

RECORD
2022/1

GSWA

WORK PROGRAM

2022–23



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

Geological Survey of
Western Australia





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Department of **Mines, Industry Regulation
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GSWA WORK PROGRAM 2022–23

PERTH 2022



**Geological Survey of
Western Australia**

MINISTER FOR MINES AND PETROLEUM
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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: Journey to the centre of the Kimberley (© 2010 PL Schubert)

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EXECUTIVE SUMMARY



Jeff Haworth, Executive Director,
GSWA (outgoing)

The Geological Survey of Western Australia (GSWA) is preparing for an exciting year in 2022–23 with the continuation of the Geoscience Data Transformation Strategy (GDTS), formalization of the Geoscience Strategy and the ambitious commencement of the WA-Array.

The 2021 Fraser Institute Survey of Mining Companies placed Western Australia at the top as the number one mining jurisdiction in the world, especially for investment attraction and best practice mineral potential. However, the geological databases ranked tenth, which is better than last year but still shows room for improvement that the GDTS aims to address.

In the 2021 calendar year, the resources sector drove the Western Australian economy, and sustained the Australian economy with record sales of \$230 billion eclipsing previous recent records. This has mainly been through traditional iron ore and liquified natural gas sales; however, we are also seeing improvement in other commodities, including nickel.

In coming years, Western Australia is looking towards critical minerals, hydrogen energy, downstream processing and manufacture, and carbon mitigation through sequestration, including geological sequestration. GSWA is tackling this work by updating its commodity flyers regularly, and assisting the State and the nation in attracting investors to Western Australia.

This work program seeks to address these areas as well as continuing to seek understanding of the geology of the State. Our newly released Geoscience Strategy outlines the detailed manner in which GSWA will implement its 'Unearthing Western Australia' strategy concerning geology. The WA-Array will be an essential part of that strategy as we seek to understand the lithospheric architecture of the State.

In 2022–23, GSWA's budget estimates are \$43.78 million (excluding departmentally funded projects), a combination of appropriated funding, Exploration Incentive Scheme (EIS) funding and new initiative funding including the GDTS, the WA-Array and carbon sequestration projects.

Staffing

Staffing estimates for 2022–23 consist of:

- 158 permanent full-time equivalent (FTE) – 151 currently filled and 7 in recruitment at the time of writing
- 10 permanent part time in 2022–23 (7.16 FTE)
- 9 FTE funded from the EIS
- 4 FTE funded from the Mining Rehabilitation Fund
- 10 contract full or part time (9.4 FTE)
- 4 staff in secondment arrangements
- ~12 short-term fee-for-service contractors (as of 1 July 2022).

This has resulted in a total of 207 staff.

Collaborative research projects

We anticipate working on 41 collaborative research projects partly funded by GSWA, including the ongoing National Collaborative Framework agreements.

Products to release

GSWA plans to publish the following flagship products:

- Maps 4
- Data packages (USBs) 3
- Digital layers 18
- Online data releases 8
- Publications 47

GSWA will also deliver the following:

- Geochronology, isotope and mineral geochemistry data via an online application (WAGIM)
- The new Geocentric Datum of Australia 2020 (GDA2020) for the Department of Mines, Industry Regulation and Safety's (DMIRS) Geoscience and Titles Information datasets.

This will be my final Executive Summary as I retire from the department at the end of this financial year, and move on to other things.

My experience in leading GSWA has been exciting and challenging over the past four years and I have enjoyed it immensely. I leave GSWA secure in the Leadership Team's capable hands, and I wish my successor all the very best knowing we have a strong, supportive and dedicated group of people within GSWA.

Jeff Haworth

Executive Director
Geological Survey and Resource Strategy

Note: all currencies are Australian dollars unless otherwise indicated.

PART ONE

Detailed work programs



RESOURCE INVESTMENT

Investment and Engagement

Manager: Warren Ormsby

Team members: Sabrina Bednarski, Sarah Sargent

An ongoing objective of this section is to facilitate the provision of resource-related information to investors for mineral and energy investment in Western Australia to accelerate exploration and development of new resources. This involves providing geoscientific, policy and regulatory information through various methods to assist with attracting new resource investment. Another emerging objective is to promote GSWA activities to relevant stakeholders including the geoscientific community and the general public.

Activities are undertaken individually by GSWA or in cooperation with 'Australia Minerals' (the collective name given to investment collaboration between the State and Territory geological surveys and Geoscience Australia [GA]).

Activities undertaken include:

- Preparing informative and up-to-date Western Australian investment-oriented presentations for delivery at virtual conferences or in person at local and overseas events
- Providing high-quality geoscientific and policy information sessions for industry and research
- Responding to investor requests for geoscience and policy, and providing information and advice
- Collaborating with JTSI, Austrade and other government agencies at a State and national level to provide advice and information on Western Australia's resources industry and mineral endowment
- Publishing commodity flyers which provide a summary of the mining and exploration activity for that commodity
- Promoting GSWA activities, and increasing our digital visibility, through social media channels
- Continuing to produce the GSWA Webinar Series.

Planned work program

It is anticipated that there will be an easing of travel restrictions that have been in place in response to the COVID-19 pandemic. However, as Western Australia goes through peak transmission it is not yet clear how international and domestic travel will be affected. With this in mind, in 2022–23, the project will fund Western Australia's presence in some capacity at key national and international events (either virtual attendance or in person) (Table 1).

Products planned for release

- Investment opportunity/commodity summary flyers updated annually (25+ flyers)
- Posters tailored for specific events will be produced as required

Table 1. Key national and international events

2–4 August 2022	Diggers & Dealers
7 September 2022	RIU Good Oil Conference
16–18 September 2022	AstroRocks Fest
14–15 October 2022	Perth Gem and Mineral Show
17–19 October 2022	IMARC, Melbourne
25 November 2022	GSWA Open Day 2022
29–30 November 2022	Australian Hydrogen Conference
November 2022	Goldfields Big Day Out
29 November – 1 December 2022	Mines and Money, London
1–3 February 2023	NAPE Summit
February 2023	RIU Explorers Conference
March 2023	PDAC, Toronto
13–18 March 2023	AEGC, Brisbane
15–17 March 2023	AOG Energy, Perth
April 2023	Paydirt Battery Metals Conference
May 2023	APPEA 2023 Oil and Gas Conference
June 2023	World Mining Congress

GEOSCIENCE DIRECTORATE

State Geoscience

Manager: David Martin

Team members: Heidi Allen, Cristina Angheluta, John Brett, Huntly Cutten, Erin Gray, David Howard, Sarah Martin, Ruth Murdie, John O'Donnell, Angela Riganti, Huaiyu Yuan

The State Geoscience branch is responsible for maintaining and communicating a coherent geoscience framework for Western Australia via GSWA databases, the GSWA website and social media, statewide layers on GeoVIEW.WA, published reports, and the State geological map. The branch consists of four sections:

- State Maps and Explanatory Notes System (ENS)
- Paleontology and Geoheritage
- Geophysics Acquisition and Processing
- Earth Imaging and Observation.

State maps and Explanatory Notes System

The State Maps and ENS section of the State Geoscience branch works with project teams and groups, guiding and overseeing development and population of GSWA databases, contributing to products, validating database content, and coordinating work across projects and divisions to better understand the geological framework and evolution of the State (Fig. 1). The section also works independently on geological problems not part of current GSWA project work and on statewide geological issues and datasets, and responds together with the Paleontology and Geoheritage section to many of the public enquiries received by GSWA.

Paleontology and Geoheritage

This section is responsible for cataloguing and documenting the fossil record of Western Australia, developing the biostratigraphic framework of the State, managing the GSWA paleontology collection, and identifying, registering and managing State sites of geological significance (State Geoheritage Sites and Reserves).

Geophysics acquisition and processing

This section plans and manages regional geophysical data acquisition projects, prepares datasets for delivery to the public and internal users, and provides internal processing and interpretation services, and advice as required. The section also manages the geophysical survey index and data repository (MAGIX), and the submission, archiving and release of airborne and some ground survey datasets submitted by the exploration industry.

Earth Imaging and Observation

This section aims to increase the knowledge of Western Australia's subsurface through the integration of geophysical, geological and geochemical data in 3D models. The program's objective is to test specific theories to allow the extension of knowledge from exposed and well-understood areas to inaccessible or data-poor parts of the Earth's crust. The ultimate goal is to understand and visualize the lithosphere of Western Australia.

Collaborative projects with leading research institutions that complement GSWA's capabilities in data acquisition, analysis and modelling form a core part of the section's activities and are funded through the EIS under Passive Seismic and Magnetotelluric Surveys.

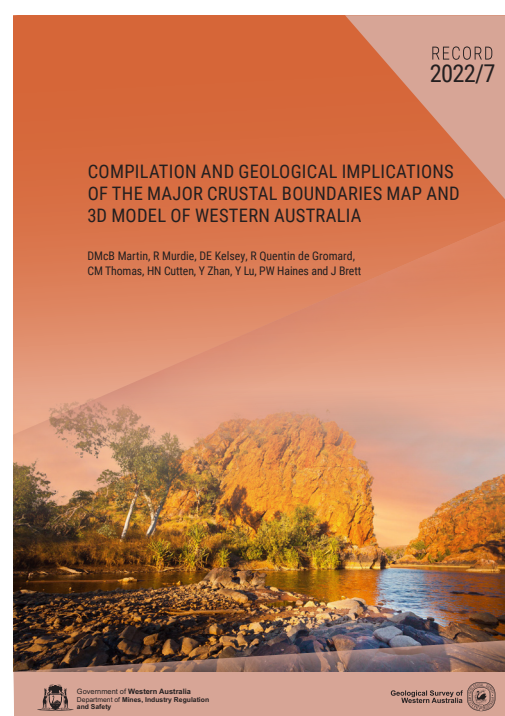


Figure 1. A recent Record released by the section

Planned work program

The planned work program for 2022–23 for the ENS and State Maps section includes updates to State geological layers and assisting with capture of legacy geochronology baseline data and records. This forms part of the handover of the newly developed geochronology module as part of the Geochronology, Isotope, Metamorphic history and mineral chemistry Explanatory Notes System (GIMENS) to the Geochronology and Geochemistry program. The section will also coordinate the compilation of geoscience vocabularies for the GSWA Data Transformation Strategy (a long-term project), and assist with system documentation/mapping as required.

The Paleontology and Geoheritage section will continue work on statewide paleontological and biostratigraphic projects, including the palynology of the southern Perth Basin, paleontology of Proterozoic sedimentary basins and the ichnology, paleontology and stratigraphy of the Southern Carnarvon Basin. Maintenance of GSWA's paleontology collection will continue, including the continued transformation of analogue specimen records to a digital format, the management of loans, and curation of new materials. Also continuing is a project to catalogue the condition of the State's registered geoheritage sites, with plans to improve the information available to the public for each locality. The newly established geoheritage nomination process will be tested using a handful of example sites prior to the section accepting and assessing nominations from the general public; at the same time, a region-by-region assessment of the State will commence, with the aim of expanding the number and variety of sites listed on the Register of State Geoheritage Sites. Finally, the section will contribute to organizing and running the Palaeo Down Under conference (PDU3) and associated field trips in July 2023.

New magnetic, radiometric, and gravity datasets will be included in updates to the respective statewide compilation grids produced by the Geophysics Acquisition and Processing section. All new geophysical data acquisition projects are conducted as part of the EIS under the Airborne Geophysical Surveys program, and the 2D and 3D Active Seismic Surveys programs.

The Earth Imaging and Observation section will continue to develop 3D stochastic modelling for the next generation of 3D modelling software by being part of ARC project LP170100985 Enabling 3D stochastic geological modelling (3D-LOOP), a large Monash University-led international project for reducing risk for the resources industry. Work in the Eastern Goldfields will focus on integrating petrophysical data with geochemical and other geophysical data. The section will also expand its capacity to monitor natural and anthropogenic seismicity (baseline monitoring in the Kimberley with CSIRO and mining induced seismicity in the Eastern Goldfields). The major new WA-Array project will use teleseismic events to image lithospheric structure, starting in the south west of the State. This is a 10-year project covering Western Australia with a 40 km grid of points which will be occupied by passive seismic and magnetotelluric (MT) measurements.

Products planned for release

- Updates to State layers in GeoVIEW.WA, including WAROX text mining layers and the metamorphic history layer
- Annual release of the Western Australian field observation database (WAROX)
- Delivery of extended ENS content and ongoing population of the database
- Internal delivery of geoscience vocabularies as part of the Data Transformation Strategy
- Paleontology Reports: reporting on paleontology section projects and publication of consultancy reports
- Field guides for Palaeo Down Under conference (Records)
- Sixth International Archean Symposium: Out with the old, in with the new – a traverse across the Archean–Proterozoic boundary in the Mount Bruce Supergroup (Record)
- Sixth International Archean Symposium: Abstracts
- Kalbarri Unearthed (book)
- Eucla basement petrophysical data and potential field modelling (Record)
- Western Australian Sites of Geological Significance (State Geoheritage Sites): registration process (Record)

Geochronology and Geochemistry

Manager: Michael Wingate

Team members: Imogen Fielding, Sarah Gain, Dominique Harmer, Frances James, Jack Lowrey, Yongjun Lu, Marlene Papiccio, Sandra Romano, Tom Scillieri, John Williams

Geochronology, isotope geology and geochemistry are integral components of GSWA's geoscience programs and mineralization studies. The geochronology program determines precise and accurate ages of minerals, rocks and geological events to understand the geological history of Western Australia and contributes to enhancing the prospectivity of the State (Fig. 2). Geochemical studies of rocks and regolith are essential for understanding the sources and petrogenesis of igneous suites, the relationships within and between igneous suites, the sources (provenance) and compositional characters of sedimentary rocks and regolith, and for constraining metamorphic modelling.

Geochronology techniques

Geochronological techniques are applied to constrain the timing of magmatism, metamorphism, deformation, hydrothermal activity and mineralization, using a range of isotope systems (e.g. U–Pb, Ar/Ar, Re–Os and Rb–Sr) and a variety of minerals (zircon, baddeleyite, monazite, xenotime, titanite, apatite, rutile, hornblende, feldspars and micas). The Sensitive High-Resolution Ion Microprobe (SHRIMP) instrument in the John de Laeter Centre at Curtin University is used extensively for U–Pb geochronology. GSWA also uses laser ablation inductively coupled mass spectrometry (LA-ICP-MS) instruments in the John de Laeter Centre and the Centre for Microscopy, Characterisation and Analysis at UWA to date detrital zircons, and to date monazite, xenotime, and other minerals in thin sections in support of metamorphism and pressure–temperature–time (P–T–t) studies, and to measure the trace element compositions of minerals.



Figure 2. GSWA geologists making measurements in the field during geological mapping and geochronology sampling in the Paleoproterozoic Kimberley Basin

Geochemistry

Whole-rock geochemistry is typically carried out for the complete set of major element oxides and a large suite of trace elements, but may also be restricted to certain element groups (e.g. precious metals, platinum group elements, etc.) depending upon project requirements. Analytical services are outsourced to several Perth-based laboratories with the main techniques applied being X-ray fluorescence (XRF) spectrometry for major elements and some trace elements, and ICP-MS for trace elements. All data are compiled in the Western Australian Geochemical (WACHEM) database and made available through the online **GeoChem Extract application**.

Isotope geology

Geochronology and geochemistry results and derivative materials are used extensively in GSWA's isotope geology studies, led by Yongjun Lu (see Enhanced Geochronology and Isotopic Mapping). These include specialized isotope geochemistry studies, including whole-rock Sm–Nd, Lu–Hf and Pb isotope analyses and zircon Lu–Hf and oxygen isotope analyses. These investigations are conducted in collaboration with external university laboratories.

Laboratory

The Laboratory section, managed by John Williams, supports the varied aspects of GSWA's geochronology, geochemistry and isotope geology programs with world-class sample preparation services provided in-house by the GSWA laboratory at Carlisle. The Laboratory section also manages archiving and retrieval of materials in GSWA's extensive geological sample collection to support numerous internal and external research projects, and coordinates petrographic services for GSWA geologists.

Geochronology database

Development of a new geochronology, isotopes, mineral chemistry and metamorphic history database application (WAGIMS) is mostly complete, and the importing of geochronology and isotope data and uploading of files are underway. The application will organize and deliver geochronology, isotope and mineral chemistry, and metamorphism data.

Project work for the branch is funded through the Enhanced Geochronology and Isotopic Mapping work program. Accordingly, details of the work program are discussed in that section.

HyLogger and the National Virtual Core Library

Manager: *Lena Hancock*

Team members: *Edward Rogers, Michael Wawryk*

The HyLogger facility is one of six State and Territory geological survey-based nodes that were established in 2009 as part of the National Collaborative Research Infrastructure Strategy (NCRIS), to provide objective mineralogical data from drillcore (and other rock samples), thereby improving our understanding of the composition of the Australian crust. HyLogger-3 technology collects mineral reflectance spectra in the visible near-infrared (VNIR), short-wave infrared (SWIR) and thermal infrared (TIR) spectral ranges, and provides objective, semi-automated interpretation of mineralogy by comparing these data to a reference library of mineral spectra using The Spectral Geologist (TSG) software (Fig. 3). High-definition digital images of the core are simultaneously obtained.

HyLogger data are processed and posted to external databases such as the AuScope portal and GeoVIEW.WA, where they can be viewed using open-access TSG software, and as the drillcore images, and mineral logs and images. Full datasets are also available upon request. The list of scanned datasets and the links to the drillcore images and other publications is updated every six months and is available on the [DMIRS website](#).

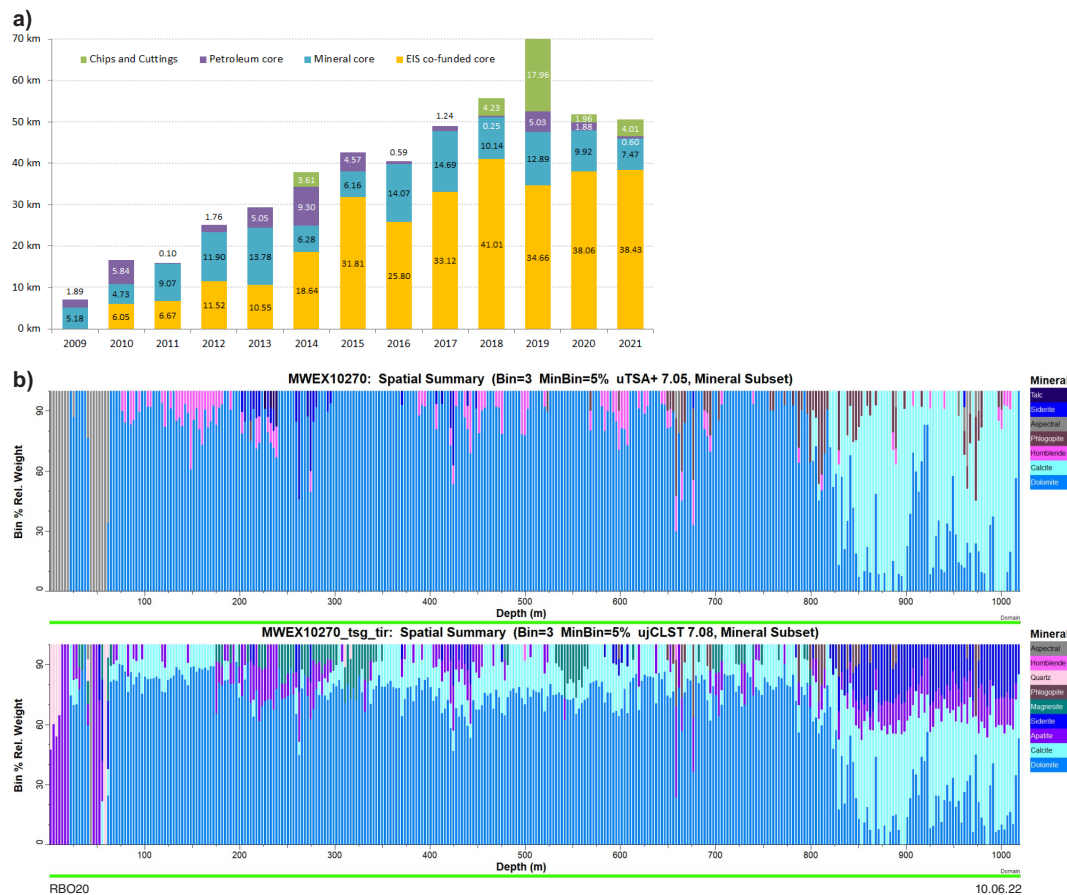


Figure 3. a) HyLogger data production; b) TSG summary mineralogy for EIS drillhole MWEX10270

HyLogger-4

HyLogger-3 will be replaced by the new HyLogger-4 system towards the end of the 2022–23 financial year. HyLogger-4 will have the additional capability of recording the mid-infrared (MIR) spectral range and higher resolution digital images to produce higher quality data over a wider spectral range.

