknowledgement of Country

We respectfully acknowledge Aboriginal peoples as the Traditional Custodians of this land on which we deliver our services to the communities throughout Western Australia. We acknowledge their enduring connection to the lands, waterways and communities and pay our respects to Elders past and present.

Access publications

All publications

Download maps, reports and digital information free from our **website**.

Hard copies

Maps, USB data packages and various premium publications are available to purchase as hard copies from the eBookshop or the First Floor Counter at Mineral House, 100 Plain Street, East Perth WA 6004. An online cart and payment system is in place. Records, Reports, Bulletins and other non-series books cannot be purchased in hard copy but are all available as PDFs to view and download free of charge.

Fieldnotes

Fieldnotes is a free digital-only quarterly newsletter published by the Geological Survey of Western Australia (GSWA). The newsletter provides regular updates to the State's exploration industry and other geoscientists about GSWA's latest work, programs, products and services.

Access Fieldnotes by:

- subscribing to the **GSWA eNewsletter** – there will be a Fieldnotes page with a link to the latest issue
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GSWA publishes a vast amount of pre-competitive geoscience information on the State, contributing to billions of dollars' worth of resources for exploration and development. To find more information about publications and maps we publish, go to our **website**.

Cover image: Proposed openpit at Kathleen Valley and pegmatite block model of the underground stopes, coloured by wt% Li_2O content, an aerial view. Image by Jamie Day (Exploration Manager, Liontown Resources)

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Pegmatites: power to the future

Global consumer demand for battery-powered electric vehicles is underpinning a spurt of dramatic growth in Western Australia's lithium minerals industry. As a result, Western Australia is now the world's largest producer of lithium (Li), with producers exploiting the Li-bearing pyroxene, $LiAlSi_2O_6$, hosted in lithium–caesium–tantalum (LCT) pegmatites. However, a recurring theme is the underperformance of some mines and processing plants to meet nameplate (or maximum amount of) spodumene concentrate production and lithium recovery.

To address these shortcomings, the Geological Survey of Western Australia (GSWA) Report 228 provides new petrological, mineralogical and geochronological data through a comparative study of some of Western Australia's important LCT pegmatite deposits (Fig. 1). With the aim of establishing a geometallurgical framework of Western Australian LCT pegmatites, mineral-textural characteristics were linked to the fundamental processes of mineral liberation, thermal alteration and chemical extraction.

These were shown to play a critical role in the production of quality lithium feedstock in Western Australian mining operations.

Report 228 demonstrates that these deposits typically display a greater level of mineralogical complexity and geochemical variability than previously considered. For example, spodumene is shown to display varying degrees of alteration (Fig. 2), which introduces impurities such as Fe, Mg, K and Rb, and can decrease the bulk density of the spodumene particles. This can reduce the effectiveness of dense media separation circuits in the production of a spodumene concentrate product.

(continued page 4)

Source: GSWA, Lithium Investment Opportunities, Sept. 2020

MAW16 09.03.22

Figure 1. Location of the main Australian (WA) LCT-pegmatite lithium resources (mines, deposits and prospects). Source: DMIRS, Lithium Investment Opportunities, September 2021

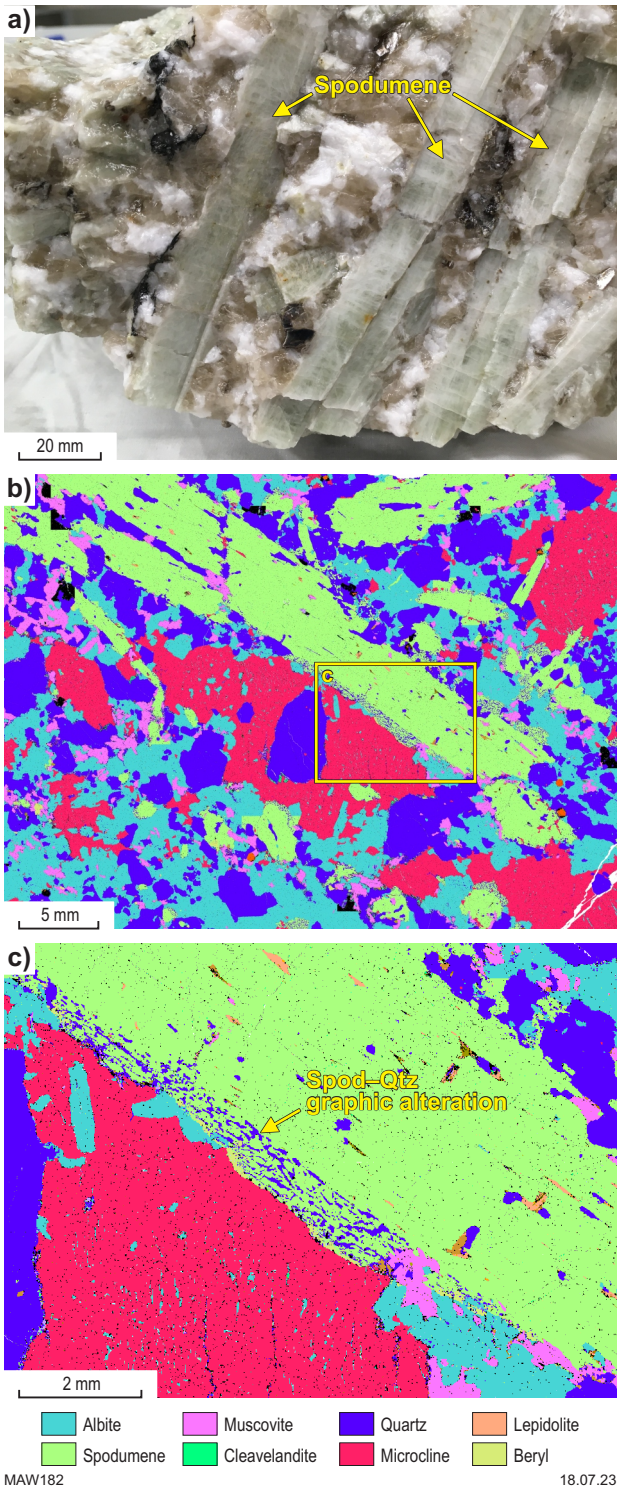


Figure 2. a) Hand specimen of LCT pegmatite from one of the locations studied in the Report; b) false-colour, mineral distribution mapping helps to define mineral associations; c) characterizes the type and extent of spodumene alteration

Physical liberation characteristics of Li-bearing mineral particles and their chemical processing behaviour were correlated to the mineral-textural variations to understand better the impact to processing and Li recovery. For example, during calcine roasting of spodumene concentrates, secondary, mica-like alteration phases can form glassy melt products that coat fracture and cleavage surfaces of spodumene. Such melt products may inhibit spodumene transformation as well as render the calcined spodumene refractory at the sulfate-roasting and water-leaching stage.