Planned work program

The facility will continue to collect and process spectral data from drillcore that contributes directly to increasing the knowledge of Western Australian geology, and of mineral and petroleum systems. Material to be analysed will include that requested by GSWA staff, academic researchers, students and industry engaged in collaborative or other research with GSWA (including core obtained as part of the EIS). New mineralogy histogram images and CSV data files will be produced for all drillcores scanned by the HyLogger and made available via the HyLogger layer in GeoVIEW.WA and the Data and Software Centre (DASC). The HyLogger team is involved in DMIRS' Data Transformation Strategy to improve storage, delivery, and access of HyLogger data through GeoVIEW.WA.

Other regular activities will include periodic uploading of processed HyLogger data to the NVCL database, ensuring the release of non-confidential data to the AuScope national portal and to the GeoVIEW.WA HyLogger layer.

Collaborative projects

HyLogger staff have initiated a collaborative project with CSIRO to digitally characterize petroleum cuttings using HyLogger images and Artificial Intelligence / Machine Learning (AI/ML) methods. The resulting protocols for automated lithology quantification will provide easily accessible objective information to the petroleum and mineral exploration industries.

In collaboration with CSIRO, HyLogger staff will deliver to GSWA, academic and industry personnel two workshops promoting the use of hyperspectral technology. These will be conducted in the Perth and Kalgoorlie Core Libraries.

HyLogger staff will also undertake the collection of geochemical data from selected scanned drillcore using portable XRF and LIBS technologies, thereby increasing the information available for drillcore archived in the core libraries and complementing mineralogical interpretations from hyperspectral data.

Products planned for release

- HyLogger data, including histogram images and data files, released to online applications (GeoVIEW.WA and DASC)
- Portable XRF data to be released to clients and online applications (GeoVIEW.WA and DASC)
- Using pXRF and pXRD in DMIRS core libraries (Record)

East Yilgarn

Manager: Jyotindra Sapkota

Team members: Matthew de Paoli, Melissa Drummond

The Eastern Goldfields Superterrane (EGST) is a highly mineralized region with world-class gold and nickel deposits, and significant deposits of other commodities including base metals, rare earth elements (REE), lithium, uranium, gemstones and industrial minerals. This typical Archean upper crustal granite–greenstone terrane forms much of the exposed eastern part of the Yilgarn Craton, and is separated from the West Yilgarn by the Ida Fault.

The EGST is divided into four shear zone bounded terranes. From west to east, they comprise the Kalgoorlie, Kurnalpi, Burtville and Yamarna Terranes. The terrane architecture has previously been interpreted to reflect the accretion of several microcontinents between c. 2800 and 2650 Ma. However, local abundance of komatiites and associated thick basaltic successions, and the identification of a basement succession broadly similar in age to regions of the western Yilgarn Craton, suggests that subsequent closure following the c. 2.7 Ga mantle plume-fed rifting of an autochthonous basement may represent an alternative geodynamic model.

Stratigraphic correlation

Although basalt-dominated greenstone sequences are mapped, intersected in drillcores and recognized in geophysical surveys throughout the EGST, correlating geological events, stratigraphy or structures within and between individual greenstone belts constitutes a major challenge. A detailed stratigraphic correlation has only been attempted in the Kalgoorlie Terrane between Norseman in the south and Agnew in the north based on systematic geological mapping at the 1:100 000 scale and supported by geochemical and geochronological datasets. In this region, most of the exposed greenstones belong to the 2801–2690 Ma Kalgoorlie Group, which comprises the lowermost mafic–ultramafic–upper mafic sequence that broadly characterizes most individual greenstone belts. Although not physically contiguous between belts, these sequences are broadly similar in rock type, stratigraphic variations and age, and so have been distinguished as stratigraphically equivalent subgroups of the Kalgoorlie Group. Greenstone sequences older than 2800 Ma are also locally exposed around Leonora (~2817 Ma), Menzies (>2803 Ma) and Norseman (~2930 Ma). The Kalgoorlie Group is overlain by the Black Flag Group (2690–2665 Ma, equivalent to the Mount White Group in the Agnew–Lawlers region), which comprises mainly turbidite-type deposits, and felsic volcanic and volcanoclastic rocks. The Black Flag Group is unconformably overlain by 2664 to 2657 Ma sequences of mainly epiclastic origin, such as the Scotty Creek Formation (Agnew–Lawlers region), the Navajo Sandstone (southwest of Kalgoorlie), the Merougil Formation (west of Kambalda), and the Kurrawang Formation.

Planned work program

Geological interpretation of the region east of the Zuleika Shear Zone, comprising the Ora Banda, Kambalda, Bulong and Parker Domains between the townsites of Callion in the north and Widgiemooltha in the south, will be finalized in the 2022–23 financial year. The new interpretation will be informed by geochemical, structural, geochronological and isotopic data collected from outcrop and diamond drillcore, including those from the 2021–22 field season. After field verification, the available company geological maps and drillhole data will be used to consolidate GSWA's mapping and stratigraphic interpretation. The geological layers over the entire region imaged by the 2019 high-resolution seismic survey will be integrated into the 1:100 000 interpreted bedrock geology (IBG) dataset.

Targeted geological fieldwork and geochemical/geochronological sampling will start to focus on the Widgiemooltha–Norseman region, as the geological interpretation will move south of the area imaged by the 2019 seismic survey. Building of a virtual field guide of important geological localities in the East Yilgarn on the ESRI StoryMaps platform will commence in the second half of the financial year (Fig. 4).

Products planned for release

- East Yilgarn Geological Information System (GIS) 2023 (including updated bedrock geology layers east of the Zuleika Shear Zone)
- Explanatory Notes and stratigraphic update

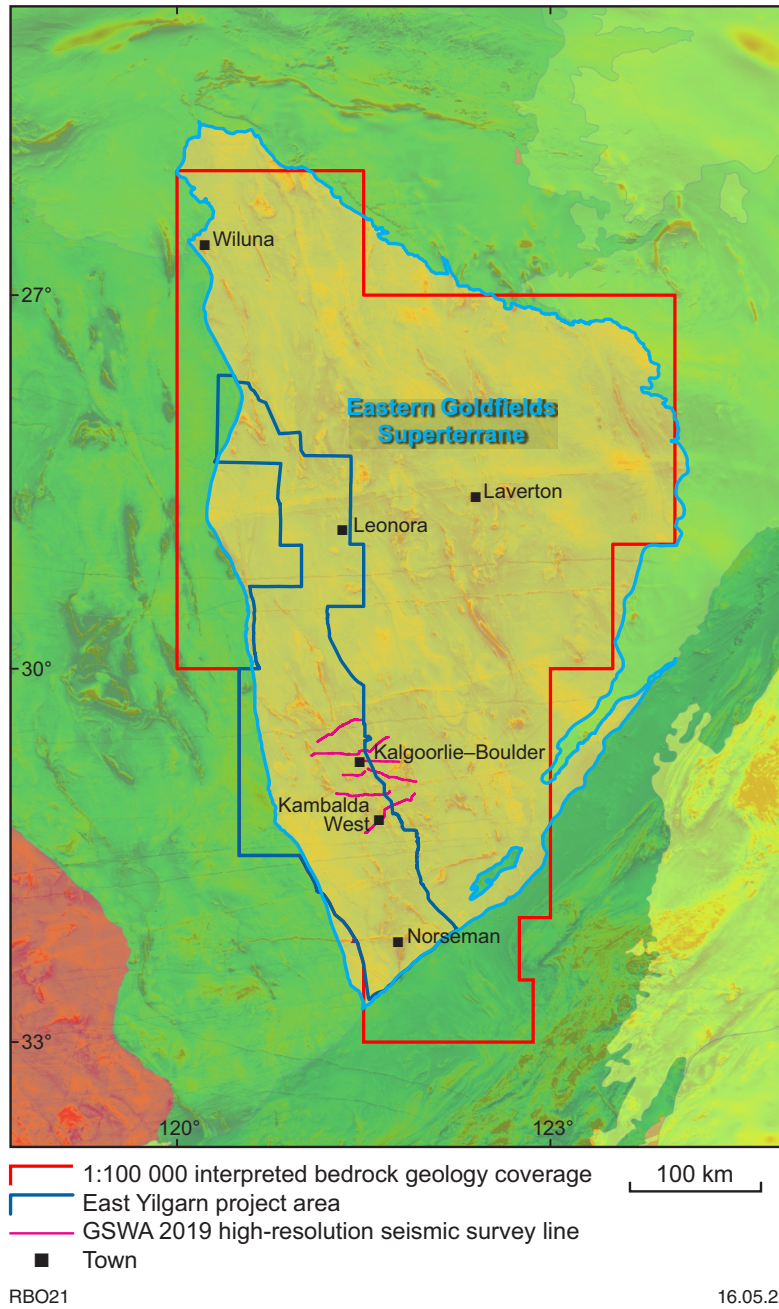


Figure 4. The Eastern Goldfields Superterrane is highlighted in light blue. The red and blue polygons outline the east Yilgarn project area and the 1:100 000 interpreted bedrock geology coverage. The purple lines represent the GSWA 2019 high-resolution seismic survey lines

West Yilgarn

Manager: Raphael Quentin de Gromard

Team members: Matthew de Paoli, Paul Duuring, Tim Ivanic, Jack Lowrey, Ivan Zibra

The West Yilgarn project examines the geology west of the Ida Fault, east of the Darling Fault and bounded to the north and south by the Proterozoic Capricorn and Albany–Fraser Orogens respectively (Fig. 5). This large region is known to include significant concentrations of gold, iron ore, nickel, copper, lead, zinc, tungsten, molybdenum, bismuth, vanadium, titanium, beryllium, lithium, tin, tantalum and uranium in a range of inferred geological settings. The ongoing prospectivity of the region has only recently been highlighted by the discovery of extensive Ni–Cu–PGE mineralization just 60 km northeast of Perth, at Julimar.

Filling the knowledge gap of the geology of the western margin of the Yilgarn Craton from the South West Terrane to the Narryer Terrane including the c. 2660 Ma ‘west Yilgarn magmatic province’ also known as the ‘west Yilgarn Ni–Cu–PGE Province’ forms the current priority of the west Yilgarn project. Understanding the geological evolution of this region, and how the varied and complex crustal entities within it have interacted geodynamically throughout the Precambrian is key to better realizing the land-use potential of the west Yilgarn region.

Narryer Terrane

The Narryer Terrane, in the northwest, contains the oldest rocks in the Yilgarn Craton and shares a tectonic contact with the Youanmi Terrane. The oldest rocks identified in the Narryer Terrane are 3.73 Ga migmatitic gneiss and layered mafic rocks; however, detrital zircon in quartzite and conglomerate at Mount Narryer and Jack Hills include zircons older than 4.0 Ga that pre-date any known rocks on Earth. These outstanding features have drawn considerable scientific attention to the felsic components of Narryer geology along the proposed terrane boundary, but the geology of the internal parts of the Narryer Terrane and of the supracrustal sequences are, in contrast, very poorly known. Greenstones in the Narryer Terrane are restricted to several belts of strongly deformed and metamorphosed rocks yielding depositional ages between 3.1 and 2.7 Ga. Proterozoic volcanic and deformational episodes are also poorly studied.

Youanmi Terrane

The Youanmi Terrane in the western part of the Archean Yilgarn Craton comprises an extensive Archean granite–greenstone terrain with a long and complex geological history. The Youanmi Terrane greenstones, incorporating the older Madoonga and Gossan Hill Formations and the voluminous Norie, Polelle and Glen Groups, were deposited between 2.99 and 2.71 Ga. Felsic plutonic rocks intruded during each of these periods of volcano-sedimentary deposition and as voluminous syntectonic, synorogenic plutons along crustal-scale transpressional shear zones during the 2.73 – 2.65 Ga Yilgarn orogeny. Granitic magmatism continued during the late- to post-orogenic stages (2.64 – 2.60 Ga) that led to final cratonization of the Yilgarn Craton lithosphere.

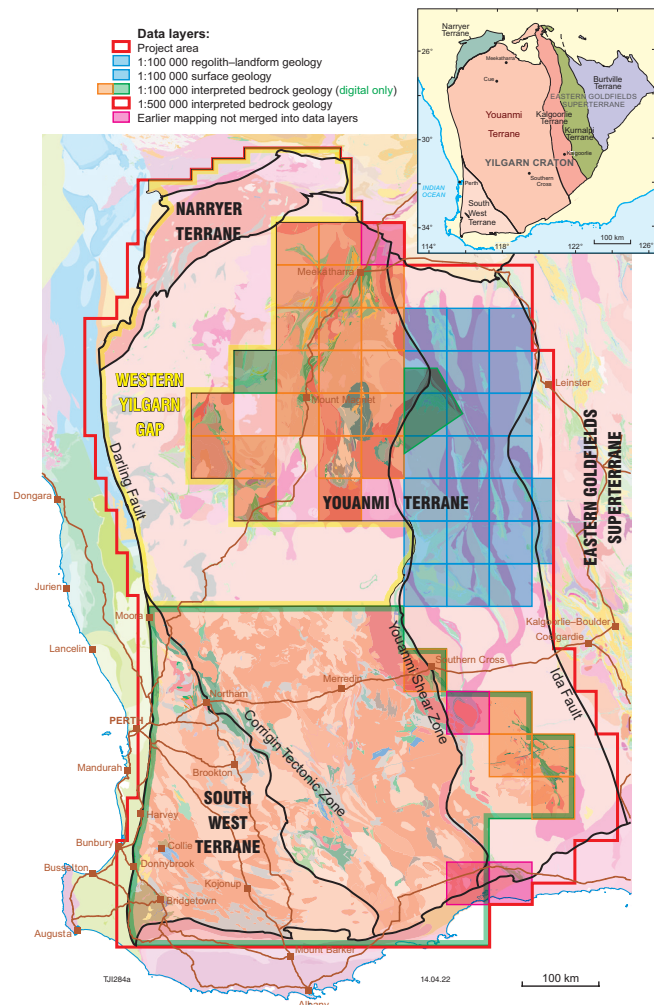


Figure 5. Simplified geological map of the west Yilgarn project area. The map shows the extent and scale of available interpreted bedrock geology highlighting the knowledge gap (yellow outline) of the western margin of the Yilgarn Craton

Much of the regional mapping and additional geoscientific work conducted so far in the Youanmi Terrane has concentrated on its Neoarchean greenstone sequences and on the relationship between synorogenic magmatism, metamorphism and deformation along large-scale shear zones. However, there is a large temporal gap in the understanding of the crustal evolution of the older components of the Yilgarn Craton, including the overall lithospheric architectural evolution, during the Mesoarchean from 3.1 to 2.9 Ga. The Youanmi Terrane hosts most of the craton's rocks within this period but they typically have a low geoscience data density and relatively poor map coverage.

Interpretations

As a result of work and interpretations that emerged from the 2020–21 Southwest Yilgarn Accelerated Geoscience Program (AGP), the boundary between the Youanmi and South West Terranes has been shifted by about 200 km towards the southwest. The redefined South West Terrane is currently regarded as a Neoarchean crustal entity, dominated by rocks younger than c. 2.7 Ga. There is no formal stratigraphy for the greenstone successions in the South West Terrane. In the hanging wall of the redefined terrane boundary, we identify the Corrigin Tectonic Zone (CTZ), consisting of a 50–150 km wide zone of southwest-verging anastomosing shear zone system formed in transpression, under granulite facies conditions and between c. 2665 and 2635 Ma. This boundary forms an obvious new search space for mineral exploration.

Planned work program

Within the 2022 West Yilgarn GIS package, we have integrated the IBG from the Youanmi 2020 GIS package and the southwest Yilgarn 2021 Geological Exploration Package. To complete this amalgamation in the coming years, our focus is on data acquisition and interpretation along the western margin of the Yilgarn Craton.

Fieldwork related to the 2022–23 work program will prioritize observations, sampling and initial interpretations, which aim at consolidating the interpreted kinematics and age of major shear zones of the Corrigin Tectonic Zone, the Darling Fault and the Narryer/Youanmi Terrane boundary.

Collaborative projects

A new collaborative PhD project (UWA) investigating the terrane boundary between the Youanmi and South West Terranes in the Toodyay–Northam area commenced in February 2022 and is projected to end in 2025.

Detailed fieldwork focusing on the Late-Archean, Proterozoic and Phanerozoic tectonic evolution of the western Yilgarn Craton margin commenced during the 2020–21 AGP and will be extended to the region around Harvey Dam aiming at deciphering the Archean history of the western Yilgarn margin along the Darling Fault.

Cooperative projects with various universities will continue, and include geochemical, metamorphic and structural studies in the northern Youanmi Terrane, 3D modelling in the western Youanmi Terrane, and structural and isotopic studies in the Narryer Terrane.

Products planned for release

- Explanatory notes update for Yilgarn Craton granites and Youanmi Terrane greenstones
- Formation of the Yilgarn protocraton by rift-related magmatism from 3.01 to 2.92 Ga to contain a significant stratigraphic update resulting from newly acquired geochronology (Record)
- Sedimentological investigation of the Mougooderra Formation, Youanmi Terrane (Record)
- Structural evolution and quartz c-axis crystallographic preferred orientation of major Yilgarn shear zones (Report)
- Fieldguide to the far southwestern Yilgarn Craton: One day excursion for the SGGMP conference, Nov 2022 (Record)
- Sixth International Archean Symposium: Fieldguide to the terrane boundary between the Youanmi and South West Terranes of the Yilgarn Craton: Three-day excursion for the 6IAS conference, July 2022 (Record)
- Sixth International Archean Symposium: A traverse across the northern Yilgarn Craton in Western Australia — from the Jack Hills to the Youanmi Terrane (Record)

Pilbara and Hamersley

Manager: Heather Howard

Team members: Olga Blay, Arthur Hickman

The Pilbara Craton, northwest Western Australia, provides the world's best-preserved geological record of late Eoarchean to Neoproterozoic crustal evolution. The Eoarchean to Neoproterozoic granite–greenstone terrane contains several of the world's oldest examples of porphyry-style mineralization, volcano-sedimentary base metal deposits, banded iron-formation (BIF), gold mineralization and pegmatite-hosted lithium, tantalum and niobium. It also hosts fossil evidence of the earliest life on Earth. Geological mapping of the granite–greenstone terranes at 1:100 000 scale was completed in 2005, along with a major revision of the stratigraphy, and revised interpretation of the structural and crustal evolution. Current work aims to make these data more accessible in digital format.

The granite–greenstones of the Pilbara Craton are unconformably overlain by the 2775–2630 Ma volcano-sedimentary Fortescue Group and the conformably overlying 2629–2420 Ma Hamersley Group of the Mount Bruce Supergroup (Fig. 6). This supergroup incorporates the world's best-preserved sequence of Archean ultramafic to felsic volcanic deposits, and arguably the world's most continuous transect across the Archean–Proterozoic boundary. The prominent BIF, and the contained iron enrichments, are among the most economically important mineral deposits on the Australian continent.

The stratigraphy of the Fortescue Group has been previously described in detail by GSWA and a rift to passive margin setting suggested. Mantle plumes have been proposed to explain the evolution of the Fortescue Basin, and a convergent setting for BIF and mafic and felsic rocks in the upper part of the Hamersley Group has been proposed. Nevertheless, the debate on stratigraphic definition, tectonic setting and evolution of the Mount Bruce Supergroup remains unresolved.



Figure 6. The Mount Bruce Supergroup, Hamersley Ranges

Objective

The main objective of the Pilbara and Hamersley project is to increase our understanding of the Fortescue and Hamersley Groups in terms of their context within the wider Mount Bruce Supergroup. The project seeks to review the relationships between the volcanic and sedimentary units, integrating this with petrogenetic constraints on magmatism to better understand the tectonic evolution of the Mount Bruce Supergroup.

Planned work program

Stratigraphically controlled, high-precision geochemical, isotopic and geochronological data will be obtained from outcrop sampling to construct a 'magmatic stratigraphy' of the Mount Bruce Supergroup in key areas that can be extended to a regional scale. Targeted mapping will be carried out and detail added to the digital map layers as it becomes available.

Work will continue towards a new release of the Northwest Pilbara 1:100 000 IBG layers. Continued geochemical data collection and interpretation will focus on a reassessment of the tectonic setting and geological evolution of the Fortescue and Hamersley Groups to be included in new Records.

Products planned for release

- A geochemical traverse through the Fortescue Group near Paraburdoo (Record)
- Sixth International Archean Symposium: Pilbara Craton: evolving Archean tectonic styles — a field guide (Record)
- Explanatory notes to accompany the 1:500 000 and 1:250 000 IBG digital map layers for the north and south Pilbara, respectively

Geoscience Mapping Through Cover

Manager: Richard Chopping

Team members: Nadir de Souza Kovacs, Sara Jakica

Geoscience Mapping Through Cover commenced in 2018–19 and is aligned with the Proterozoic Margins work program. It is linked to Participation in the MinEx CRC work program and contributes to the understanding of the MinEx CRC project area for Western Australia ('The Gap' – see Proterozoic Margins work program). Activities will be conducted within MinEx CRC, with support for the National Drilling Initiative (NDI), and conducted through MinEx CRC Program 3 work program. Collaborative research will be funded through the EIS from two project areas: Regolith and 3D Paleosurface Mapping.

The mapping of different regolith types and thickness is integral to geoscience studies and exploration. Regolith mapping includes the use of orthophotos, satellite imagery (e.g. ASTER) and geophysical data that images near-surface cover (e.g. airborne electromagnetic [AEM], passive seismic) linked to field-based studies and analysis of drillcore. A scale-independent regolith–landform classification scheme has been developed and is applied regardless of the geological terrain, and a new module for regolith units has been developed within ENS. The compiled maps and documentation provide context for landscape evolution studies and dating of regolith materials, with an aim to produce 3D and 4D models of the regolith in case study areas.

Passive seismic

Over the past decade, GSWA has demonstrated the application of single-station passive seismic (using Tromino instruments; Fig. 7) to provide estimates of the depths to various horizons or basement in shallow cover and up to a depth of 1 km. The focus for 2022–23 is to continue the application of multiple geophysical techniques with an emphasis on passive seismic approaches to understand regolith mapping using near-surface geophysics in areas of interest for the MinEx CRC drilling project and other key areas of GSWA interest. Related to this, Geoscience Mapping Through Cover staff will be involved in understanding the changes in physical properties that are influenced by weathering and landscape evolution in conjunction with MinEx CRC researchers.

This will include coordination of work to jointly use passive and active seismic methods around recently acquired reflection lines, for example, the Kidson line in northern Western Australia or the Eastern Goldfields high-resolution seismic survey near Kalgoorlie. Additionally, joint interpretation with other available geophysics to better define thickness of cover will be undertaken to support NDI drilling programs.

Additionally, the link to the Proterozoic Margins work program will be enhanced by integration of landscape/landform evolution and understanding of key Proterozoic aged margins of the State. Modern landscapes are derived from potentially ancient subsurface features, and the integration of the work of these groups will assist in mapping the covered geology of the State.

Planned work program

- Further application of small-array passive seismic data acquisition to map regolith layers and paleochannels in conjunction with geophysical data, and to provide estimates of depth to basement
- Dating of regolith materials using the (U–Th)/He method, in collaboration with the John de Laeter Centre
- A targeted geochemical sampling approach, in conjunction with geochronology and biochemistry sampling, will be used during regolith mapping and regolith profile studies. This will provide information about paleoweathering patterns and local geochemical dispersion patterns from bedrock
- Assistance to the Department of Primary Industry and Regional Development in geological understanding of the western Yilgarn Craton, primarily in the Wheatbelt, for groundwater in fracture aquifer systems.

Products planned for release

- Multiphysics regolith thickness mapping in the Ravensthorpe region (external publication)



Figure 7. Tromino passive seismic instruments being prepared for data acquisition, used for understanding paleovalleys in the Yangibana region

Proterozoic Margins

Manager: Fawna Korhonen

Team members: David Kelsey, Chris Phillips, Jennifer Porter (MinEx CRC Embedded Researcher)

The Proterozoic Margins section amalgamates the activities of the former North Australian Craton, Albany–Fraser Orogen and Eucla basement projects, and resides within the Geoscience Mapping Through Cover branch. The primary objective is to investigate and map the geology of the remote greenfields regions in the vicinity of the Northern Territory and South Australian border (Fig. 8), informally known as ‘The Gap’, and to provide essential data and knowledge towards GSWA’s commitment to the NDI of the MinEx CRC. Collaborative projects with leading research institutions will be funded through the EIS, primarily under the Proterozoic Margins and Novel Geochronology and Isotope Analyses projects.

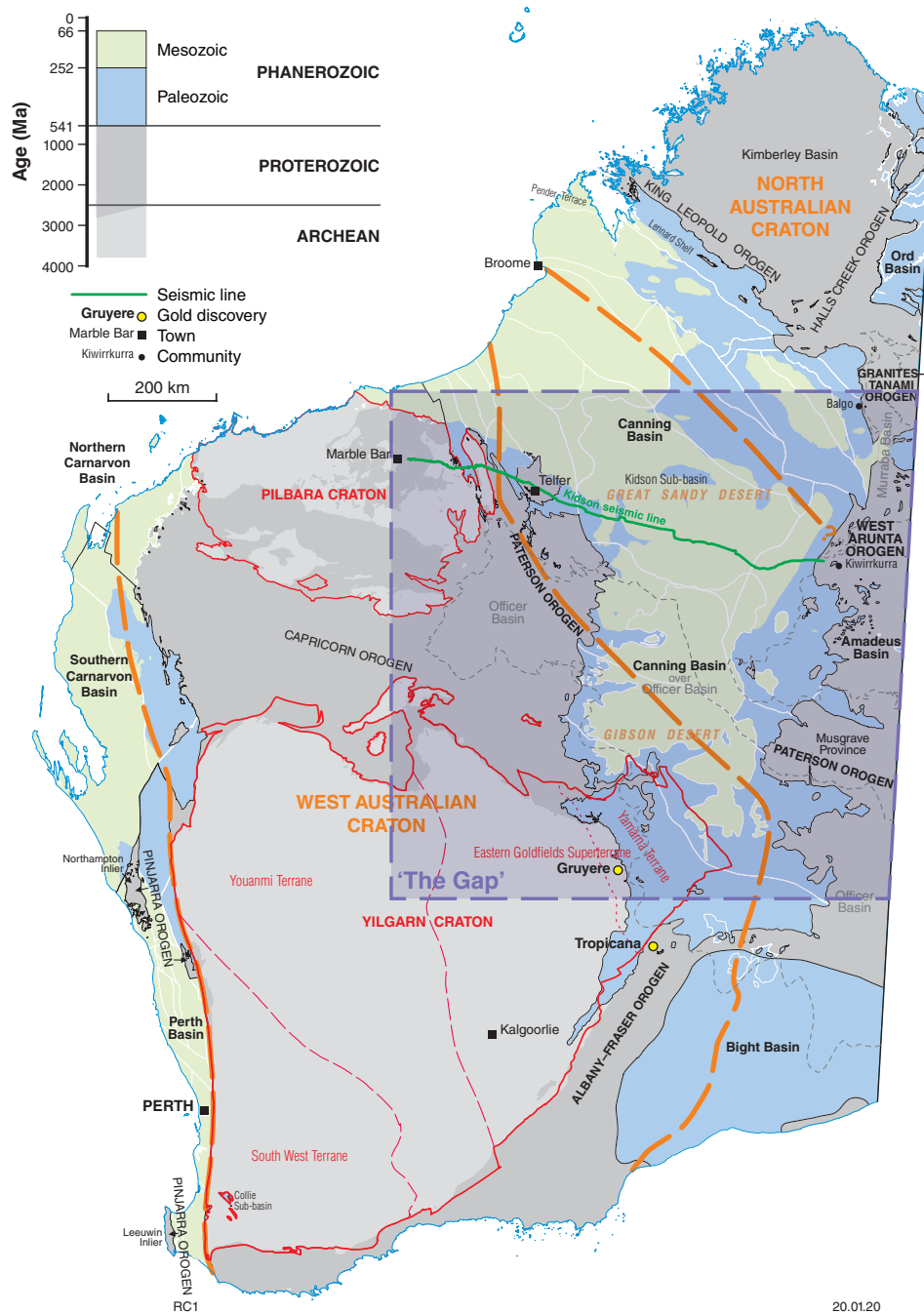


Figure 8. Location of ‘The Gap’, which is the informal name for the region of the remote desert country of central eastern Western Australia

Interpretation

Much of the region is covered by younger basins and regolith, and a major component of the work program of Proterozoic Margins is to interpret geophysical data and produce IBG maps. This work incorporates knowledge gained from field mapping and drillcore analysis, with particular emphasis on using EIS co-funded drillcore housed at the Perth and Kalgoorlie core libraries. The project builds on the successful approach developed in the Albany–Fraser Orogen and Eucla basement projects. Currently, the Paterson Orogen, the Far East Yilgarn and the West Arunta region are the main focus of new work.

One of the aims of the Proterozoic Margins section is to open up new frontiers in mineral exploration by understanding the magmatic, sedimentary and tectonic environments. This provides fundamental information to enable exploration teams to evaluate prospectivity and generate new project areas, and search for potential targets. The integration of statewide metamorphic studies to Proterozoic Margins will strengthen the geological mapping and prospectivity assessments of greenfields in Western Australia.

Planned work program

The primary work program for Proterozoic Margins for 2022–23 is on geological interpretations and products to support understanding of basin and basement geology of The Gap region. Sampling and analysis of existing diamond drillcore from the West Arunta and Paterson Orogens will continue, and a drilling program as part of the MinEx CRC NDI in The Gap region has been proposed, pending access. Basin studies will focus on Meso- to Neoproterozoic basins in the region using drillcore and legacy samples. Metamorphic and geochronological analyses on the Paleoproterozoic–Neoproterozoic Wunaamin Miliwundi and Halls Creek Orogens will also occur. Interpretation of AEM data over the Canning Basin will be conducted collaboratively with GA, assisting understanding of the basin itself and any potential for basin-hosted resource systems.

This year will be the final year for the MRIWA collaborative research project M521 studying the Paterson Orogen. This will provide a solid basis in the coming years for products providing a deeper understanding of this key region for minerals exploration.

Products planned for release

- Basement geology and fluid systems of the West Arunta from drilling data (Record)
- Metamorphic History records, as appropriate
- ENS entries for geological studies, as appropriate
- The preservation of legacy collections project – a template for preserving high-value collections for future research (Record)
- Sedimentology and stratigraphy of the Kimberley Basin (Report)

MINERALS AND PETROLEUM RESOURCE DIRECTORATE

Mineral Systems

Manager: Warren Ormsby

Team members: Matt Clarke, Paul Duuring, Lauren Grech, Sidy Morin-Ka

The Minerals Exploration Geoscience branch focuses on providing information to assist and encourage mineral exploration in Western Australia. A major part of this role involves studying mineral systems from both an empirical and genetic basis and providing timely relevant information to the mineral exploration industry. The work in this area is complemented by projects funded by the EIS (see Mineral Systems).

The branch makes extensive use of the HyLogger (see HyLogger and the National Virtual Core Library) to assist with detailed studies of alteration assemblages in diamond drillcore and other specimens from mineral deposits and exploration drilling. It is also increasingly using exploration information from the Western Australian Mineral Exploration reports (WAMEX) database.

Mineral Systems Atlas

Information is disseminated via DASC, GIS packages, internal and external publications, the online Mineral Systems Atlas and associated Guide, and presentations to the minerals industry (Fig. 9). The Atlas currently contains GIS-based map layers of significant geological 'proxies' for critical metallogenic processes, for the komatiite-hosted nickel, BIF-hosted iron, rare-element pegmatite and mafic intrusion-hosted vanadium mineral systems.

Planned work program

This year will see the continuation of various projects with a focus on the following themes:

- Controls and indicators of mineralization using gold as the primary example due to this commodity having the most geochemical, geological and endowment-related information. For gold, there will be an emphasis on craton-scale mineralization controls, particularly in the South West Yilgarn region
- Information relevant to critical and battery minerals will continue to be compiled, examined and published, including integrating information obtained from the AGP and relevant collaborative studies, and obtaining relevant data from WAMEX. Prospectivity studies will focus on rare-element pegmatites and mafic–ultramafic intrusion hosted Ni–Cu–PGE mineralization
- Commence work on mineral systems associated with sediment-hosted base metals, especially those that have the potential to assist in locating related critical minerals such as cobalt, gallium, germanium and indium.

The branch will work collaboratively with other areas within the divisions to share resources and expertise for mutual benefit. An example of this will be the overlap with the New Energy Systems branch in the battery minerals area. Collaboration with other government and academic institutions, and a network of affiliated exploration and mining companies via collaborative research projects funded by the EIS (see Mineral Systems) will continue where it contributes towards achieving the objectives of this program.

Collaborative projects

Current collaborative projects, most of which are wholly or partly funded by the EIS (see Collaborative Projects and Mineral Systems under the EIS), include:

- ARC Linkage project LP190100635 — Realising Australia's rare earth resource potential (partners: The University of Adelaide, The Australian National University, The University of Queensland, University of Cambridge UK, Geoscience Australia, Geological Survey of Queensland, Geological Survey of New South Wales, GSWA, resource companies)
- Minerals Research Institute of Western Australia (MRIWA) project M10433 — Detection of distal footprints in the Southwest Yilgarn: Linking basement and cover (partners: MRIWA, CSIRO, resource companies)

In addition to involvement in the above projects, the branch will continue working on the following current projects:

- The compilation of GIS layers and information on mafic–ultramafic intrusion-hosted Ni–Cu–PGE mineral system will be completed and prepared for publication in the Mineral Systems Atlas and on DASC
- The compilation of GIS layers to add to the existing Mineral Systems Atlas with the emphasis on craton-scale structural features that appear to provide pathways for all types of mineralization and on the rare-element pegmatite and komatiite-hosted Ni–Cu–PGE mineral system
- Literature and data reviews to inform the scope and direction of a new sediment-hosted mineral system study
- Further work on REE studies in the Kimberley/Western Tanami region to complement the ARC Linkage project with planned fieldwork subject to access constraints, including any COVID-19 pandemic restrictions.

Products planned for release

These are in addition to the EIS projects listed in Mineral Systems work program.

- Potash GIS layers in the Mineral Systems Atlas and on DASC and associated documentation (as a Record and Guide)
- Manganese GIS layers in the Mineral Systems Atlas and on DASC and associated documentation (as a Record and Guide)
- Study of the John Galt Rare Earth Element deposit in the East Kimberley (Record)
- Komatiite-hosted Ni–Cu–PGE deposits: a mineral system analysis (Record)
- External publications

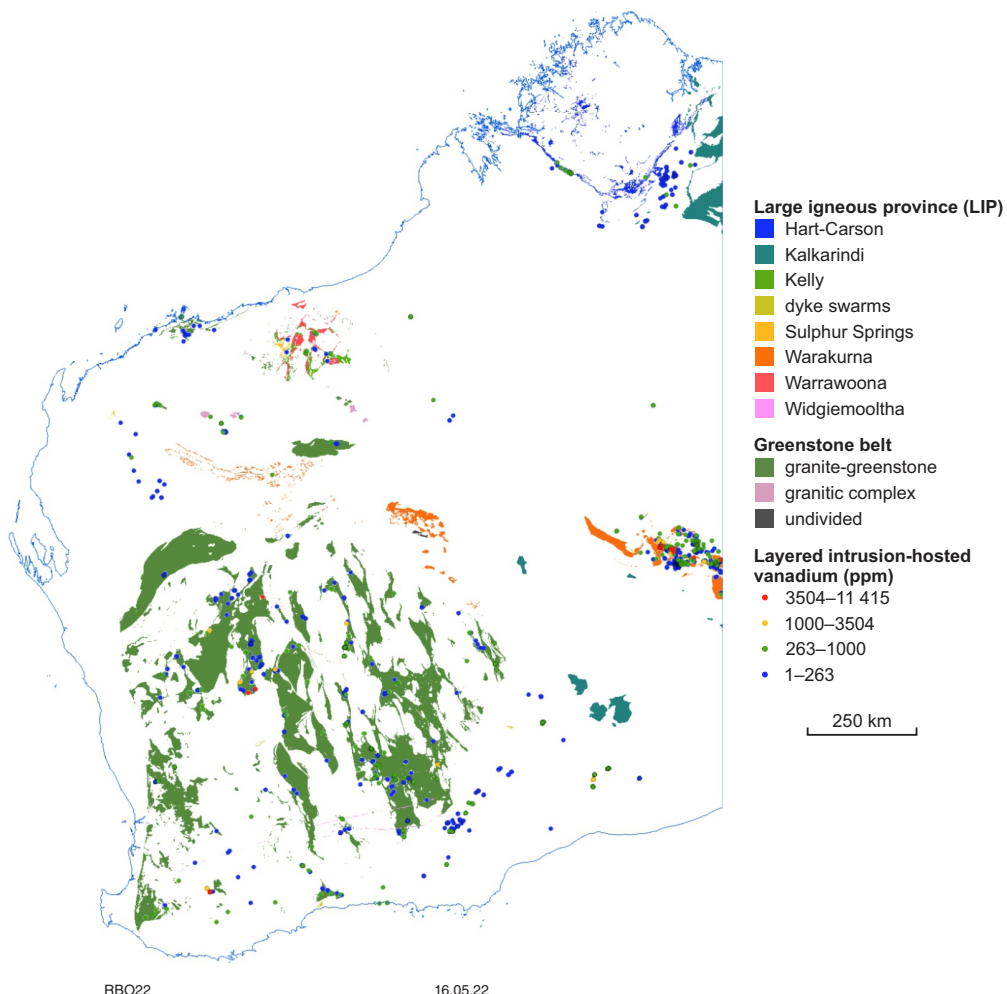


Figure 9. Mineral Systems Atlas, 2021

Energy Geoscience and Carbon Strategy

Manager: Deidre Brooks

Team members: Norman Alavi, Richard Bruce, Julie Cass, Louisa Dent, Louisa Ellis, Peter Haines, Arthur Mory, Leon Normore, Charmaine Thomas, Yijie (Alex) Zhan

The primary goal of the Energy Geoscience and Carbon Strategy branch is to develop consistent, basinwide stratigraphic, structural and energy system frameworks for Western Australia's sedimentary basins, both onshore and in State Waters. The aim is to encourage increased exploration for energy resources such as petroleum, geothermal, helium, natural hydrogen and coal, as well as identify subsurface areas for potential CO₂ sequestration, and temporary hydrogen and gas storage to secure the State's energy future.

Collaboration

The team works in collaboration with other divisions of DMIRS and external organizations, including the Commonwealth Scientific and Industrial Research Organisation (CSIRO), The University of Western Australia (UWA), Curtin University, Department of Jobs, Tourism, and Science Innovation (JTSI), Northern Territory Geological Survey (NTGS), Geological Survey of South Australia, Geological Survey of New South Wales and Geoscience Australia (GA).