Thus, the geological characteristics of LCT pegmatites and their mineral-textural relationships were integrated into a geometallurgical framework, based on the fundamental understanding of their geometallurgical characteristics and classification type. The result is the categorization of LCT pegmatites into five, broad ore types with similar processing options. The framework summarizes the main aspects, issues, impediments and potential solutions related to the comminution and liberation, and lithium refining (calcination and acid bake processing) of Western Australia's LCT pegmatites. It lists key factors important in selecting a processing option for treating ores, including the lithium mineral host and incorporated impurities, the particle size of the Li host and related mineral-texture characteristics.

How to access

Report 228 MRIWA Report M532 – The Geology, Mineralogy and Geometallurgy of EV Materials Deposits in Western Australia by M Wells, M Aylmore and B McInnes is available as a free downloadable PDF from the Department of Mines, Industry Regulation and Safety (DMIRS) eBookshop.

For more information, contact **Martin Wells**.

From errors to insights: deep learning unlocks the potential of the mineral exploration database

Curtin University
OIL AND GAS INNOVATION CENTRE

The collaborative efforts of the Geological Survey of Western Australia (GSWA) and Curtin University have led to an innovative trial of deep-learning methods applied to data derived from the Western Australian Mineral Exploration (WAMEX) database. This extensive database contains vital geochemical data contributed by the exploration and mining industry. Scripts were run on the original WAMEX database to harmonize the company analyte names to the matched standard analyte names, and to recalculate assay values in the various company-supplied units of measure to a standard unit. However, the presence of errors in unit reporting, incorrect assignment of analytes and in some cases, due to the low accuracy of the chosen analytical technique, these errors pose significant challenges in terms of time and cost for manual identification and correction.

To overcome these obstacles, a data-driven approach was developed. Through careful pre-processing and training of deep-learning networks, spurious data are identified and replaced with imputed values, while missing analyte values are estimated whenever possible. The surface stream sediment and shallow drillhole datasets demonstrated exceptional performance among the various datasets, albeit with slightly higher error metrics observed in the soil dataset. The rock chip, drillhole aircore, and 'others' datasets exhibited the highest occurrence of spurious data. Notably, elements such as Ni, Cu and Zn showcased remarkable predictability, while Ag, As, Hg and Au displayed comparatively lower predictability due to weaker correlations with other elements. Predictability also diminished for most analytes at extremely low or high concentrations, aligning with ranges having limited training data. Although the tabulated deep-learning geochemical data remains in the experimental phase and has not been publicly released, a list of samples was shared with GSWA for further verification and targeted correction in the WAMEX database. For large databases such as WAMEX, cleaning of the data should be performed as an iterative process in which obvious spurious data are identified, removed from training, and then the networks retrained.

The employment of deep-learning methods yielded favourable outcomes at a reasonable computational cost, eliminating the need for laborious manual feature engineering typically associated with other statistical approaches. These results demonstrate the effectiveness of this approach across various types of geochemical data encompassed in the WAMEX database, including surface and drillhole sample media, as well as diverse laboratory analytical methods. Moreover, the deep neural networks-based estimation approach may benefit mineral explorers by indicating new regions of exploration interest, or simply by highlighting gaps in collected data — the latter informing future data collection strategies that reduce levels of uncertainty and exploration risk.

How to access

Report 237 Deep-learning identification of anomalous data in geochemical datasets by Puzyrev et al. is available as a free downloadable PDF from the Department of Mines, Industry Regulation and Safety (DMIRS) eBookshop.

For more information, contact **Paul Duuring**.

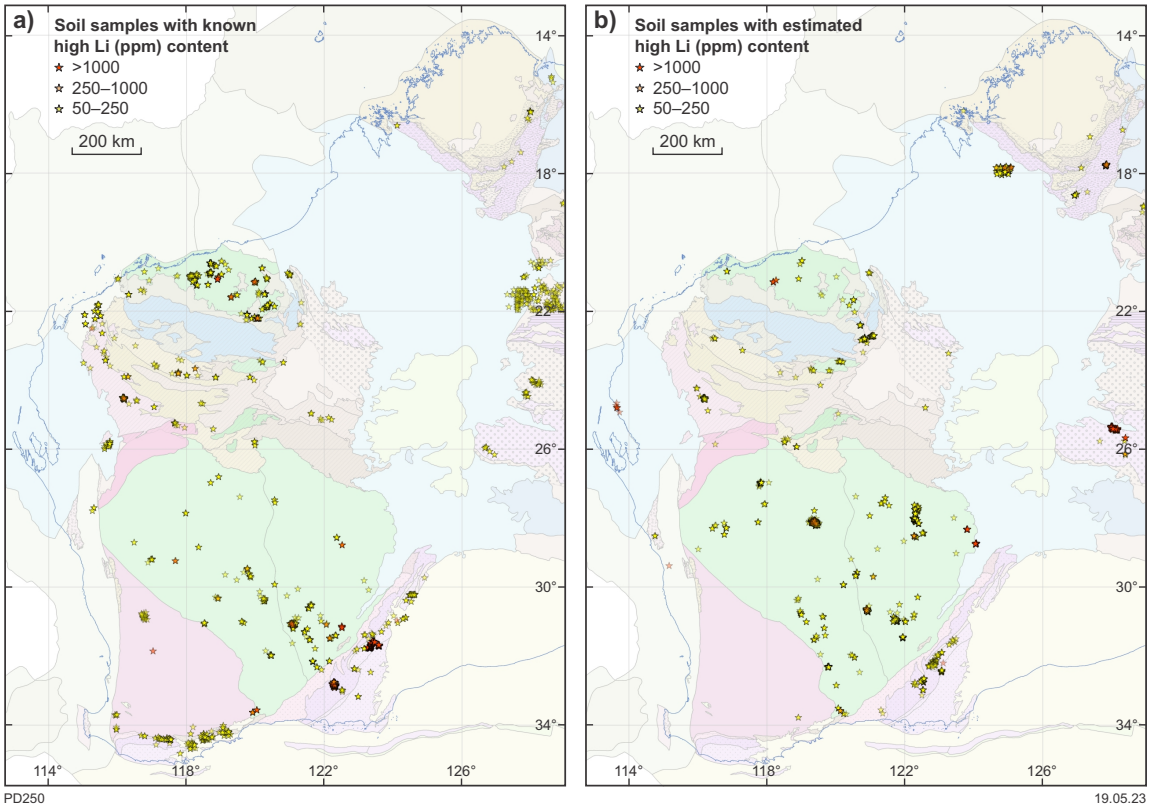


Figure 1. Gap analysis of lithium content using deep learning: a) WAMEX soil samples with known high Li values; b) surface samples demonstrating high Li content (missing or erroneous values have been replaced with imputed values generated by the deep learning method)

Wireline log interpretation of Olympic 1

Users can now explore reservoir quality through an integrated interpretation of petrophysical and petrographic data from the Ordovician and Permian of the Canning Basin at the Olympic 1 petroleum exploration well. The study focused on reservoir targets (Figs 1, 2) and the impact of acoustic properties.