The current focus of the branch is the Amadeus, Canning, Northern and Southern Carnarvon, Officer and Perth Basins. The Perth, Northern Carnarvon and Canning Basins have proven petroleum systems but, along with the Western Australian side of the Amadeus and the vast Officer Basins, they are all underexplored.

The branch will expand on the geological assessment of the characterization and distribution of salt within the basins of Western Australia to better understand the seal potential of salt-bearing formations, focusing on the Carnarvon, Canning and Officer Basins (Fig. 10).



Figure 10. Salt in core from the formation Mallowa Salt taken from the petroleum exploration well Willara 1, Canning Basin

Natural hydrogen

During 2021–22, a new project showed promising results for the existence of natural hydrogen in the Canning Basin. This investigation will continue with another field trip which may incorporate new autonomous soil gas sampling, the results of which may lead to the establishment of a new industry in Western Australia.

Multiyear studies on the stratigraphic and structural framework of the northern Perth Basin have been on hold and will recommence in 2022–23 after the salt study in the Carnarvon Basin is completed. The project will include new biostratigraphic evaluations, well correlations, seismic interpretation and two-way time (TWT), velocity, isopach and depth mapping.

A Report listing and interpreting all the organic geochemistry data for all the petroleum source rocks in the State is being revised and will be released in 2023–24. The temperature data available from a variety of sources is being compiled by the Western Australian petroleum and geothermal management system (WAPIMS) for input into future temperature modelling and revision of geothermal prospectivity in selected regions of Western Australia.

Energy Systems Atlas

During the 2022–23 financial year, the branch will continue to work with the WAPIMS team to deliver meaningful data in useful formats to the energy industry through the Energy Systems Atlas. The Energy Systems Atlas consists of GIS layers within WAPIMS relating to energy such as oil, gas, geothermal, CO₂ sequestration, helium and hydrogen. Existing layers show data availability, plots of key data types, and existing structure maps. Further interpretive information will be added in 2022–23.

The State Government will provide funding over two years to update and expand the Western Australia Carbon Dioxide Geological Storage Atlas which will provide Government and industry with a clearer understanding of the potential for carbon capture and storage in the State by identifying new CO₂ geological storage sites and further analysing known storage sites.

The atlas will cover new geographic areas and stratigraphic intervals not included in the first atlas and will use higher resolution maps (including major faults), and reservoir and seal information from wireline logs in both the new regions and those originally investigated.

The outcome of the study will be the identification of a wider distribution, and an increased number, of potential sites which could be considered for future CO₂ storage projects, including State Waters in the Carnarvon and northern Perth Basins. In addition the atlas will, where possible, provide site or area-specific geological characterization of the reservoir quality and possible sealing formations, and an estimate of storage capacity. It will comment on technical feasibility, containment confidence, risk factors and cost considerations such as depth, reservoir complexity and maturity.

Planned work program

Products listed at the end of this section were the focus of geoscience studies during 2021–22 and will be released in 2022–23. New data produced from these projects will be incorporated into the Energy Systems Atlas.

Work will continue or recommence on the following studies that will provide relevant data that can feed into the Energy Systems Atlas in future years:

- Documentation of results from fieldwork in the Lucas Outlier (Murabba Basin)
- Age Dating and isotopic characteristics of the Canning Basin basement and intrusives
- Barnicarndy 1, stratigraphic well, post-well analysis
- Structure, stratigraphy and prospectivity of the Amadeus and Officer Basins
- Fieldwork in the Carnarvon Basin to study the stratigraphy of the Byro Group
- Sedimentological description of the Harvey 2, 3 and 4 cores
- Documentation of the play types in the Perth and Canning Basins.

Products planned for release

- Mesozoic Unearthed (book)
- AEM interpretation of the Canning and Ord Basins (Report)
- Harvey 2, 3 and 4 core descriptions (Record)

New Energy Systems

Manager: Trevor Beardsmore

Team members: ad hoc via collaboration

Western Australia is undergoing a New Energy Transition, driven by the State Government's Climate Policy that coordinates action to achieve net-zero greenhouse gas (GHG) emissions by 2050, while further building a prosperous and resilient economy. Initiatives such as the Energy Transformation Strategy and the Future Battery Industry Strategy aim to capitalize on the State's impressive natural resource endowment, technical know-how and prime geographic location to shift to predominantly 'green' domestic energy generation, and build a fully integrated green energy industry that exports products and expertise to a demanding world (Fig. 11).



Figure 11. New energy initiatives aim to capitalize on the State's natural resource endowment

New Energy Transition

This New Energy Transition impacts the entire Western Australian community, and a whole-of-government approach will be required to manage it. Within this context, GSWA will be making important contributions, by providing geoscientific information and advice that:

1. Promote the discovery and recovery of necessary mineral and energy resources
2. Assist with mitigating resultant waste streams
3. Inform the development of government policies and regulations.

Resources include those required for the technologies to generate energy from renewable and non-renewable sources, and to store this energy for future use (including export). They might be primary or byproduct materials and energy occurring in conventional or novel settings, including bedrock, groundwaters, mine residues and disused mine infrastructure. Wastes include solid residues from physical mining and processing of raw materials, and actual and 'embedded' greenhouse gas emissions from resource extraction activities and energy generation — but might also be potential resources in a regenerative 'circular' economy.

The resources industry and Government both require information on the known or prospective availability of relevant raw material and storage resources in Western Australia, and on evolving trends in domestic and international market demand for these resources. The role of this section is to develop and coordinate a work program specifically focused on delivering this information.

Planned work program

In 2022–23, the section will continue work on several projects that address GSWA's commitment to the New Energy Transition, specifically establishing several statewide datasets upon which more detailed studies can be based:

- Characterize the actual and prospective type, quantity and value of byproduct or co-product 'battery/critical' mineral resources in conventional and novel mineral deposits in bedrock, groundwaters and mining/mineral processing residues. This will highlight regions of future development and capital expenditure, and place Western Australia's resource endowment in the context of global demand, quality and value
- Characterize geological reservoirs for the temporary storage of 'new energy' sources (hydrogen, 'pumped hydro', geothermal) and permanent geosequestration of waste greenhouse gases, in mafic–ultramafic bedrock packages, mine residues (tailings and rock waste), and old mine infrastructure (open pits).

There will necessarily be close intra- and inter-Agency collaboration to harvest the data and knowledge that will be needed to achieve the proposed outcomes.

Products planned for release

- Preliminary estimate of potential greenstone reservoirs for CO₂ sequestration (Report and associated GIS data files)
- Catalogue of current and proposed 'battery mineral' projects in Western Australia (Record and database)
- Preliminary catalogue of Western Australian mining residues with potential for 'battery mineral' resources and/or greenhouse gas sequestration (Record and database)

Petroleum Exploration Information

Manager: Felicia Irimies

Team members: Alan Bloore, Fiona Dodd, George Karniewicz, Janine Malligan, Richard O'Brien, Yasinta Situmorang

This section is involved with the monitoring, administration and release of petroleum and geothermal data submitted under the *Petroleum and Geothermal Energy Resources Act 1967* (WA) and the *Petroleum (Submerged Lands) Act 1982* (WA), covering onshore and territorial sea.

NOPTA

From 1 January 2012, the National Offshore Petroleum Titles Administrator (NOPTA) assumed responsibility for a range of regulatory and administrative functions for Commonwealth Waters that had previously been the responsibility of the designated authorities. This includes the regulation of documentary information and petroleum mining samples (petroleum data), in accordance with Part 7 and Part 8 of the Offshore Petroleum and Greenhouse Gas Storage (Resource Management and Administration) Regulations 2011 (RMA Regulations).

Under the State–Commonwealth National Collaboration Framework, DMIRS will continue to provide services to the Commonwealth in the handling of core, cuttings and thin sections that relate to petroleum exploration in offshore Commonwealth-controlled waters. It will continue to make those samples available for viewing, further sampling and loan. DMIRS is also assisting NOPTA and GA to develop and maintain the National Offshore Petroleum Information Management System (NOPIMS), with close links to WAPIMS and the Core Information Management System (CIMS).

The section adds quality-assured geoscience information to the WAPIMS database, undertakes transcription and scanning programs related to State activities, and ensures data submitted are complete and in a format easily used by explorers. It also manages the release of data online through WAPIMS, including documents related to offshore activities occurring before 1 January 2012 (Fig. 12).

Priorities for transcribing and scanning legacy data are set in part by the future activities of the Energy Geoscience and Carbon Strategy section and the Specific Area Gazettes conducted by the Resource Tenure Group.

Welcome to WAPIMS

Petroleum & Geothermal Information Management System

Search the Petroleum Exploration Database

WELLS	SURVEYS	TITLES	FIELDS	CORE LIBRARY	FACILITIES	RELEASED DOCUMENTS	GIS MAP
<div> <div>Well name</div> <input type="text"/> </div> <div> <div>Well operator</div> <input type="text"/> </div> <div> <div>Field</div> <input type="text"/> </div> <div> <div>Basin</div> <input type="text"/> </div> <div> <div>Title</div> <input type="text"/> </div> <div> <div>Is offshore?</div> <input type="text"/> </div> <div> <div>Spud date from</div> <input type="text"/> <input type="text"/> </div> <div> <div>Spud date to</div> <input type="text"/> <input type="text"/> </div> <div> <div>Report types</div> <div>Select...</div> </div> <div> <div>SEARCH</div> </div> <div> <div>CLEAR ALL</div> </div>							

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Figure 12. WAPIMS online interface

Planned work program and outcomes

The section will continue loading legacy scanned and transcribed data for access via the web and add new data as received, continue quality control for onshore well log data submitted from industry and create reports and data packages, available through WAPIMS.

Planned activities and outcomes are to:

- Continue creating enhancements to WAPIMS including:
 - upload the scanned seismic sections (depending on DMIRS data storage capacity)
 - create forms and public reports to release online all the public geoscientific data captured in WAPIMS (State and Commonwealth)
 - add new map layers
 - add new data to 'Data By Depth' functionality
- Continue vectorizing all the onshore line sections without digital data to SEG-Y; priorities based on work done by the Energy Geoscience and Carbon Strategy branch
- Continue the data transcription program including the remaining nine track tapes
- Continue accessioning the thin sections submission for State and Commonwealth wells and release them to the public
- Continue sampling approvals for State and Commonwealth activities and monitor retrieval of the analysis reports and the slides generated
- Assist in relocating Western Australian core from GA to the Perth Core Library
- Plan for future scanning of the thin section collection in collaboration with other teams as part of the Data Strategy
- Relocate and review the archived items stored at Iron Mountain and prepare for uploading the digital data into a cloud system
- Review and update Guidelines for petroleum data submission and release based on Parts 8 and 9 of the Mines and Petroleum Regulation Amendment Regulations 2018.

Mineral Exploration Information

Manager: Julia Thom

Team members: Monique Brouxhon, Subashni De Biran, Dale Finnigan, Narelle Gardiner, Fiona MacCorquodale, Robert Pizzi, Christine Suchodolski

DMIRS has a statutory obligation to manage the collection, storage and release of company exploration reports containing geoscience information on mining tenements in Western Australia; this function is performed by GSWA. The archive of statutory exploration information is a valuable resource, providing a means whereby companies can assess the potential of an area and develop exploration strategies using legacy data, which minimizes duplication of exploration effort and enables more efficient exploration.

The reports and information also provide valuable input to GSWA mapping and resource assessment projects and activities.

Drillhole and geochemistry database

The section manages the company mineral drillhole and surface geochemistry database, which contains all company drilling and surface geochemistry data that has been submitted to DMIRS in digital format.

In addition, the section manages the processes that allow internal and external stakeholders to view and sample the valuable mineral core collection housed in the two core libraries (Fig. 13).

Planned work program and outcomes

- Review and release surrender reports and their associated annual reports as they are received, together with the 16th annual release of reports under the provisions of Regulation 96(4) of the Mining Act, commonly known as the 'sunset clause'; this will ensure that access to this historical data increases
- Release reports that relate to exploration on dead tenements, although many of these relate to tenements under the *Mining Act 1904*, to which the 'sunset clause' does not apply
- Continue to review the mineral exploration reports for compliance with the Guidelines for Mineral Exploration Reports on Mining Tenements, to ensure all data is included in the report prior to archiving, and it is then ready for release via the 'sunset clause' or normal cancellation process
- Expand the reviewing process to allow reviewing geologists to enter information from company exploration reports into the MINEDEX database
- Convert all sunset clause release reports in WAMEX to searchable text for upload to the database and to the WAMEX search site
- Work on continual improvements to the WAMEX database to increase its searchability
- Continue work of cleansing and harmonizing geochemistry data in the Mineral Drillholes database and improve the search interface
- Continue training in the use of the WAMEX and mineral drillhole and surface geochemistry databases in both Perth and Kalgoorlie, and develop, update and deliver training and exercise manuals on those databases
- Develop a core library database, in collaboration with WAPIMS, for mineral core with links to the mineral drillhole and WAMEX databases, to enable better searching for drillcore and a more efficient and less manual process of managing, viewing and sampling the mineral core
- Continue to identify and collect historical drillcore suitable for the Perth and Kalgoorlie core libraries
- Continue the capture of attribute information for legacy mineral exploration core submitted to the core libraries in Perth and Kalgoorlie.

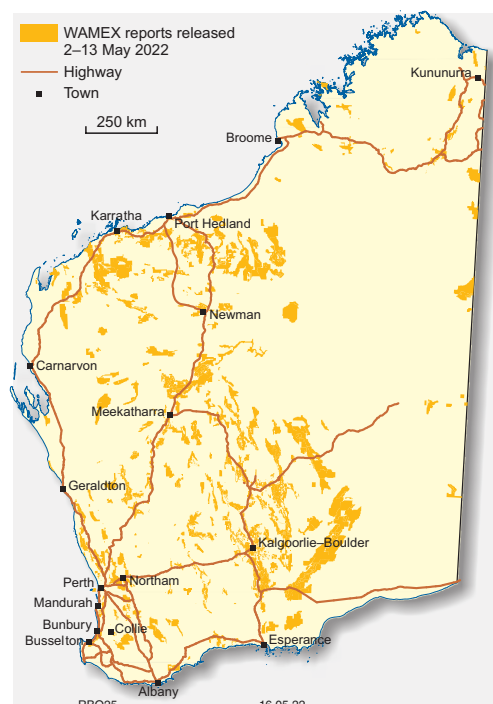


Figure 13. Sunset Clause reports released in 2021

Mines and Mineral Deposit Information

Manager: Nicole Wyche

Team members: Cecilia D'Ercole, Andrew Johnston, Sue Murray, Tamal Pal

This branch tracks mineral exploration and mining activities in Western Australia by collating data on mineralized sites, exploration and mining projects, mineral resources and mineral production. This allows DMIRS to provide data and specialist technical advice and publications on most mineral commodities. Data users include DMIRS divisions, other government agencies, research organizations, and a range of industries and individuals.

MINEDEX

A key component of this work is the maintenance and enhancement of Western Australia's Mines and Mineral Deposits database (MINEDEX). MINEDEX is a core DMIRS business system that provides a broad range of searchable data on minerals industry activity (current and historic), and hosts compliance documents such as environmental registration files. MINEDEX provides spatial and textual data for internal and public users. MINEDEX also generates unique site and project identification codes used throughout DMIRS to reference activities for compliance reporting in departmental business systems, including the Environmental Assessment and Regulatory System (EARS), the Royalties Management System (RMS) and the Safety Regulation System (SRS). MINEDEX also provides nightly updates of spatial data for use in DMIRS spatial data applications, including TENGGRAPH and GeoVIEW.WA, and provides data downloads via DASC (Fig. 14).

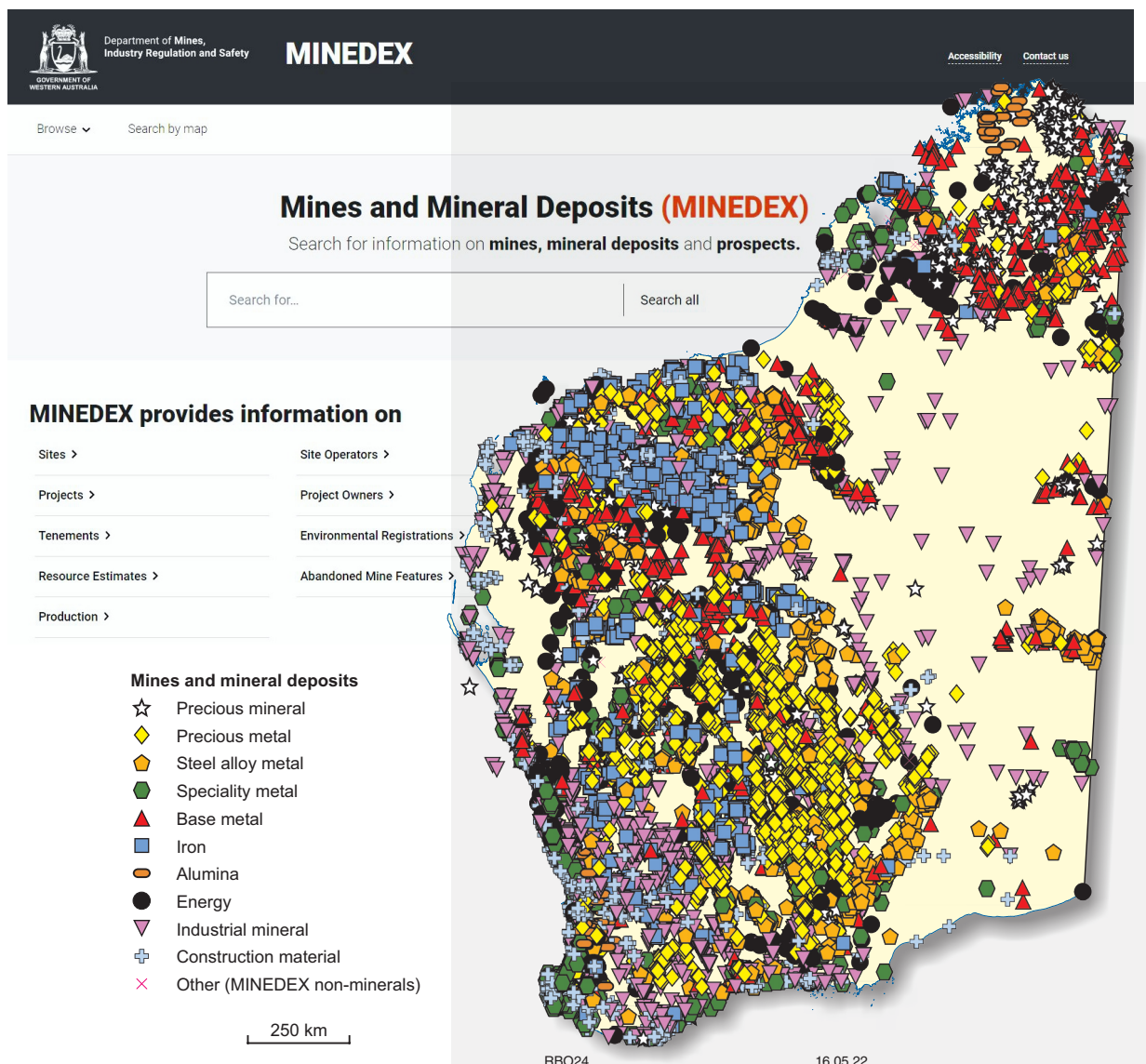


Figure 14. Mining and exploration activity points throughout Western Australia from MINEDEX

The branch produces commodity-related publications including the annual Mines – Operating and Under Development and Major Resource Projects maps, the Atlas of Mineral Deposits and Major Petroleum Resources book and map (produced every second year), investment opportunity commodity flyers, and posters showcasing trending exploration results. In 2020–21, the ability to deliver spatial layers of MINEDEX resource estimate data was developed, and custom spatial layers of resource estimate data were released in 2021–22.