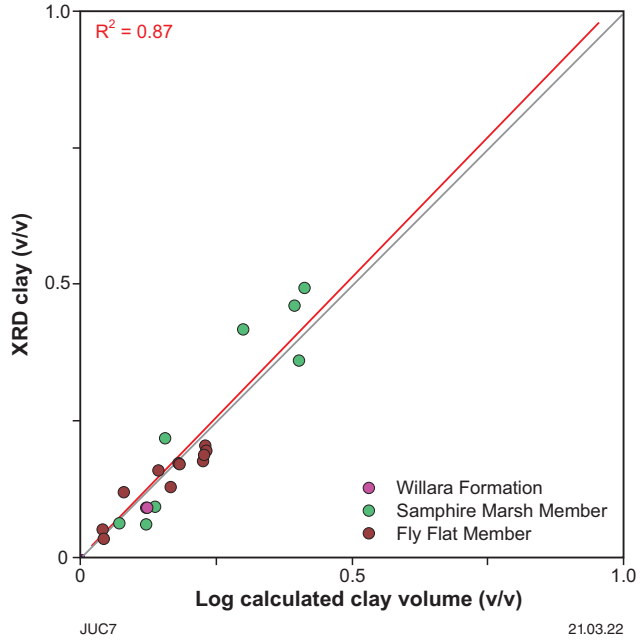


Figure 1. XRD-derived clay volume compared to final log-derived clay volume highlighting the excellent positive correlation achieved with an R2 value of 0.87

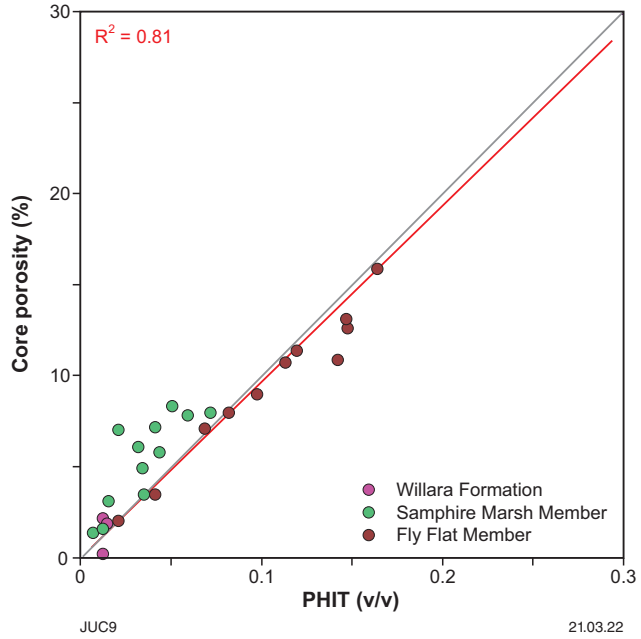


Figure 2. Core-measured porosity compared to log-derived total porosity highlighting the excellent positive correlation achieved with an R2 value of 0.81

The main conclusions are:

- The petroleum and geosequestration reservoir and seal potential of the Fly Flat and Samphire Marsh Members of the Nambeet Formation is highly dependent on mineralogy and associated pore geometries to generate pore-space connectivity.
- Enhanced porosity and permeability within the Willara Formation's dolomitized zone indicates its local potential as a petroleum reservoir.
- Claystone facies within the Grant Group could not be differentiated from the Goldwyer Formation in the seismic reflection data prior to drilling, so the position of the Meda Unconformity was shallower than expected and the Goldwyer Formation was absent. Thus, the primary target for this exploration well lacked a seal, thereby highlighting the importance of robust seismic interpretations (Fig. 3).

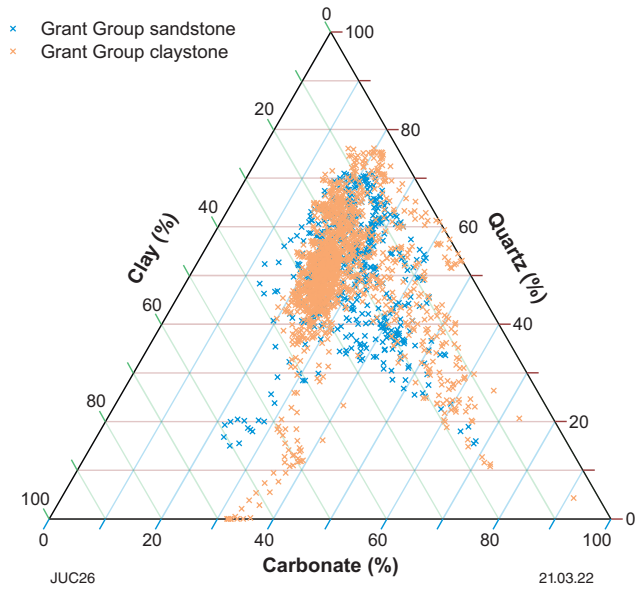


Figure 3. Sandstone and claystone facies have comprehensive wireline log coverage in the Grant Group. This ternary diagram shows that mineral assemblage remains relatively unchanged as the grain size is dramatically reduced moving from sandstone to claystone, indicating grain size as the main control on reservoir quality

How to access

Record 2022/13 Petrophysical evaluation of the Permian and Ordovician in Olympic 1, Canning Basin,Western Australia by Cass et al. is available as a free downloadable PDF from the Department of Mines, Industry Regulation and Safety (DMIRS) eBookshop.

For more information, contact **Julie Cass**.

Characterization of ballast stones from the wreck site at Trial Rocks

The *Trial* was a ship of the British East India Company that left Plymouth, England, in September 1621, bound for the East Indies. On 25 May 1622, the ship struck rocks and sank off the northwest coast of Western Australia (Fig. 1). The crew of the *Trial* are believed to have been the first Englishmen to sight or land on Australia, and the wreck to be Australia's oldest known shipwreck.