Planned work program

In 2022–23, the branch will focus on the following core business tasks:

- Populating MINEDEX with current industry activity data
- Maintaining and improving MINEDEX
- Managing the RMS production report and the data generated by this report
- Servicing other DMIRS databases' dependencies on MINEDEX
- Providing specialist information to internal and external stakeholders on mining industry activities
- Providing specialist publications (see product list below)
- Providing MINEDEX training for internal and external customers
- Developing system documentation for the GSWA data strategy projects.

Business improvement projects

The following projects are planned to improve our service delivery:

- Improving MINEDEX SQL reports
- Improving MINEDEX help documentation
- Incorporating MINEDEX capture into WAMEX report assessment workflow.

Products planned for release

- Release of more custom spatial layers for resource estimate data
- Major resource projects, Western Australia 2022 (map)
- Mines – operating and under development, Western Australia 2023 (map)
- Kimberley Mineral Resource and Petroleum Projects 2023
- Significant exploration activity in Western Australia (poster for GSWA Open Day and Diggers and Dealers)

Land Use Planning

Manager: Samantha Carter

Land Use Management: Lauren Pike, Andrea Wootton

Land Use Geoscience: Steven Batty, Samantha Dykmans, Jordana Gardiner-Haukohl, Joshua Guilliamse, David Hamdorf, Kevin Ridge, Caroline Strong, Hannah Wallace

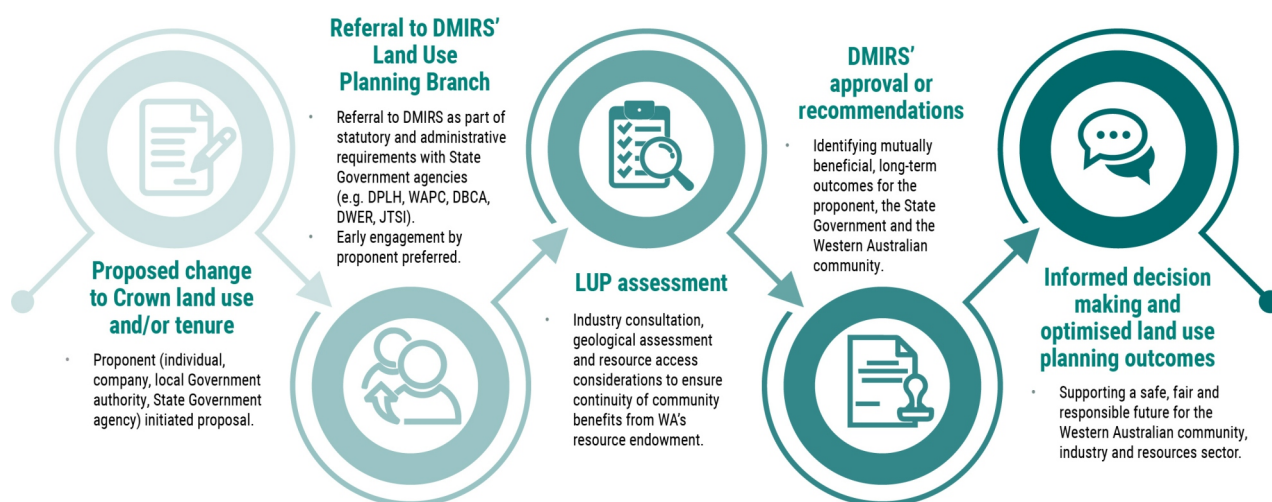
The Land Use Planning (LUP) branch helps shape and inform land use planning policy and outcomes by providing advice based on geoscience, resource mapping and prospectivity assessments.

Collaboration

The branch collaborates with Industry and Local Government Authorities (LGA), as well as other government departments such as the Departments of Planning; Lands and Heritage; Premier and Cabinet; Biodiversity, Conservation and Attractions; and Jobs, Tourism, Science and Innovation to assist with land use decisions and managing impacts arising from land use/tenure changes.

Access for exploration and development

The primary aim of the branch is to maintain access for exploration and development of the State's mineral, basic raw material, petroleum and geothermal energy resources while assisting with the delivery of State land use objectives. In addition, the branch provides significant input into strategic and statutory planning and policy advice that relates to the State's resources. A key role of the branch is to ensure early engagement with regard to proposed land use/tenure changes to ensure informed decision making and provide opportunities to optimize land use planning. This is done by identifying mutually beneficial, long-term outcomes for the proponent, the State Government and the Western Australian community (Fig. 15).



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Figure 15. Assessment and decision-making workflow

Much of LUP's core workload is externally generated and consists of proposals for land use/tenure changes and applications for licences and permits on Crown land, as well as private land subdivisions and other land use planning proposals. These are routinely received from State agencies and LGA. LUP also has a key role in providing high-level advice to State Government and has an active involvement in State priority projects, such as Plan for Our Parks and Native Title Settlement Agreements. LUP examines and assesses the implications for access to mineral and energy resources. It makes recommendations and provides advice where necessary and appropriate.

Mining Act compliance advice

LUP also provides geoscientific and administrative advice to assist decision making under the Mining Act, when consideration needs to be given to mineral resources, mineral prospectivity and reported mineral exploration activities. Mining Act assessments are referred to LUP from both the Resource and Environmental Compliance Division and Resource Tenure Division.

Compliance referrals to LUP are valuable when decisions must be made on applications for expenditure exemptions, extension of terms or retention status that are supported by information regarding work done, mineral deposits, mineral ore or identified mineral resources. Tenure referrals are also made to LUP when retention licences are sought for pre-2006 mining tenements with identified mineral resources.

Mining Lease assessments

LUP has an important role in the assessment of mining lease applications by providing information to Resource Tenure Division regarding strict compliance of applications with the Mining Act, and information to the Director of GSWA regarding submitted mineralization reports and supporting statements. LUP can also assist mining lease applicants with pre-submission advice regarding the most appropriate application route and the guidelines for mining lease applications.

Informed decision making

Competing interests in land across the State requires careful consideration and informed decision making by Government, including balancing conflicting land tenure/uses and managing potential unintended consequences. Access to mineral and energy resources can be impacted by land use/tenure changes, and LUP aims to ensure the continuity of community benefits from Western Australia's resources endowment. This is underpinned by our core functions:

- Shape land use policy and outcomes through engagement and collaboration with government agencies and LGA
- Inform decision making by providing advice and geoscientific resource mapping data to government, LGA, industry and the public
- Foster coexistence, transitional and sequential land uses, particularly around townsite planning and rural land use
- Assess proposals (including industry referrals) and provide approvals and recommendations for proposed land tenure and land use changes throughout the State.

Planned work program

The branch will continue to provide information, advice, assessment and approvals in response to routine requests from other government agencies, LGA, industry and internal requests, while being involved in the following key priority government projects:

- South West Native Title Settlement
- Wiltingin Determination Area Indigenous Land Use Agreement (ILUA)
- Tjiwarl Native Title Settlement
- Carbon farming
- Hydrogen projects
- Plan for Our Parks conservation initiative
- Land Administration Act amendments
- Divestment of the Aboriginal Land Estate.

It is anticipated there will continue to be substantial land approvals and recommendations associated with the various Native Title Settlement projects over the next few years.

Plan for Our Parks is a major conservation initiative comprising a minimum of five million hectares of new conservation reserves by 2024. Carbon farming and hydrogen projects are being driven by the State Government's commitment to the diversification and decarbonization of the State's economy, especially the transitioning to a future prosperous low-carbon economy and reaching net zero greenhouse gas emissions by 2050. LUP has and will continue to undertake significant consultation with industry and other government agencies during the assessment/refinement of these key government projects.

Product planned for release

- [Aboriginal land, conservation areas, mineral and petroleum titles and geology, Western Australia – 2023 \(map\)](#)

GEOSCIENCE AND TITLES INFORMATION

Incorporates Geoscience Publishing, Titles Information and the Western Australian Core Libraries

General manager: Paul Duncan

Geoscience Publishing

Incorporates Editing and Publishing, Mapping and Events, Graphics, Discover Geology

Manager: Robin Bower

Editing and Publishing

Manager: Robin Bower

Team members: Bec Hitchings, Bernd Striewski

The production and delivery of sought-after and important geoscience products relies on experienced, dedicated staff. These staff members include project managers, geoscience editors, cartographers, graphics officers, geologists, desktop publishers and online coordinators who all work together to release products.

The Editing and Publishing team, within the Geoscience Publishing section, is responsible for the production of geoscience products including geoscientific maps, Reports, Records, posters, flyers data packages and various promotional products for delivery as digital media, and via the internet. A quarterly newsletter, Fieldnotes, is released four times a year via the GSWA eNewsletter. This section also produces the GSWA work programs and annual reviews to record future and past work.

Once a product is submitted, the production process commences. Editors complete their editing, data checking and proofreading with author liaison, then manuscripts are professionally designed by desktop publishing for release on the DMIRS eBookshop. Data products are hosted on GeoVIEW.WA or DASC, and maps are uploaded to the eBookshop and distributed to customers. There is a robust quality control process to ensure that we provide high-quality products to our customers (Fig. 16).



Figure 16. A selection of products produced by the section

Mapping and Events

Manager: Shaun Coldicutt

Team members: John Bennett, Xavier Bezu, Irena Lesiak, Sue Mulligan

The Mapping and Events team is made up of geospatial officers who produce geoscience, resource, and petroleum and mineral titles maps, as well as presentation material for events participated in and hosted by GSWA. This section also prepares posters and flyers for events and the DMIRS website. While complex State and project maps are produced each year, the section has the capability of creating maps with a quick turnaround for discussion purposes as requested by the Division's geoscience professionals. Figure 17 exhibits some of the variety of products compiled and produced by this section.

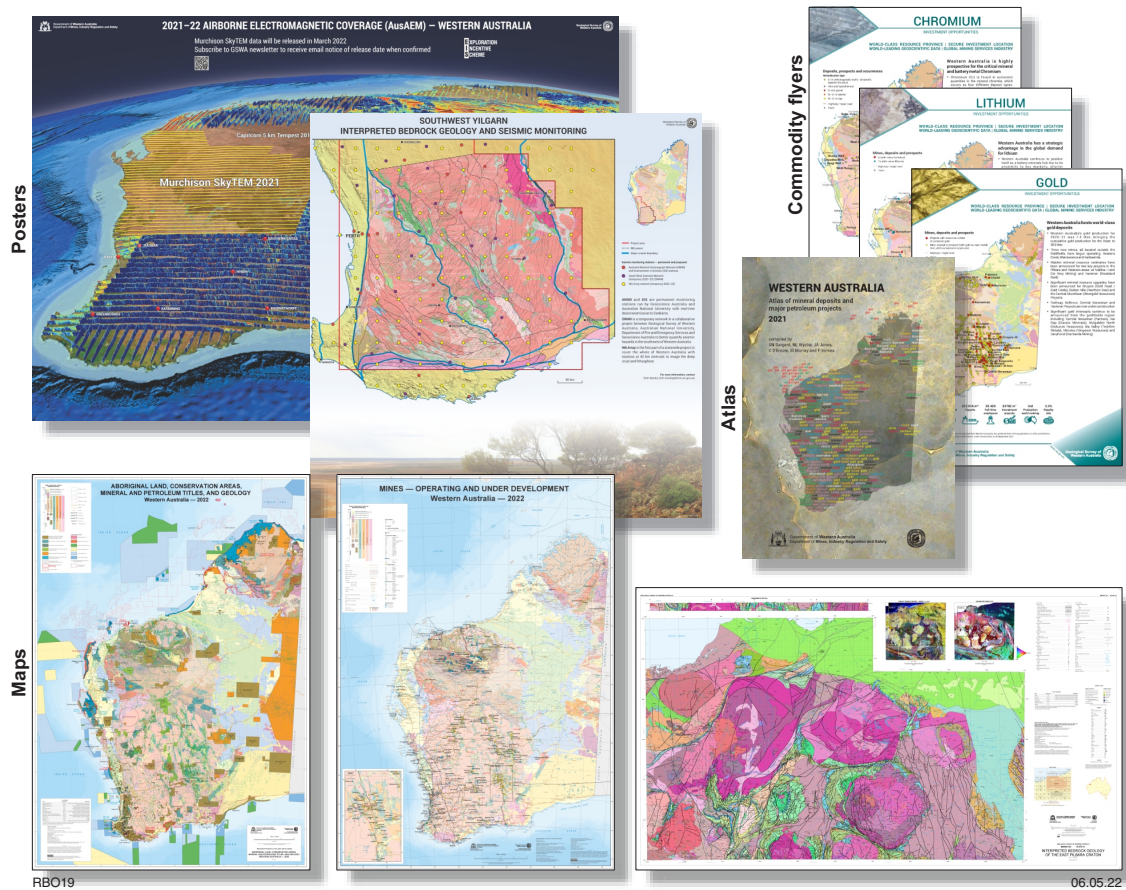


Figure 17. The variety of mapping products for eBookshop and events

Graphics

Manager: Michael Prause

Team members: Deenikka Loprese, Adam Symonds

The Graphics section provides support to numerous sections within GSWA, with the variety of the work produced by these sections innately driving the type of 'graphical' support provided.

The principal role of the section is to help authors prepare figures for publication and/or display. This can vary from simply applying in-house formatting rules to diagrams, cleaning up and annotating photographs, and assisting in the assembly of posters for display, to cooperatively helping authors with complex projects from an early creation stage. This happens all while maintaining the uniform professional look expected from GSWA publications.

An example of how the Graphics team assists in a complex project can be seen by Adam Symond's work with the Energy and Basins section to create the Digital Core Atlas series from scratch. He assisted with the implementation of a flipbook solution for viewing core tray data, and subsequently manipulated this data into an appropriate graphical format.

Manipulating raw data into an easy-to-read graphic is a process the section does well. Helping authors visualize concepts in 3D and transfer this knowledge to a reading audience via a simple 2D graphic is another way the section helps the business of other GSWA sections.

Often, authors try to portray too much data in a figure, creating an ambiguous story. Graphics is capable of manipulating this data into other formats to remove ambiguity. An example of this is converting a scatter plot into a density pie plot (Fig. 18) where symbol size is used to indicate the number of points in a region, and the pie sector indicates the distribution of data among the categories being graphed. The count value for the largest symbol is also displayed, providing an indication of the quantity of data being graphed.

Note how the scatter plot on the left gives a 'false' impression that the dark green dots dominate the chart, yet the density plot on the right tells a different story. This occurs because many points are being hidden behind the green data points.

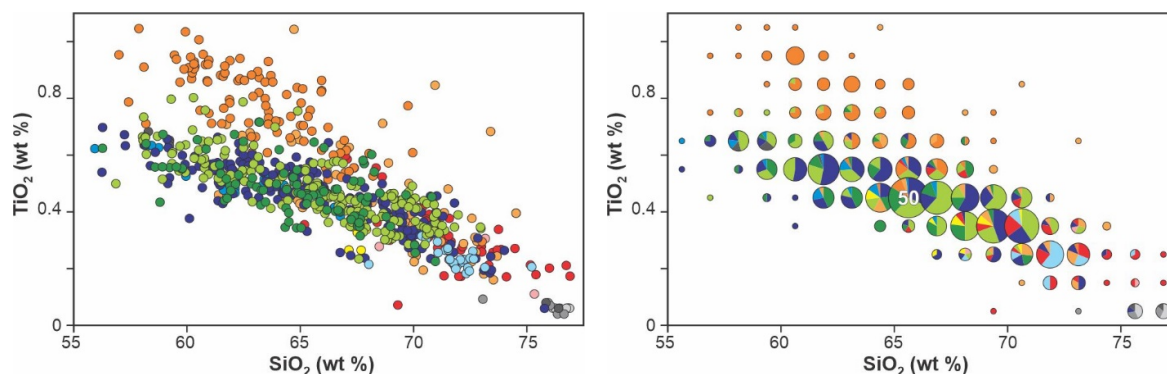


Figure 18. The comparison of a scatter plot (left) to a density pie plot (right)

Discover Geology

Manager: Stephen White

Team members: Ryan Aston, Sarah Goss

Through 2022–23, the Discover Geology team will continue its program of compiling geoscience products for non-specialist audiences. The team's main aims are to:

- repurpose published GSWA products in diverse, innovative, interactive formats
- increase awareness among the geotourism sector, and the wider public, that GSWA is the authoritative source of geoscience information in Western Australia
- support geotourism initiatives within DMIRS and in collaboration with outside organizations.

Planned work program

Following the successful release in 2021–22 of two StoryMaps, the ArcGIS Online platform has demonstrated it is an engaging and effective means of releasing products to a wider audience. StoryMaps will continue to be the main medium for delivering Discover Geology products (Fig. 19).

Activity in 2022–23 will further develop capability with ArcGIS Online by increased use of multimedia and spatial content. This includes specialist photography and video to complement material available from previous GSWA products. Acquiring this content will entail at least one field trip to northern Western Australia, and a possible field trip to the southwest.

One goal of the program in the coming year is to improve the efficiency of StoryMap preparation and compilation, so that a collection of products available for customers and stakeholders is published online in a timely way.

Products planned for release

- A great barrier reef in the Age of Fishes, west Kimberley
- The Boogardie Orbicular Granite
- Diamonds in Western Australia
- Critical mineral resources in Western Australia
- Limestone caves of southwest Western Australia
- Pearls in Western Australia
- John Forrest National Park geotrail (Everywhere app)



Figure 19. The growing catalogue of products

Titles Information

Incorporates Title Certification, Title Support, Title Services (Native Title)

Manager: Craig Wainwright

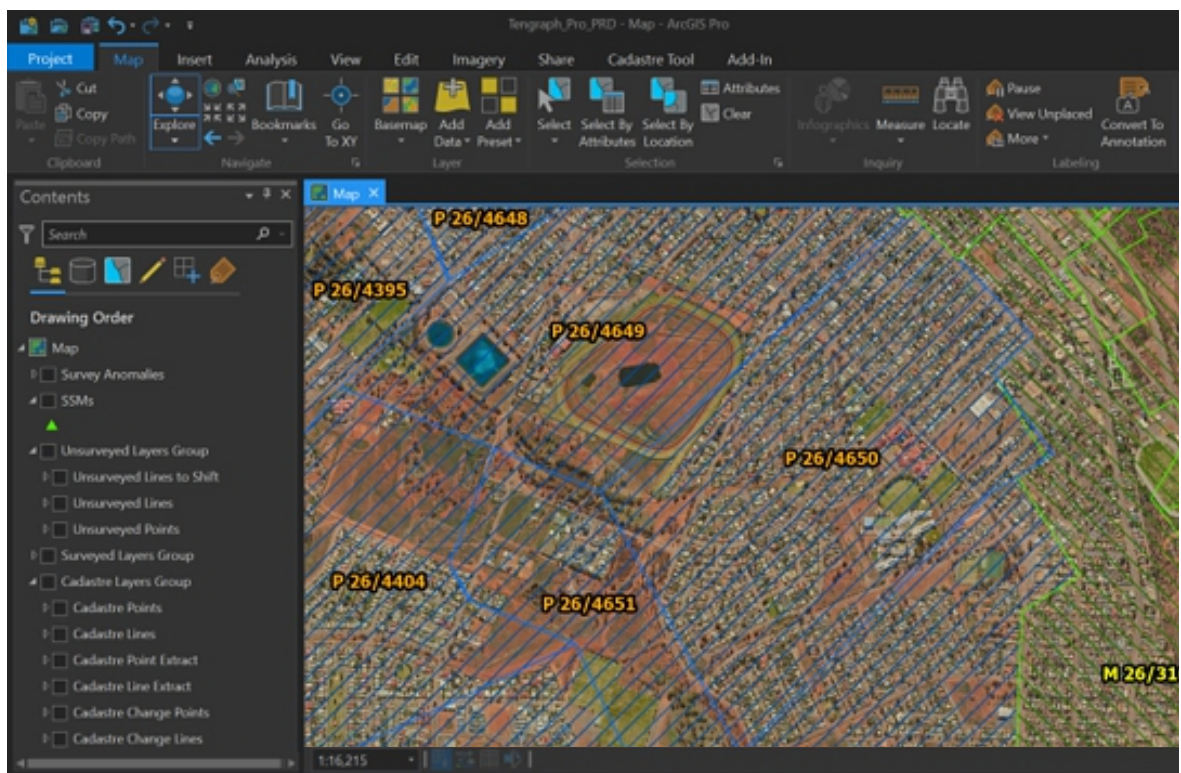
The Titles Information section is a highly experienced group of spatial science officers committed to their vital role of supporting the grant of title process and maintenance of all relevant spatial data layers in DMIRS TENGGRAPH Web. They ensure that all lease and licence holders' tenements are reliably maintained as they pass through the various dealings and compliance processes during their life cycle. Staff manage a vast array of spatial layers all required to accurately appraise and assess grant conditions on tenements.