A wreck thought to be the *Trial* was located at Trial Rocks by divers in 1969 but has not been identified unequivocally. Twenty-three ballast stones recovered from the wreck site were provided by the Western Australian Museum to the Geological Survey of Western Australia to determine whether they are likely to have originated from Plymouth or nearby rocks in southwestern England.

Detailed petrography demonstrated similar lithologies between the ballast stones and the Devonian sandstone and siltstone of the Dartmouth and Meadfoot Groups exposed in Plymouth Sound and other parts of southwestern England.

U–Pb geochronology of detrital zircons from a ballast stone indicates a youngest age component at c. 580 Ma, consistent with the maximum depositional age for Devonian rocks in southwestern England. The Sm–Nd isotope results for three ballast stones are also an excellent match with data for Paleozoic sedimentary rocks in southwestern England. Based on the results of this study, an origin for the ballast stones in Plymouth Sound or the surrounding area cannot be ruled out.

How to access

Record 2022/16 Characterization of ballast stones from the wreck site at Trial Rocks by Wingate, MTD, Lu, Y, Fielding, IOH, Maas, R, Smithies, RH and Gain, SEM is available as a free downloadable PDF from the Department of Mines, Industry Regulation and Safety (DMIRS) eBookshop.

For more information, contact **Yongjun Lu**.

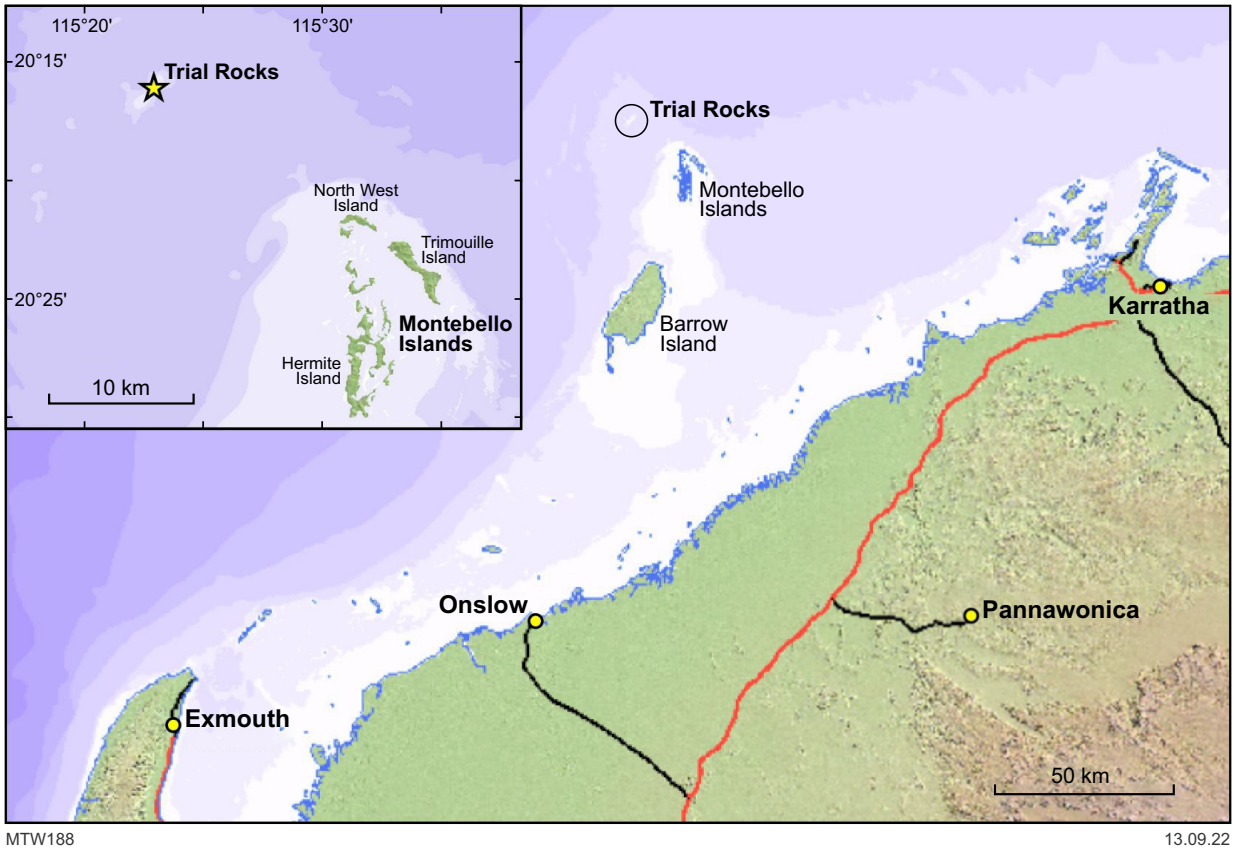


Figure 1. Location of Trial Rocks, north of the Pilbara coast, northwestern Western Australia

First direct study of the Lasseter Shear Zone beneath the eastern Canning Basin at the Top Up Rise prospect

Characterizing basement beneath the Canning Basin remains a frontier of Australian geoscience. This study utilized five diamond cores drilled in 2012–13 from the Top Up Rise prospect, located within the Lasseter Shear Zone system underlying the eastern margin of the Canning Basin (Fig. 1). Lithologies include upper amphibolite to lower granulite facies metasedimentary and granitic schists and gneisses, amphibolites, metagabbros and metadolerites. Alteration and sulfide mineralization attest to at least two hydrothermal fluid flow events. Metasedimentary rocks have detrital zircon age spectra that are very similar to the ‘Detrital P’ signature of the North Australian Craton (NAC). Therefore, the NAC continues westwards beneath the easternmost Canning Basin, at least as far as the Lasseter Shear Zone. Low-volume partial melting occurred at 1624–1604 Ma, dated by zircon rims (Fig. 2). Massive metagabbro and olivine metagabbro were emplaced at c. 968 Ma, and metadolerites are younger than c. 968 Ma. The latest event involved high-strain deformation during the Neoproterozoic Petermann Orogeny (c. 610 Ma), revealed via in situ Rb–Sr dating of white mica (doi:10.1016/j.epsl.2022.117969). The Lasseter Shear Zone is interpreted to mark the western edge of the NAC, making it prospective for mineral deposits.

How to access

Record 2022/17 Crystalline basement beneath the eastern Canning Basin at the Top Up Rise prospect by Kelsey et al. is available as a free downloadable PDF from the Department of Mines, Industry Regulation and Safety (DMIRS) eBookshop.

For more information, contact **David Kelsey**.

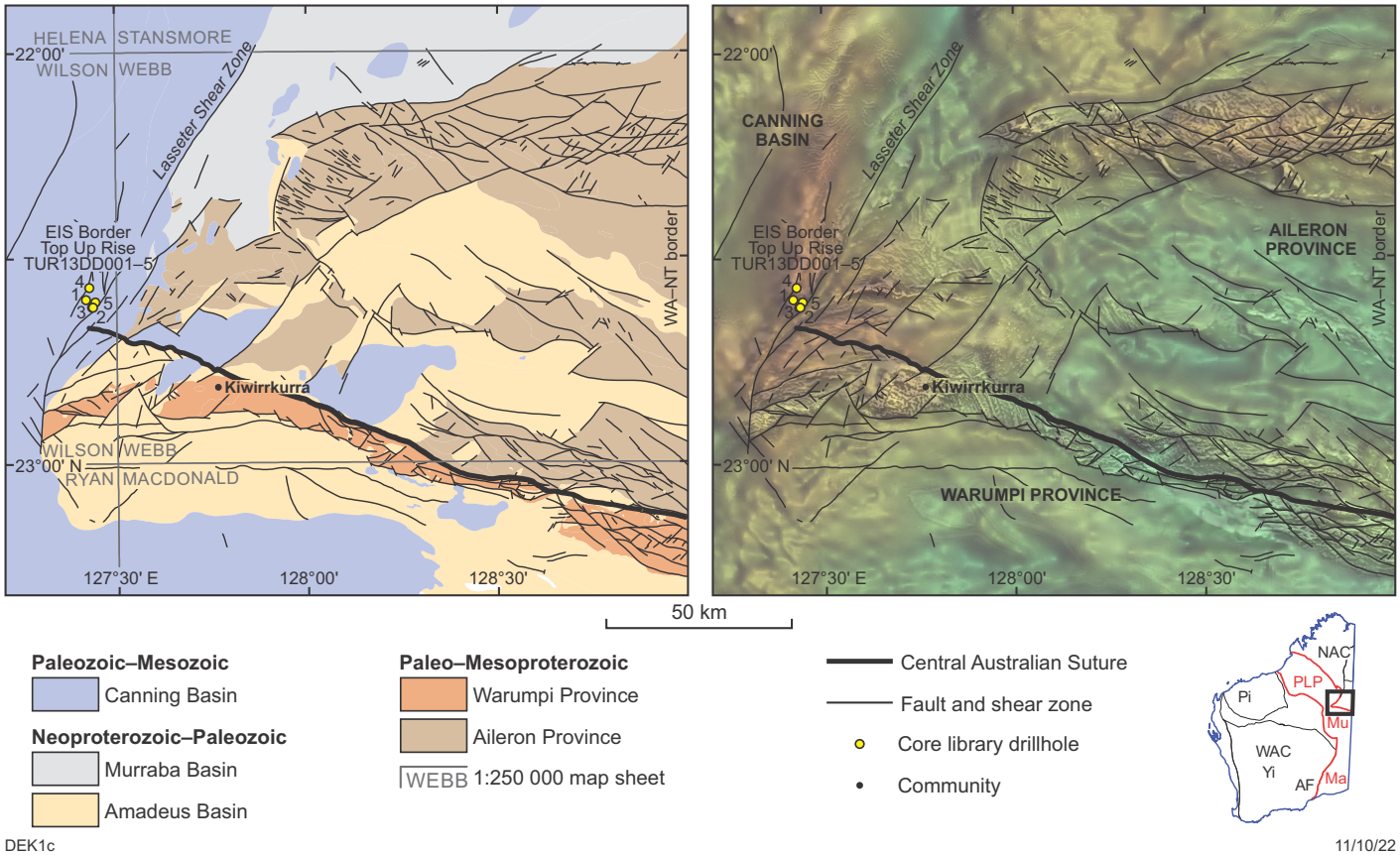


Figure 1. Simplified map of tectonic units (a) showing the Top Up Rise prospect drillcores within the Lasseter Shear Zone system, which defines the major eastern boundary of the Canning Basin and the western boundary of the Aileron and Warumpi Provinces. The gravity image (b) shows the northeast-trending ridge bound by northeast-trending shear zones coincident with the Lasseter Shear Zone. Modified from Hollis et al. (2013). Inset shows State tectonic domains adapted from Lu et al. (2022). Abbreviations for inset: AF, Albany–Fraser Orogen; Ma, Madura Province; Mu, Musgrave Province; NAC, North Australian Craton; Pi, Pilbara Craton; PLP, Percival Lakes Province; WAC, West Australian Craton; Yi, Yilgarn Craton. Black box in inset shows location of the main images

Searching for treasure

The Discover Geology section within the Geological Survey's production team has been busy working on some popular geology projects for the interactive StoryMaps platform.

Diamonds Down Under: Seeking Western Australia's Treasure

Who doesn't love diamonds and who doesn't love digging in the dirt trying to find them! One is a lot easier than the other, we know…

The latest StoryMap has plucked, overhauled and updated information from the diamond chapter in **Mineral Resources Bulletin 25 Gemstones of Western Australia (2nd edition)** and other GSWA publications to produce an interactive online product with new images and current information (Fig. 1).

This new product incorporates interactive diamond occurrence and prospectivity maps plus new videos, and includes information about:

- The history of diamonds and some special examples
- How the hardest natural material on Earth forms
- Characteristics and physical properties
- Exploration and types of deposits
- Special Western Australian discoveries, e.g. Argyle and Ellendale diamond mines (Fig. 2)
- Potential of the industry in Western Australia

This is a fantastic immersive experience for amateur geologists, gemmologists and anyone interested in this prized gem.

Figure 1. A collection of cut, 0.02, 0.03 and 0.04 ct solitaire diamonds weighing in total 5.36 ct. (Image courtesy Swamibu, CC BY 2.0, via Wikimedia Commons)

How to access

Diamonds Down Under: Seeking Western Australia's Treasure compiled by TJ Ivanic, RS Bower and SR White is available as a link from the Department of Mines, Industry Regulation and Safety (DMIRS) eBookshop.

For more information, contact **Robin Bower**.

Figure 2. The extensive Argyle AK1 openpit in 2013 prior to transition to block cave underground mining (Image courtesy Rio Tinto)

Diving through limestone

Flanking the western margin of the Kimberley region is an astonishing 385–363 million-year-old (Devonian) fossil reef system. In its day, it would have rivalled the Great Barrier Reef in overall length and species diversity.

Today, the fossil reef forms a series of long, narrow limestone ranges in the remote northern plains of Western Australia, usually accessible only by four-wheel drive. Our recently published StoryMap uses interactive maps, video, photographs and time slices to take a virtual dive into the history of this ancient reef system.