Historical and live tenement data

This section also delivers historical and live tenement data to the State Solicitor's Office (SSO) as part of the process of determining Native Title claims across Western Australia through the Federal Court of Australia and now emerging Compensation Claims.

The Survey Backlog has now been reduced to normal operational levels which is a significant achievement.

The New TENGGRAPH Pro System (Fig. 20) was implemented in February 2021. Identified enhancements to this system continued throughout 2021–22 and will continue throughout 2022–23.



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Figure 20. The upgraded TENGGRAPH Pro system

Title Certification

Manager: Andrew Pollard

Team members: Matt Aravidis, Dennis Bettesworth, Neil Dinnison, Greg Dutkiewicz, June Graham, Dean Hubbard, Rasa Kam, Lucio Pallotta, Dale Rayner, John Stevens, Graham Wyles

The Title Certification section performs a vital statutory role in relation to surveying and certification of Mining Leases required under Section 80 of the *Mining Act 1978*, which requires issuing of survey instructions for survey of all leases at time of grant of the lease. The section engages with leaseholders and approved surveyors to manage the survey process. Survey Projects are managed within eMiTS, Survey Projects Screen. Survey instructions are issued to a holder's nominated approved surveyor who performs the survey of lease/s within a project.

Online lodgement

Online lodgement of surveyors' field notes, digital CSD File and Surveyors Form 44 Report was implemented on 1 July 2021. Lodged surveys are integrated into Landgate via SMARTPLAN and into DMIRS TENGRAPH Web via ArcGIS Pro. The section is responsible for the production of legal Certified Survey Documents in ArcGIS Pro. It plays a statutory support role for the certification and spatial validation of all unsurveyed applications and the various boundary changes that occur due to dealings on tenements as they pass through their life cycle from initial lodgement, Grant and through the variety of compliance processes that impact the spatial extent of tenements. This section also monitors the impacts that Landgate cadastre updates have on DMIRS surveyed and unsurveyed mining tenure, and spatially adjusts tenement boundaries as required (Fig. 21).

Planned work program

- Ongoing management of the survey process in conjunction with DMIRS approved list of surveyors
- Management of Survey Projects in eMiTS
- Surveying of Mining and General Purpose Leases under Section 80 of the *Mining Act 1978* – survey backlog reduction
- Integration of new surveys in Landgate's SMARTPLAN and DMIRS TENGRAPH Web, and the production of legal survey documents
- Certification and plotting of unsurveyed tenement applications – graticular and non- graticular
- Spatial update of surveyed and unsurveyed tenements impacted by Landgate's cadastre update
- Scanning of survey documents.

Special project

- GDA2020 implementation – proposed August/September 2022.

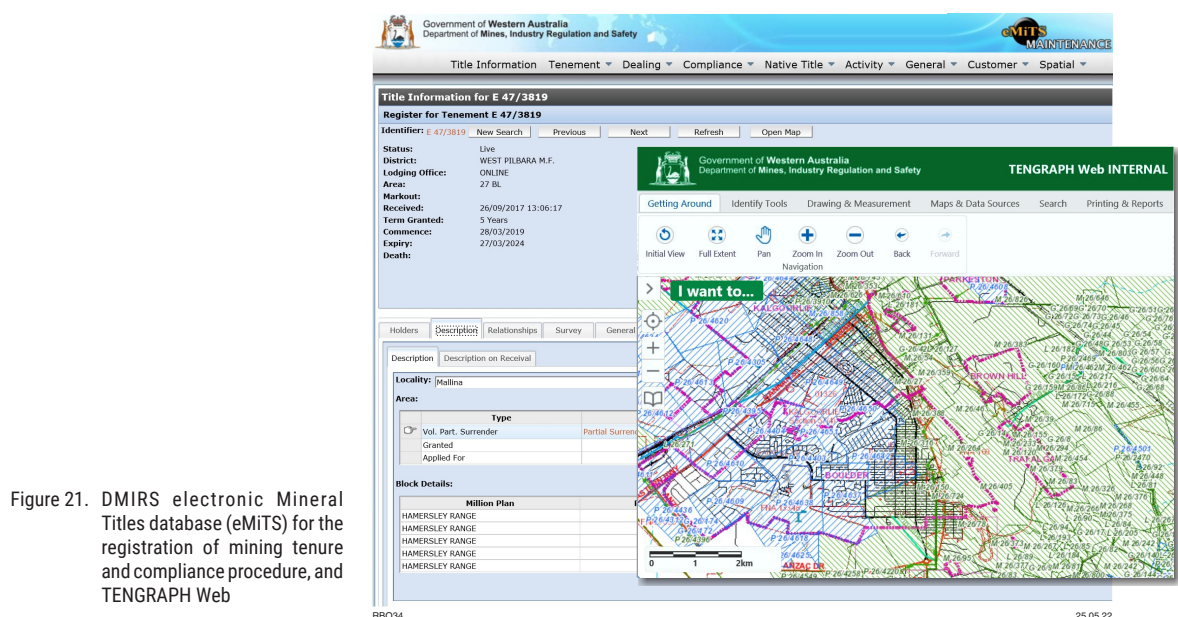


Figure 21. DMIRS electronic Mineral Titles database (eMiTS) for the registration of mining tenure and compliance procedure, and TENGRAPH Web

Title Support

Manager: Sean Doherty

Team members: Tanya Quaglia, Sue Shadbolt, Phil Sinagra

The Title Support section supports the process of granting mining titles. The section is responsible for maintaining all other layers in TENGGRAPH Web other than tenements and Native Title claim layers. It is also responsible for ensuring all DMIRS administrative layers including File Notation Areas (Section 16[3]) layers and Section 19s are maintained, Landgate cadastre is updated on a quarterly basis, and all other special category land layers are sourced from respective agencies to retain currency. This is to ensure accurate appraisal of tenements and the setting of grant conditions (Fig. 22).

The section supports:

- LUP branch by mapping File Notation Areas (Section 16[3]) clearances under the *Mining Act 1978* to alert stakeholders to Crown Land use proposals
- Resource and Environmental Regulation group by mapping land that is exempt from mining activities as defined under Section 19 of the Mining Act. Landgate administrative and cadastre layers and other special category land layers are sourced from the respective agencies, for example heritage, conservation and water.

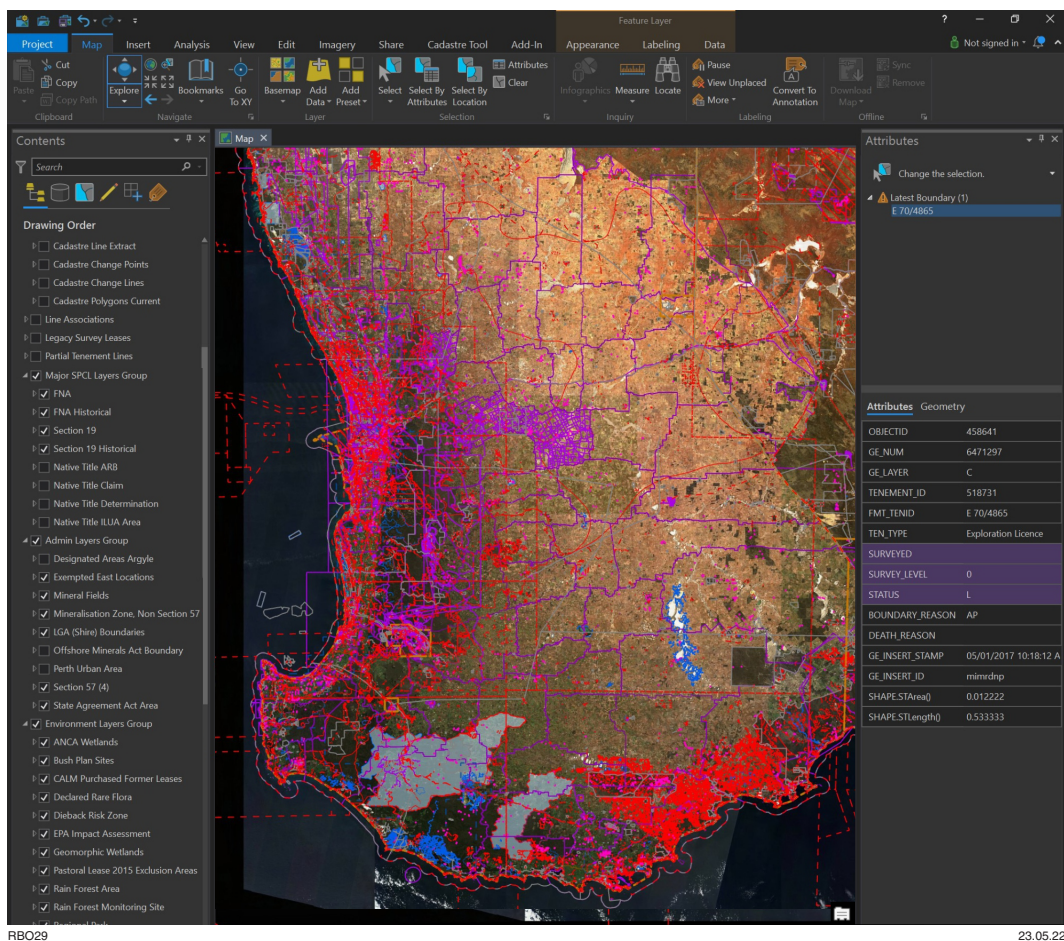


Figure 22. File Notation Areas, Section 19 boundaries and Special Category Land Layers grouped within TENGGRAPH Pro

Planned work program

- Ongoing management of DMIRS Administrative Layers, Cadastral Layers, Standard Survey Marks, Environmental and all Special Category Land layers within TENGGRAPH Web, File Notation Areas, Section 16(3), Section 19
- Support the appraisal and grant process by providing current Land and Administrative Layers facilitating accurate appraisal and grant conditions on Mining Leases and Exploration/ Prospecting Licences
- Further streamlining of Special Category Land Layers updates via FME Workbenches.

Title Services (Native Title)

Manager: Amanda Roscoe

Team members: Ireen Akter, Suzanne Giblett, Jason Knott, Vishnu Nallan, Sowjanya Pynoori

The Title Services section is primarily responsible for providing services stipulated under an agreed Memorandum of Understanding (MoU) established with the Department of The Premier and Cabinet (DPC) and the SSO. This MoU relates to the provision of historical and current mining tenement title and spatial details that contribute towards the Federal Court's determination of Native Title claims lodged over the State of Western Australia. This takes the form of GIS packages of historical and current mining title data delivered to the SSO via Landgate (Fig. 23).

Figure 23. Old Miner's Right documentation

The section produces GIS analysis and 'Right to Negotiate' and Resource Access Native Title maps for the Resource Tenure Division. The team has become involved in research and data collation for the first phase of the Tjiwarl Native Title claim Compensation Area. Several map packages have been delivered for this compensation claim. Other Native Title compensation claims have been lodged so this will be an increasing form of work undertaken by the team in 2022–23. This section is responsible for maintaining Native Title related layers within TENGGRAPH Web.

Native Title Project

The Native Title Project is a long-standing project with a 21-year life span to date which, due to the nature of Native Title, is diversifying and unfolding into other areas of work. The DPC, SSO and DMIRS are in negotiation to establish permanency to this team by providing current contractors employed under the MoU via funding by DPC, an alternative appropriated direct funding model, to ensure security for the professional staff that have served this project so well over many years.

Planned work program

- Provide support to the National Native Title Tribunal and Federal Court for determinations of Native Title claims under an MoU with the DPC and SSO
- Provide historical and current Mining Title data to support Native Title litigation, negotiation and compensation matters relating to Native Title claims
- Produce GIS datasets and GIS mapping and analysis products to assist all matters relating to Native Title
- Manage Native Title layers in TENGGRAPH Web.

Western Australian Core Libraries

DMIRS core libraries at Carlisle (Perth) and Kalgoorlie house important collections of samples of representative geology and mineral endowment of Western Australia. These collections have been sourced over many decades from government stratigraphic drilling, mineral industry donations, the EIS Co-funded Exploration Drilling Program, petroleum industry onshore and offshore drilling, geothermal drilling, water bores and geotechnical drilling. This constitutes a significant source of pre-competitive geoscience information that exhibits the mineral and energy prospectivity of the State and encourages innovative resources exploration.

The core libraries at Carlisle and Kalgoorlie also house the extensive core generated since 2009 from the EIS Co-funded Exploration Drilling Program. After a short six-month confidentiality period, this core is a great boost to explorers and academia, providing new core from greenfield areas and allowing testing of new ideas and concepts.

Perth Core Library

Manager: Paul Stephenson

Team members: Bill Anderson, Matthew Chappell, Fiona Dodd, Peter Drobek, Simon Fanning, Dane France, Mark Harrison, Andy Leighton, Kris Neill, Shane Preedy, Diran Rinal

The Perth Core Library is the western hub of the National Offshore Petroleum Data and Core Repository (NOPDCR). It will store two-thirds of all Commonwealth-managed petroleum core derived from offshore drilling from around Australia. This is managed under two agreements between DMIRS, GA and the National Offshore Petroleum Titles Administrator (NOPTA), providing a significant step towards a seamless service to the petroleum exploration industry.

The Perth Core Library is used by DMIRS, industry and academia as a geoscience training facility, and also houses the HyLogger spectral scanner, one of the six nodes of the National Virtual Core Library (NVCL) that collects extensive, objective, pre-competitive mineralogical data from archived drillcore.

Usage of the Perth Core Library remains at very high levels (Fig. 24).

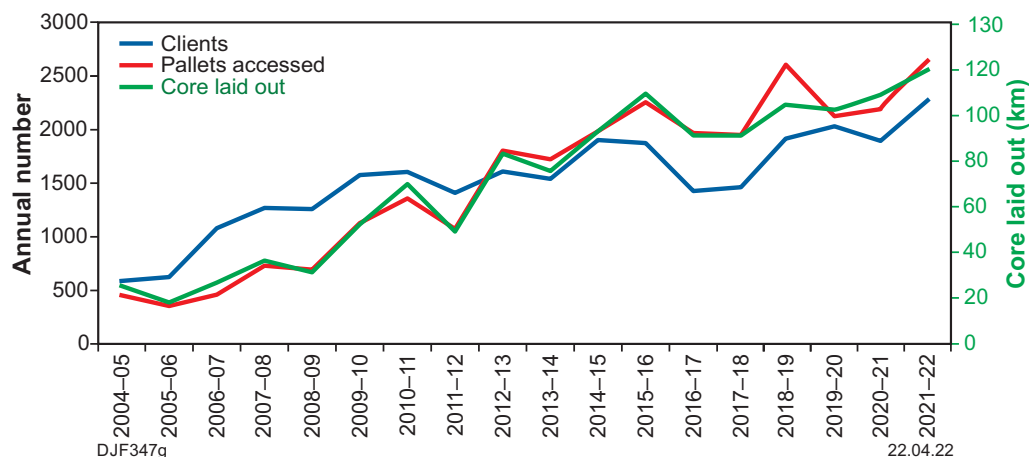


Figure 24. Use of Perth Core Library services

Planned work program and outcomes

Staff will continue to maintain the same level of service to stakeholders. Developments include:

- Potentially receiving donations from Exxon Mobil of core and cuttings from Victoria and Tasmania (~250–300 pallets); discussions between Exxon Mobil and GSWA are in progress
- A new forklift, and Almonte cutting saw has been acquired
- Provision of XRF and XRD service
- Premier Coal donation
- New outside racking bench installed for EIS core.

Joe Lord Core Library

Manager: Debbie Caple

Team members: Steven Black, Jason Dunstone, Scott Ruhle

Expansion works funded by the State Government as part of its COVID-19 Goldfields–Esperance Recovery Plan have been completed at the Joe Lord Core Library in Kalgoorlie. Some outstanding defect and contingency work remain to be completed.

The 6750-bay expansion was officially opened on 24 November 2021 by the Hon Bill Johnston, Minister for Mines and Petroleum with Welcome to Country undertaken by local Wongutha man, Gary Cooper.

This world-class library stores core samples containing valuable geoscientific information for exploration companies and others searching for new resource discoveries (Fig. 25).

The Joe Lord Core Library at Kalgoorlie is used by DMIRS, industry and academia as a geoscience training facility. Researchers and explorers can inspect the samples and review results to reduce the technical and financial risk of exploration activities. The expansion has provided better access, more space and improved facilities to view and analyse the drillcores, which has already seen an increase in usage levels.

Planned work program and outcomes

In 2022–23, staff will continue to maintain the same high level of service to stakeholders.

Developments include:

- Completion of a 6750-bay expansion with proactive engagement to improve current usage levels, which have seen an increase in otherwise normally quiet times
- Re-bituminize outside areas and carpark
- Installation of additional shade sails to the expanded outdoor viewing area
- Securing funding for new forklift
- A review about the relocation of slides from the Core Store in Kalgoorlie to the core library to enable customers the opportunity of having the slides available when viewing core
- Continuing to maintain a high level of service to the mining industry as well as to the academic sector.



Figure 25. Pallets stacked at the Joe Lord Core Library, Kalgoorlie

GEOSCIENCE DATA MANAGEMENT

General manager: Deavi Purnomo

Geoscience Data Services

Manager: Daniel Then

Team members: Michael Dawson, Gary Hartley, Joe Hogen-Esch, John Kirk, Sreedhar Nallan, Brad Tapping

Geoscience Data Delivery

Manager: Leo Liu

Team members: Annick Francois, Wendy Hampton

Geoscience Data Governance

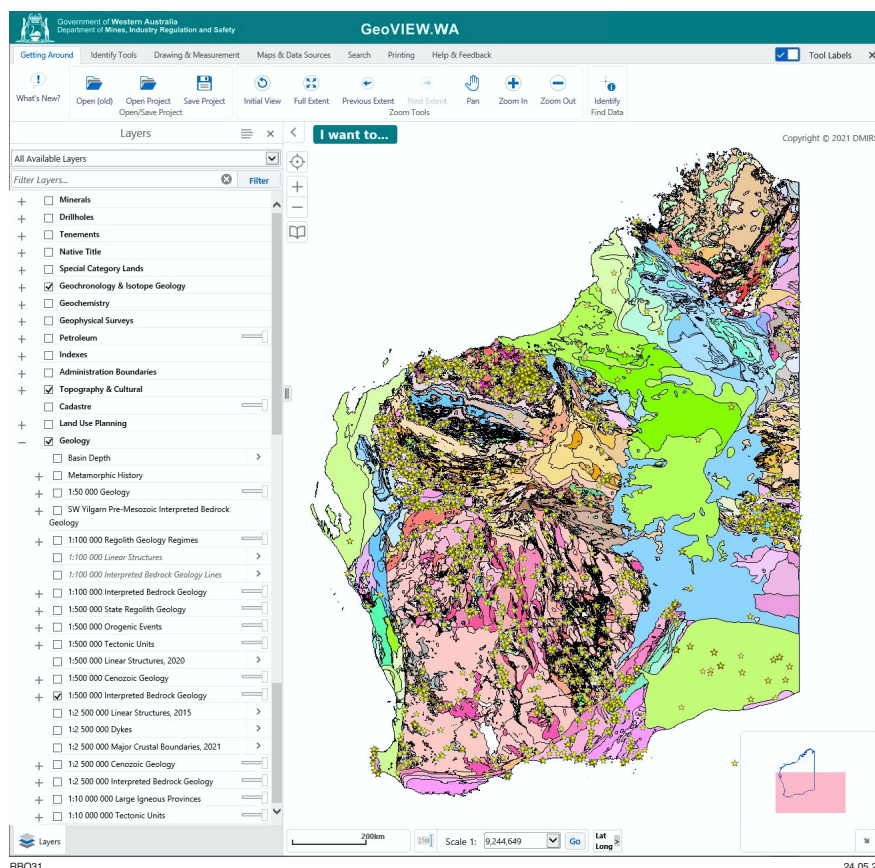
Manager: Chee Ng

Team members: Carly Chor, Terry Farrell, Yanrong Li

Staff members in these teams include data management, geospatial and web mapping professionals (Fig. 26). These program areas reside in the Geoscience Data Management branch, which is responsible for:

- Data architecture, design, creation, management, delivery and production of GSWA's geoscience data and databases
- Provision of geoscience data and spatial system development, management and delivery for the division
- Acquisition and integrity of both mineral and petroleum titles information in DMIRS Spatial Data Infrastructure environment
- Development and maintenance of quality assurance processes that align with national and international standards
- Development of data models and standards required for spatial geoscience data management in cooperation with internal and external geoscience bodies
- Development and management of web-based applications as a data publications platform
- Maintenance and development of all GSWA's application, system, software and infrastructure delivery
- Implementation and delivery of Geoscience Data Transformation Strategy.

Figure 26. The branch is responsible for maintenance and development of all GSWA's applications



PART TWO

Exploration Incentive Scheme
– detailed work programs



DRILLING AND EXPLORATION PROMOTION

Government–Industry Co-funded Exploration Drilling

Manager: Charlotte Hall

Team members: Monique Brouxhon, Louisa Dent

This program supports innovative drilling by companies in underexplored areas. It is designed to stimulate geoscience-based, targeted exploration, and contribute to the economic development of underexplored areas in Western Australia, where additional drilling and exploration activities will lead to new geoscience information and discoveries.

Encouraging exploration

The program is preferentially funding high-quality, technical and soundly based projects that promote new exploration concepts and technologies. Proposals from applicants are assessed by an independent panel based on geoscientific and exploration targeting merit and data generated.

An advisory committee, chaired by the Deputy Director General of the Resource and Environmental Regulation Group in DMIRS, and consisting of representatives from the main industry representative groups and research sector, endorses the selection process of the co-funding projects, provides advice to the department on program guidelines, and feedback from industry. The committee, which meets twice yearly, also ensures that the program is relevant to the exploration industry.

Co-funded Exploration Drilling Program

The Co-funded Exploration Drilling Program undergoes a transactional and probity audit on the co-funding twice a year by an external auditor. The probity audit ensures the selection process is transparent, impartial and defensible for any round. The transactional audit reviews the process and control in the administration of the refund payments for previous rounds made in the previous six months. The external auditor prepares a final report on the transactional and probity results every six months, which is then presented to the DMIRS Internal Audit branch for further oversight.

The program refunds up to 50% of direct drilling costs with capped values for different categories of applicant. A review of the capped values in late 2021, and in consultation from the resources industry resulted in a change of the capped values for the first time since the co-funding started. In addition, two deep holes were included in the maximum capped field of \$220 000 (new value). This was in recognition that successful applicants were trending away from the single deep hole in preference to two diamond holes of 500–700 m, but were capped at \$150 000 while incurring costs higher than a single hole (\$200 000).

The old and new capped values are shown in Table 2.

Table 2. Old and new capped values for exploration drilling Rounds

	<i>Capped value – Round 1 to 24</i>	<i>New capped value – Round 25 onwards</i>
Prospector	\$30 000	\$40 000
Multi-hole	\$180 000	\$200 000
Single deep hole	\$200 000	\$220 000
Two deep holes		\$220 000

Figure 27 shows the number of offers made in a financial year and the number of projects completed. Successful applicants are required to complete the proposed drilling project within 12 months. Final drilling reports with assay results and diamond core, where cored drilling is undertaken, are submitted to DMIRS. Final reports and core are released to open file after a six-month confidentiality period.

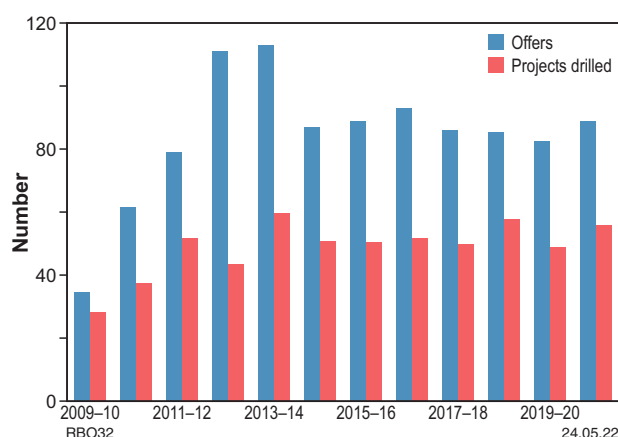


Figure 27. EIS Co-funded Drilling Program statistics. Number of projects offered funding vs project actually drilled, by financial year

Planned work program

During 2022–23, drilling from three rounds will be undertaken by exploration companies. These are Rounds 24, 25 and 26.

Other work will include:

- Final closure of Round 23 including receipt of all final reports to WAMEX, issue of final payments and receipt of diamond core if drilled. Applicants have three months after the drilling period ends to complete analytical and scientific data acquisition to allow inclusion in the final report
- Completion of Rounds 24 and 25 drilling periods, including receipt of interim and final reporting requirements
- Release of co-funded drilling reports, not confidential, to DMIRS online WAMEX open-file database
- Call for submissions for applications for Round 26 (August 2022) and Round 27 (February 2023)
- Audits by an external auditor on the probity of the selection process for Rounds 26 and 27 and transactions for the last 12 months
- Summary of 2021–22 co-funded drilling for inclusion in the GSWA annual review 2020–21.

Government–Industry Co-funded Energy Analysis

Manager: Charlotte Hall

Team member: Louisa Dent

The co-funding initiative, the Energy Analysis Program (EAP), has been designed to encourage exploration of petroleum and geothermal resources in Western Australia.

The program will make funding available for analysis of existing State resources (core, sidewall core, cuttings, and oil, condensate, water, and gas samples) and to allow re-analysis or reprocessing of existing digital data. By studying existing material, it will avoid the requirement of ground access and allow for completion of a project within 12 months. Analysis of material and data will be limited to that acquired within regions that are under Western Australian legislation, excluding Commonwealth regions (offshore) which are likely to require additional approvals.

COVID-19 recovery plan

The program was developed in the second half of 2020, in response to the State Government COVID-19 recovery plan. It was modelled on the successful co-funded Exploration Drilling Program. A total pool of \$250 000 has been apportioned from the annual EIS funding. Individual project refunds will be up to 50% of the analysis costs to a maximum of \$50 000 (ex GST). The funds will not be for company staff to do the research, but for a third-party expert business that will invoice the successful applicant for the work undertaken. This is similar to the drilling refund, where the third party is the drilling company. In both co-funding programs, the third-party invoices provide auditable documentation that the work has been completed.

Find more details, documents, guidelines and schedules for the [EAP](#).

The number of applications and grants offered is shown in Table 3.

Table 3. Number of applications and grants offered per series of the EAP

Series number	Number of applicants	Grants offered
Series 1	12	8
Series 2	8	6
Series 3	1	1

Planned work program

During 2022–23, Series 4 and 5 will open for application on 1 August 2022 and 6 February 2023, respectively. Successful applicants of Series 2 and Series 3 will be required to submit their completed project reports by 31 October 2022 and 30 April 2023, respectively.

Products planned for release

- Release of final reports and results from Series 1, 1 September 2022
- Release of final reports and results from Series 2, 1 March 2023

REGIONAL GEOSCIENCE MAPPING

Airborne and Ground Geophysical Surveys

Manager: David Howard

Team member: John Brett

The Airborne and Ground Geophysical Surveys component of the EIS encompasses the acquisition and processing of aeromagnetic, radiometric, gravity and airborne electromagnetic (AEM) data on a regional scale for statewide coverage at increasing levels of resolution. Currently, all these regional surveys are undertaken in collaboration with GA under National Collaboration Framework (NCF) agreements.

Western Australia currently boasts complete coverage of the State with medium-resolution aeromagnetic and radiometric surveys (with 200–400 m line-spacing), and 5–8 km wavelength resolution ground and airborne gravity surveys (with 2500 m station or line-spacing). The current focus is on completion of broad-reconnaissance airborne electromagnetic coverage at a line spacing of 20 km – the AusAEM-WA program.

Planned work program

In 2022–23, we will see completion of AusAEM 20 km data coverage in Western Australia. Data from the SkyTEM surveys over the Southwest and Murchison blocks released in 2021–22 complemented the already completed coverage of the eastern blocks surveyed with the TEMPEST system in 2020–21 to take coverage to 90% (Fig. 28). Surveys of the remaining areas in the east and northeast of the State, fully funded by the EIS, will be carried out as part of GA's latest tranche of AusAEM work under its Exploring for the Future program.

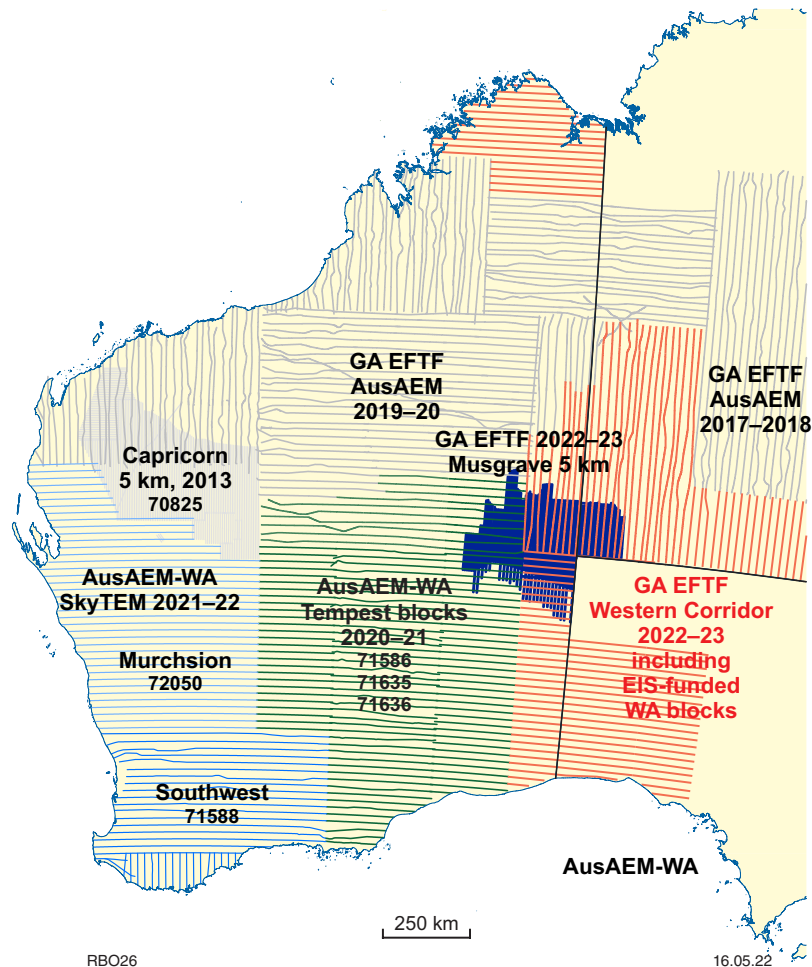


Figure 28. Location of AusAEM survey areas in Western Australia. Numbers refer to dataset registration numbers in MAGIX data repository

Passive Seismic and Magnetotelluric Surveys

Manager: Ruth Murdie

Team members: Cristina Angheluta, Richard Chopping, Klaus Gessner

The aim of the Deep Earth Imaging program is to obtain a variety of geophysical data that underpins the understanding of the geological evolution of the lithosphere in Western Australia over some four billion years of Earth's history. The program's objective is to acquire, process, analyse and publish data that allow GSWA to integrate geophysical and geological information across the West Australian, North Australian and South Australian Cratons and the intervening Neoproterozoic and Phanerozoic basins. These data also contribute to understanding the localization of mineral systems within the upper crust. In addition to collaborating with GA on the active-source seismic acquisition, GSWA engages with Macquarie University, Australian National University (ANU), UWA and the Institute of Geology and Geophysics, Chinese Academy of Sciences (IGG-CAS) in the acquisition of passive source seismology and magnetotelluric surveys. GSWA activities that derive from the data acquired and processed in this section are also described in the 3D Geoscience and 3D Lithosphere Visualization Project sections.

Planned work program

Australian Research Council (ARC) project LP180101118 Enhanced 3D seismic structure for southwest Australia with ANU, GA and the Department of Fire and Emergency Services (DFES) is currently in the data collection phase which will run until October 2022.

The passive seismic project in the Pilbara in collaboration with Macquarie University, UWA and IGG-CAS has rolled southwards and will run until March 2023. It was ideally placed to capture the M4.8 event of 13 November 2021.

Satellite communications will be added to the Canning Basin baseline monitoring network stations (Fig. 29) to enable these stations to send real-time data. More stations will be added to the Kalgoorlie network. Data is already streaming to GA from eight stations from these two networks.



Figure 29. Installing a seismic monitoring station from the Kimberley Baseline Earthquake Monitoring project

2D and 3D Active Seismic Surveys

Manager: David Howard

Team members: ad hoc as required

Deep crustal, active seismic surveys were previously included as part of the program of deep earth imaging together with passive seismic and magnetotelluric surveys. In 2021–22, with completion of the AusAEM program in reach, GSWA decided to increase funding to both active as well as passive seismic acquisition. Active seismic acquisition was separated administratively, under its own cost centre, from the expanded passive seismic (WA-Array) and magnetotelluric (AusLAMP-WA) programs designed to investigate the deeper lithospheric architecture, and which have remained as the Passive Seismic and Magnetotelluric Surveys work programs.

Currently, Western Australia has an aggregate coverage of 7326 line-km of active seismic transects as shown in Figure 30, which also illustrates the impact of EIS funding on the rate of acquisition. In the 17 years between 1988 and 2005, a total of 2483 km of lines was acquired, mostly funded by GA (and its antecedents). With the contribution of EIS funding, in the nine years between 2010 and 2019, GSWA and GA acquired a total of 4843 km of data — twice the number of kilometres in half the time.

GSWA is now looking to expand the number of transects in key lithostructural areas to improve our understanding of the major crustal structures in the State.

Planned work program

In 2022–23, GSWA will request tenders for new data acquisition in the South West Terrane and in the area of the North Perth Basin, in the State's Midwest region. The total number of lines and kilometres of data will depend on tendered prices and available budget, but it is anticipated that an aggregate of up to 700 km should be possible, with acquisition planned for 2024. Candidate lines are shown in Figure 30.

Products planned for release

- Depending on timing and rate of progress, raw and processed seismic data from the surveys will be released.

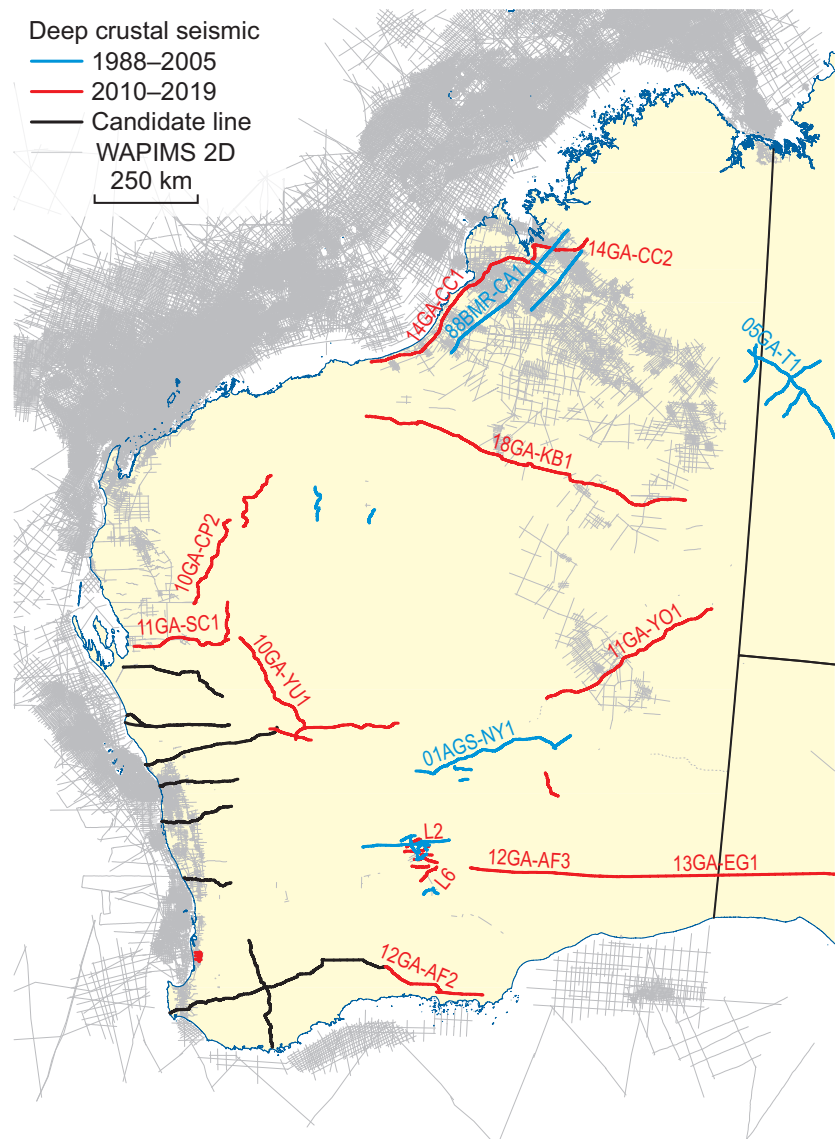


Figure 30. Location of deep crustal and other seismic lines

RBO30

24.05.22

ENCOURAGING EXPLORATION THROUGH COVER

Regolith and 3D Paleosurface Mapping

Manager: Richard Chopping

Team members: Nadir de Souza Kovacs, Sara Jakica, Jennifer Porter (MinEx CRC Embedded Researcher)

This program funds collaborative research with leading research institutions that complement GSWA's capabilities in regolith, surface and landscape mapping, including data acquisition, analysis and modelling under the Geoscience Mapping Through Cover and Participation in MinEx CRC projects. In addition to collaborating within the MinEx CRC, GSWA engages with other research institutions such as CSIRO.

The detailed work program is presented under Geoscience Mapping Through Cover and Participation in MinEx CRC. The Regolith and 3D Paleosurface Mapping project is not planned to specifically fund any collaborative research programs in 2022–23, having concluded its investment in the CSIRO UltraFine+ project (Fig. 31).



Figure 31. Reanalysing soil samples from Kiwirrkurra for increased precision in the CSIRO UltraFine+ project

MinEx CRC Program 3

Manager: Richard Chopping

Team members: Nadir de Souza Kovacs, Sara Jakica, David Kelsey, Fawna Korhonen, Chris Phillips, Jennifer Porter (MinEx CRC Embedded Researcher)

This program commenced in 2018–19 and is linked to Geoscience Mapping Through Cover. The MinEx CRC was granted by the Commonwealth Government in March 2018 and brings together industry, government and research organizations. It represents a 10-year investment in the next generation of mineral system discovery research. The CRC, which commenced in January 2019, comprises three programs:

- Drilling Technologies
- Data from Drilling
- The NDI.

GSWA is a participant in Program 3, the NDI and Project 6, automated 3D modelling.