Taking as its starting point **GSWA Bulletin 145 Devonian reef complexes of the Canning Basin**, the coastal setting, origin, evolution and ultimate demise of the fossil reef system are illustrated where the 3D structure is best exposed.

Defining features in the story include:

- Pillara Range, Menyous Gap – earliest evidence of the reef
- McWhae Ridge – barrier reef promontory blanketed by slope limestone
- Windjana Gorge / Bandilngan – later stages of reef building
- Gogo fish fossils and changes in reef species over time
- Mimbi Caves and rugged range tops – classic karst landscapes

Through this story, viewers can explore a wonder of the ancient marine world remotely, or prepare for their own outback adventure.

How to access

Western Australia's fossil great barrier reef is available as a link from the Department of Mines, Industry Regulation and Safety (DMIRS) eBookshop.

For more information, contact **Stephen White**.

Figure 1. View of the front of the limestone range at Windjana Gorge, captured from video fly-over

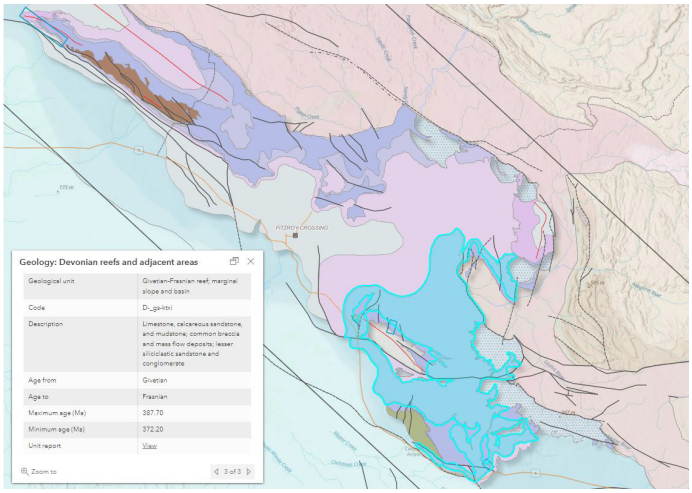


Figure 2. Interactive map of the Devonian reefs with pop-up of information about the selected limestone unit

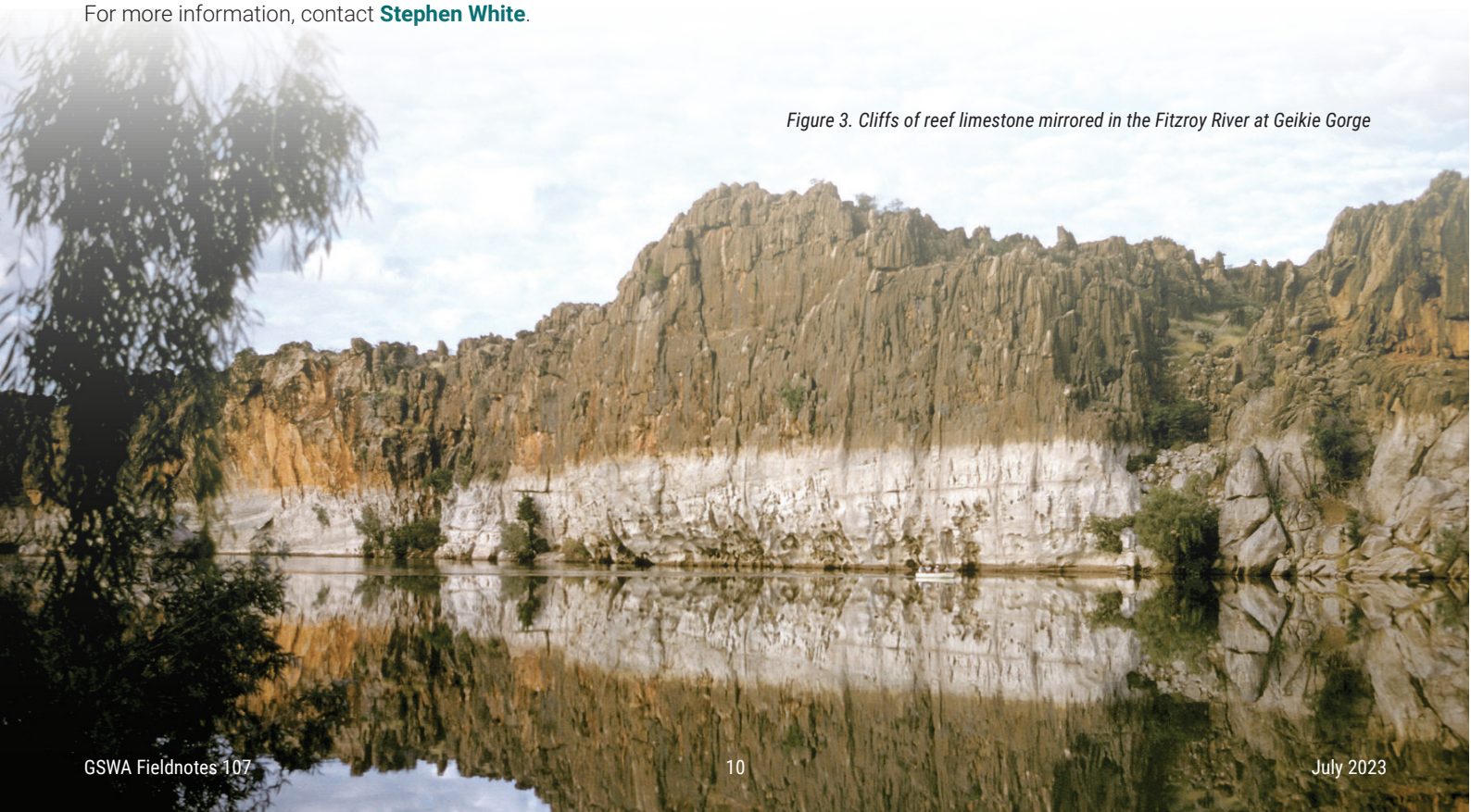


Figure 3. Cliffs of reef limestone mirrored in the Fitzroy River at Geikie Gorge

Paterson NDI project and pre-drilling workshop

The Geological Survey of Western Australia (GSWA) is a key participant in MinEx CRC, the world's largest mineral exploration collaboration bringing together industry, government and research organizations. A major project of the MinEx CRC is the National Drilling Initiative (NDI), which manages and delivers drilling programs in multiple case study areas across Australia. The NDI drills multiple holes in each case study region to map the regional geology and architecture, and define the potential for mineral systems in 3D.

The first NDI project for GSWA will be in the northwestern Paterson Orogen, an area prospective for sediment-hosted Cu and other base metal resources. These resources are critical for the transition to a net-zero carbon emissions future. The project area is located at the broader Nifty mine camp within the Yeneena Basin, about 30 km southwest of the Telfer Cu–Au deposit. The NDI campaign will test the mineral system at distances up to 25 km from the Nifty ore body. A key challenge in mineral exploration, especially in greenfields and under cover, is the transition from the regional to the deposit scale across the camp scale. At the camp scale, it is often not possible to directly detect a mineral system, although we also lack sufficient predictive power to help localize drilling targets. The NDI work in the Paterson will directly address this challenge.

The proposed program at Nifty will drill up to 10 stratigraphic boreholes to a depth of up to 500 m each, using new, low-cost coiled tubing (CT) drilling technology; these holes are complemented by seven diamond drillcores on loan from Cyprium Metals. Collectively, these drillholes define a transect within and distal to the deposit, and are intended to sample a range of cover and basement geology, as well as distal alteration facies related to the deposition of the Nifty mineral system. The physical samples and data acquired during the drilling will be used to obtain new precompetitive datasets in areas with identified data gaps, and develop models and interpretations of under-cover mineral systems on a range of scales. The drilling is planned to start in early July 2023.

(continued page 12)

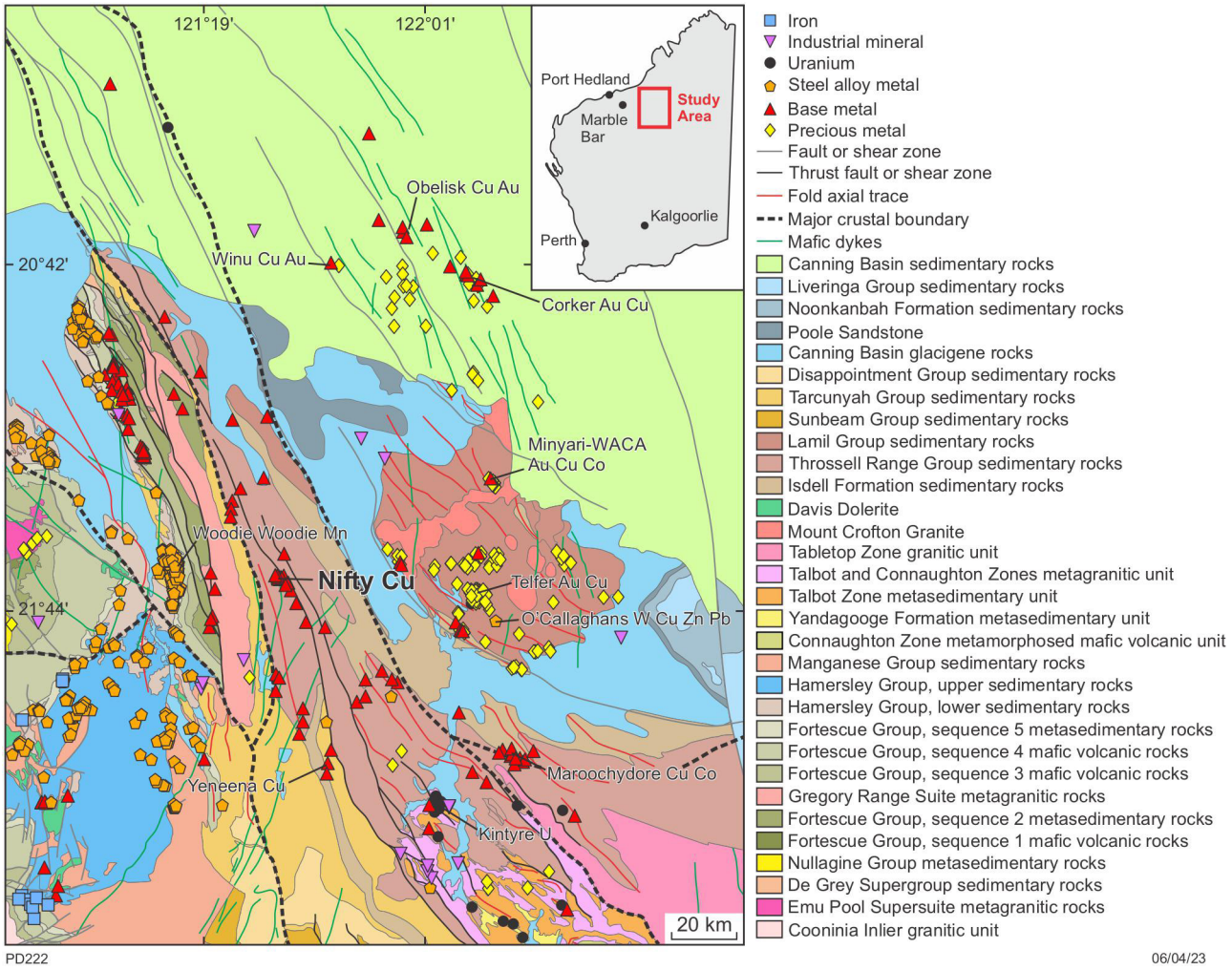


Figure 1. Lithological subdivisions, structures and mineralization in the northwestern Paterson Orogen, Western Australia. The Paterson NDI area (Nifty prospect) is located within the Yeneena Basin, east of the extended Pilbara Craton margin

Figure 2. David Huston (Geoscience Australia) presents on the Paterson regional geology and metallogeny at the pre-drilling workshop

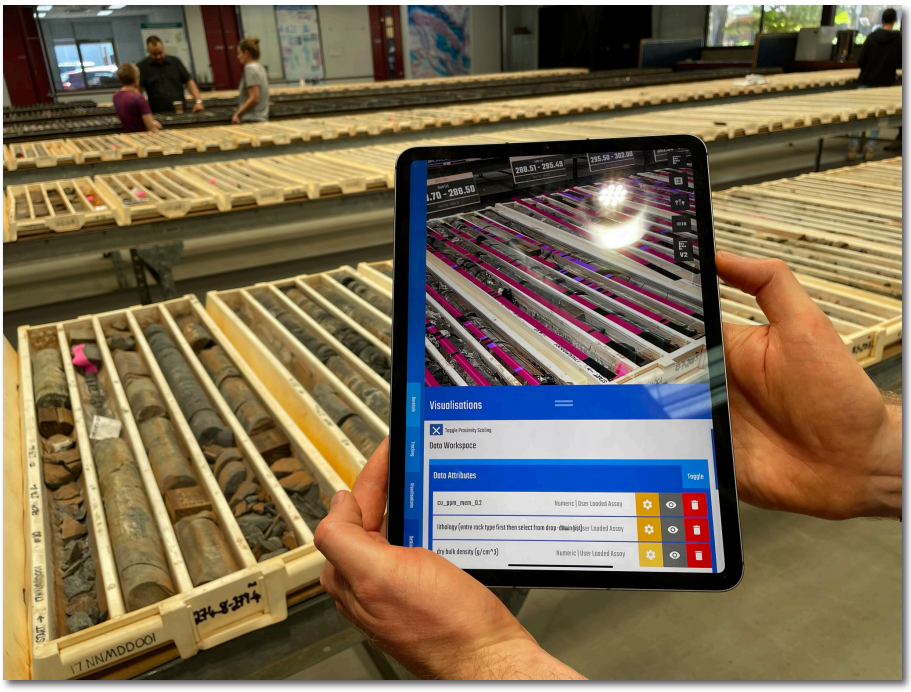


Figure 3. Core viewing of the diamond drillcore used the augmented reality platform, allowing data to be visualized and interrogated with the core

To facilitate the commencement of the NDI in Western Australia, GSWA recently hosted a two-day pre-drilling workshop that was well attended by government agencies, industry and academic researchers from across Australia. The first day focused on a series of presentations and discussions that highlighted the goals of the Paterson NDI project, geology and metallogeny on the regional and deposit scales, and project proposals from several of the collaborative researchers. The second day at the Perth Core Library offered an opportunity for project participants to see and discuss the stratigraphy and mineralization, and to sample the existing diamond drillcore.

The core viewing and related discussions were enhanced by the augmented reality platform developed by the University of South Australia and MinEx CRC. This system seamlessly integrates all of the available data streams derived from core samples into an immersive digital workflow. Available datasets for the workshop included hyperspectral data, geochemistry and petrophysics, which allowed researchers to select the most appropriate samples for their projects. Additional information and data will be released by GSWA as it becomes available.

For more information, contact **Fawna Korhonen**.

Product releases

• PUBLICATIONS •

Atlas of mineral deposits and major petroleum projects, 2023
T Pal, C D'Ercole, SI Murray, A Johnston and CM Thomas

Report 228 MRIWA Report for Project M532 — Geology, mineralogy and metallurgy of eMaterial resources in Western Australia
Aylmore, M, Wells, M and McInnes, BIA

Report 240 Structural evolution and quartz c-axis crystallographic preferred orientation of major Yilgarn Craton shear zones
Zibra, I and Peternell, M

Report 241 Sedimentology and revised stratigraphy of the Kimberley Basin, Western Australia
Phillips, C

Report 242 Regional petrophysics: Eucla Basin and Basement 2022–23
Mortimore, C and Bourne, B

Record 2023/2 6IAS: Out with the old, in with the new – a traverse across the Archean–Proterozoic boundary in the Mount Bruce Supergroup
Martin, DMcB and Howard, HM

Record 2023/3 Register of State Geoheritage sites, Western Australia: nomination and registration process
Martin, SK

Record 2023/4 6IAS: A traverse across the northern Yilgarn Craton in Western Australia – from the Jack Hills to the Youanmi Terrane
Zibra, I and Kemp, AIS

Record 2023/5 Spatial trends and relationships emerging from the systematic classification of granitic rocks of the Yilgarn Craton
Smithies, RH, Lowrey, JR, Champion, DC, Lu, Y and Gessner, K

Record 2023/6 6IAS: Pilbara Craton, evolving Archean tectonic styles – a field guide
Van Kranendonk, MJ and Smithies, RH

Record 2023/7 Introduction to geochronology information, 2023
Fielding, IOH, Lu, Y and Wingate, MTD

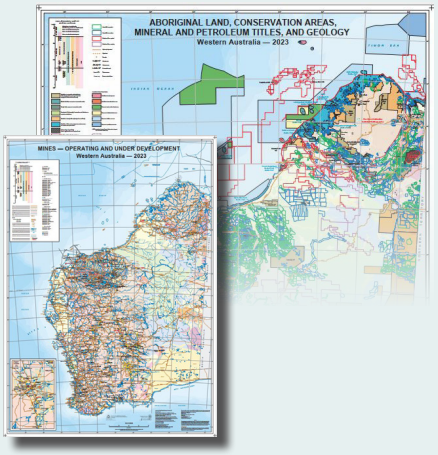
Record 2023/8 6IAS: 6th International Archean Symposium — abstracts
Gessner, K, Johnson, TE, Hartnady, MIH and Wiemer, D

Record 2023/10 Eastern Goldfields geochemical barcoding project – notes to accompany 2023 data release
Lowrey, R and Smithies, RH

Record 2023/11 Yilgarn Granite Project – notes to accompany 2023 data release
Lowrey, JR, Smithies, RH and Champion, DC

Record 2023/12 Systematic classification of Yilgarn Craton granitic rocks
Lowrey, J

• MAPS •



Aboriginal land, conservation areas, mineral and petroleum titles and geology, Western Australia – 2023
Ridge, KJ

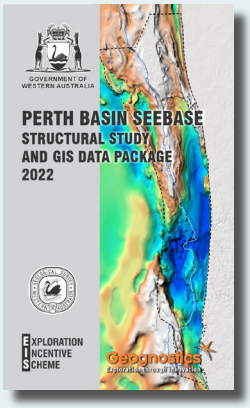
Mines – operating and under development, Western Australia 2023
Pal, T, D'Ercole, C, Murray, SI and Johnston, A

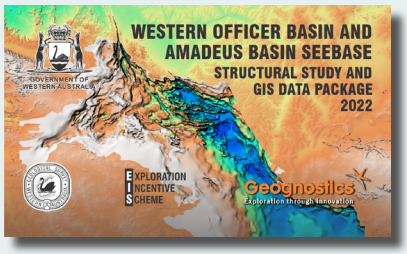
Can be ordered online for the cost of postage

• DATA PRODUCTS •

Resource estimates by project (Alumina, Al_2O_3)
Resource estimates by project (copper)
Resource estimates by project (lithium)
Resource estimates by project (nickel)
Resource estimates by project (silver)
Samarium–neodymium isotope map of Western Australia

• SEEBASE products •





Perth Basin SEEBASE structural study and GIS data package 2022

Western Officer Basin and Amadeus Basin SEEBASE structural study and GIS data package 2022
Geognostics Australia Pty Ltd

USBs available to purchase for $55

• ONLINE PRODUCTS •

Diamonds Down Under: Seeking Western Australia's Treasure (StoryMap)
TJ Ivanic, RS Bower and SR White

WAROX field observations