Research in the three programs in MinEx CRC includes:

- Developing more productive, safer and environmentally friendly drilling methods to discover and drill out deposits, including coiled tubing drilling technology
- Developing new technologies for collecting data while drilling and bringing forward mine production
- Implementing the NDI — a world-first collaboration of geological surveys, researchers and industry that will undertake drilling in underexplored areas of potential mineral wealth in Australia (Fig. 32).

Find more information on the [MinEx CRC website](#).



Figure 32. The MinEx CRC coiled-tube drill rig exploring for the National Drilling Initiative (photo courtesy MinEx CRC)

MinEx CRC Program 3

The NDI is designed to maximize the benefits of collaborative work across the geoscience research community, CSIRO, GA and geological survey organizations across Australia. The NDI vision is to drill multiple holes using new technologies developed by the MinEx CRC to map the regional geology and architecture of greenfields regions, and define the potential for mineral systems in 3D. The NDI will generate a large amount of new data and add value to existing data.

To support the work of the NDI, phase 2 projects for the MinEx CRC relating to this are:

- Project 7.1 – understanding a mineral system from inside out
- Project 7.2 – mapping and characterizing regolith interfaces
- Project 7.3 – propagating geology and properties from drillholes across scales
- Project 7.4 – NDI data delivery
- Project 7.5 – NDI support.

These projects aim to be mutually supportive, with a focus on understanding how to map geology from information provided by drilling data. GSWA staff are involved as in-kind contributions to these research efforts, with Richard Chopping also leading Project 7.3.

Project 6

Project 6 of the MinEx CRC is developing tools to support the automatic creation of 3D models. This project sits within data from the drilling program of the CRC. It aims to develop algorithms and software that enable the integration of drillhole and other data to create first-pass 3D models that are reproducible, provide uncertainty estimates, and draw upon a broad range of datasets. Project 6 is also related to the international **Loop consortium**.

The NDI in Western Australia

Although resource rich, Western Australia contains much of Australia's most remote and underexplored regions, particularly those that lie under regolith and basin cover. Increasingly, geological surveys will be expected to undertake mapping in covered terranes using drilling technologies. The NDI in Western Australia will focus on how to undertake such mapping programs efficiently and effectively. Focus will be on the region that underlies the Canning Basin, including the Officer and Amadeus Basins, and basement rocks of the Paterson and West Arunta Orogens, the far eastern edge of the Yilgarn Craton (Yamarna Terrane), and the Warri-Anketell Gravity Ridge, which appears to form a link between the Paterson Orogen and Musgrave Province. This area is informally defined as 'The Gap'. This work will align with other project work including Geoscience Mapping Through Cover, Proterozoic Margins, Energy Geoscience and Carbon Strategy, and external collaborative projects through MRIWA.

Planned work program

Multiple drilling campaigns will be conducted under the NDI in Western Australia, with an aim to complete drilling between 2022 and 2024, pending field access and availability of the coiled-tube drill rig. The specific location of these campaigns will be released once field access is confirmed, but will focus on key margins within 'The Gap'.

Proterozoic Margins

Manager: Fawna Korhonen

Team members: David Kelsey, Chris Phillips, Jennifer Porter (MinEx CRC Embedded Researcher)

This program funds collaborative research with leading research institutions that complement GSWA's mapping and analytical capabilities under the Proterozoic Margins project. In addition to collaborating within the MinEx CRC, GSWA engages with other institutions including Curtin University and The Centre for Exploration Targeting (CET) at UWA (Fig. 33).

The detailed work program for the 2022–23 financial year is presented under Proterozoic Margins with the EIS Proterozoic Margins project funding the MRIWA M521 project (CET), focusing on basin evolution, geophysical data interpretation and numerical modelling for the Paterson Orogen.



Figure 33. Fieldwork in one of the remote Proterozoic margins of Western Australian geology

Petrophysics

Manager: Charlotte Hall

Team member: Cristina Angheluta

Acquisition and dissemination of petrophysics data has been identified as a target in the GSWA Geoscience Strategy 2021–25 and ranks high in the list of focus areas in the Uncover Roadmap. In 2020–22, GSWA initiated a pilot project to acquire a suite of petrophysical measurements on some 3500 samples from selected drillcores in various geological settings. Over these two years, petrophysical measurements were made on drillcore samples from the Paterson Orogen, West Arunta, Eucla basement, Eastern Goldfields Superterrane, Mt Weld, South West Yilgarn and Albany–Fraser Orogen. The objective of the pilot project was to assess the ‘value proposition’ for systematic petrophysical data acquisition as a complement to both EIS co-funded drilling and regional geophysical survey data, and as an input for constraining interpretation models from those data.

Planned work program

In 2022–23, GSWA will expand on the results of the pilot project and develop a regular ongoing EIS program to 2027. The project will be for the provision of a ‘regional petrophysical coverage’ of significant type-lithologies, alteration and mineralization styles. Additional measurements will be added as required.

In 2022–23 about 2000 samples will be selected for petrophysical measurements, with samples from new and ongoing projects, including but not limited to:

- EIS and company core from southwest Yilgarn (this data will contribute to the SOWETO project (**Uncovering the buried mineral wealth of the SW Yilgarn**))
- EIS and company core from the Eastern Goldfields Superterrane (this data will contribute to the ongoing petrophysical barcoding project)
- EIS and GSWA stratigraphic core from the Eucla basement (Fig. 34)
- EIS core from the West Arunta.

Work will continue on several projects within the broader petrophysics project, including:

- Paterson Orogen ‘petrophysical stratigraphy’ project
- Kalgoorlie Group ‘petrophysical stratigraphy’ project (work so far suggests we are more likely to characterize packages of stratigraphy, or anomalies within stratigraphic units)
- Petrophysical barcoding of the Kalgoorlie Group mafic rocks (this accompanies the geochemical barcoding project)
- Petrophysical data acquisition from the southwest Yilgarn (this data will contribute to the SOWETO project)
- Application of machine learning methods to petrophysical data, with promising results so far from CSIRO’s Data Mosaic.

Products planned for release

Petrophysical data and reports (by Terra Petrophysics) will be released from the work completed in 2021–21. These include a dataset and report on:

- Mt Weld 2021–22, data and analysis from EIS co-funded diamond core MWEX10270
- Paterson Orogen 2021–22, data and analysis from 13 EIS co-funded drillcores from the Paterson Orogen
- Albany–Fraser Orogen 2021–22, data and analysis from an EIS co-funded core, two donated cores and samples of ore (donated by IGO) from the Fraser Zone.

Petrophysical data only will be released from:

- Southwest Yilgarn (this data will contribute to the SOWETO project)
- Selected drillcore from the Norseman area in the Eastern Goldfields Superterrane
- Eucla basement

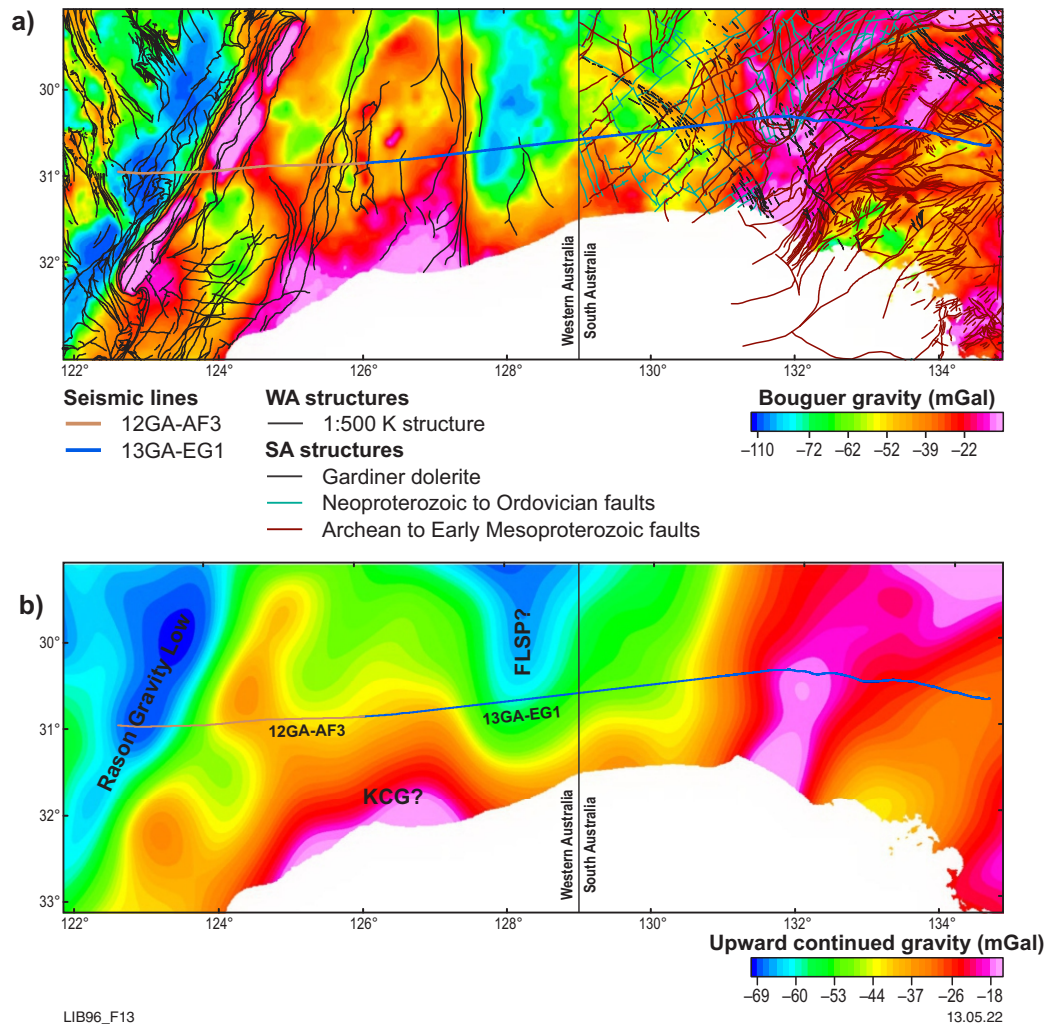


Figure 34. Upward continued Bouguer gravity data in the Eucla basement

PROSPECTIVITY MAPPING

3D Lithosphere Visualization Project

Manager: Ruth Murdie

Team members: Klaus Gessner, Huaiyu Yuan (Macquarie University)

This program funds collaborative research with leading research institutions that complement GSWA's capabilities in data acquisition, analysis, and modelling under the State Geoscience work program. The emphasis is on 3D visualization (Fig. 35), hypothesis testing, numerical modelling and verification using all available datasets. The detailed work program for 2021–22 is presented under the State Geoscience work program, with the Lithosphere Visualization Project funding the following collaborative research programs:

- ARC project LP170100985 Enabling 3D stochastic geological modelling (3D-LOOP)
- Tectonic evolution of the Canning Basin (IGG-CAS)
- Deep imaging of the Eastern Pilbara (IGG-CAS).

Models being developed include:

- 3D model of the Kalgoorlie region of the Eastern Goldfields
- 3D model of the Yalgoo–Singleton Dome
- 3D model of the Capricorn Orogen.

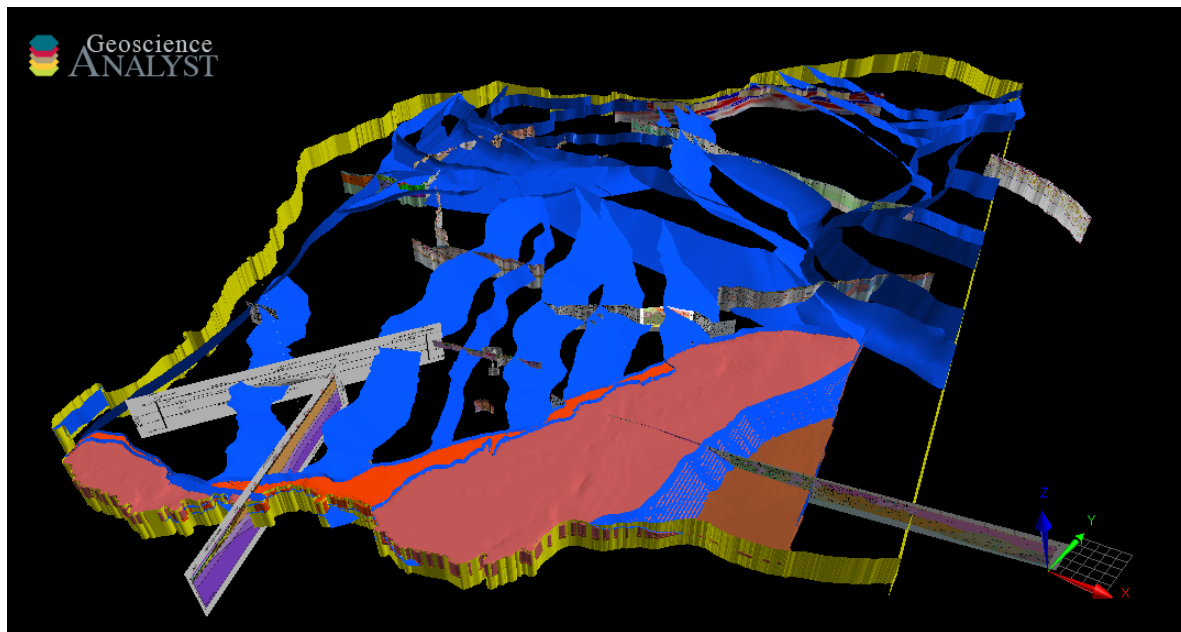


Figure 35. Screenshot of the WA State 3D geomodel from the Geoscience Analyst Viewer

Mineral Geoscience

Manager: Warren Ormsby

Team members: Paul Duuring, Sidy Morin-Ka

Under this program, GSWA collaborates with other government, university and industry partners to study specific aspects of Western Australian mineral systems. These projects are partly to fully funded by the EIS, with the Mineral Geoscience branch managing in-house participation (Fig. 36).

Projects underway in 2022–23 include:

- ARC Linkage LP190100635 – Realising Australia’s rare earth resource potential (\$20 000 per annum over three years)
- MRIWA M10433 – Detection of distal footprints in the South West Yilgarn: Linking basement and cover (\$750 000 over three years).

Planned work program

GSWA is a collaborator in the ARC Linkage project ‘LP190100635 – Realising Australia’s rare earth resource potential’, with the University of Adelaide, ANU, GA, the Geological Surveys of New South Wales and Queensland, and several REE-focused resource companies. This three-year project commenced in October 2020.

The university researchers are combining experimental petrology, numerical modelling of lithosphere architecture and magma evolution, and petrological and geochemical studies of prospective or known areas of unconformity-related and peralkaline volcanic REE mineralization across Australia, to develop comprehensive metallogenic models and exploration tools. Case studies will include the Browns Range and John Galt REE deposits in the East Kimberley – West Tanami region of northern Western Australia. It is with these studies that GSWA is most closely affiliated.

GSWA is also a partner in the MRIWA M10433 project ‘Detection of distal footprints in the Southwestern Yilgarn: linking basement and cover’, along with MRIWA, CSIRO and resource companies. This three-year project commenced in December 2021.

Gold prospectivity

This study is re-evaluating the gold prospectivity of the southwest Yilgarn through the application of recent advances in geochemical technologies, targeting chemical and isotopic anomalies in cover rocks that have been proven to provide vectors to mineralization in the more thoroughly explored central and eastern terranes of the Yilgarn. Basement mineralization studies are initially taking place around the Tampia gold camp, but will include most known examples of gold mineralization in the study area.

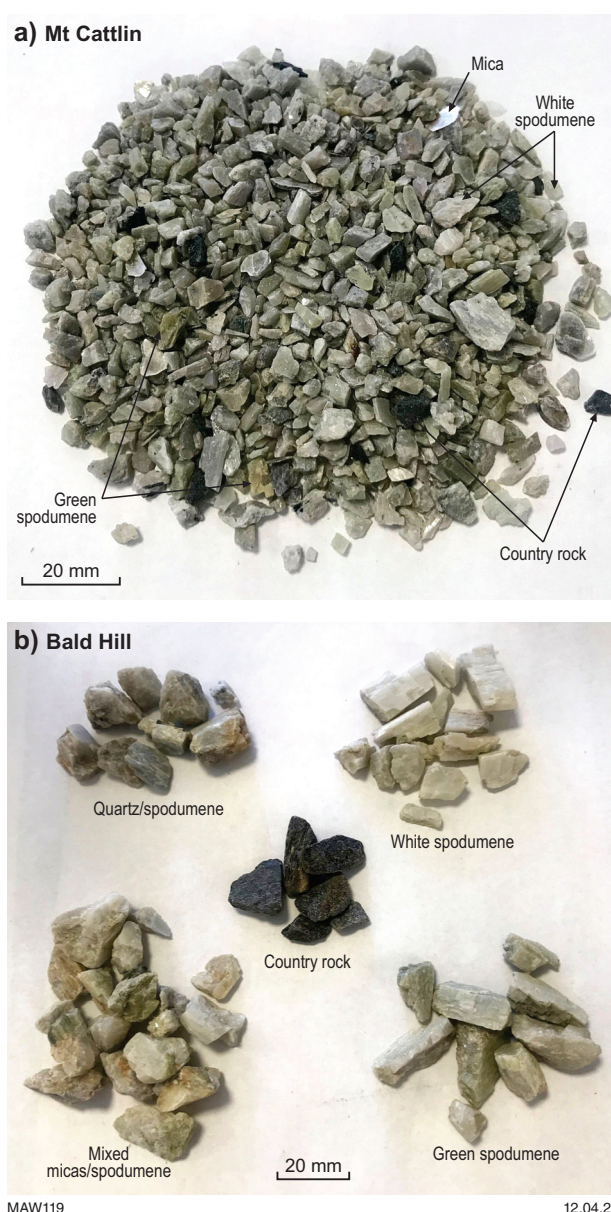


Figure 36. Examples of concentrates showing spodumene with variation in colour and the presence of gangue minerals, which have been collected along with spodumene in the beneficiation circuits

Planned outcomes include new GIS datasets, landscape variability mapping, geochemical dispersion models and identifying the most efficient sample media to detect geochemical footprints linked with gold deposits in the region.

Products planned for release

- Cobranded GSWA–MRIWA Report for Project M532 – Geology, mineralogy and metallurgy of eMaterial resources in Western Australia
- Western Yilgarn laterite geochemistry database – new data including HyLogger scans, CSIRO Report on critical minerals in laterite related to pegmatite mineral systems of the western Yilgarn Craton
- Deep learning identification of spurious data in geochemical datasets. Report by Curtin University and GSWA
- Other results from the REE (ARC Linkage) and LCT pegmatite (MRIWA) projects will be published in external publications

Energy Geoscience

Manager: Deidre Brooks

Team members: Norman Alavi, Richard Bruce, Julie Cass, Louisa Dent, Louisa Ellis, Peter Haines, Arthur Mory, Leon Normore, Charmaine Thomas, Yijie (Alex) Zhan

The main aim of this program is to collect pre-competitive data to assist in determining the State's potential for petroleum and alternative energy sources that might provide for the State's growing energy requirements. This program comprises several distinct subprograms.

Geophysical projects that continue from the previous financial year into 2022–23 incorporate pre-competitive data which was funded through the EIS in 2018. These projects aim to improve the structural and stratigraphic definition of the Canning, Perth, and Northern and Southern Carnarvon Basins and include:

- Seismic interpretation of Kidson Sub-basin and Crossland Platform, using the EIS co-funded acquisition of the Kidson Seismic Survey and EIS-funded, reprocessed 2D seismic lines in the Kidson Sub-basin, Cobb Embayment and northwestern Canning Basin
- Multiyear seismic interpretation of the Southern Carnarvon and northern Perth Basins, using EIS-funded, newly reprocessed 2D seismic lines in the Southern Carnarvon Basin and the Coolcalalaya Sub-basin of the northern Perth Basin, and incorporating results from the EIS-funded Carnarvon and Perth Basin SEEBASE products.

Collaborative projects

An EIS-funded Canning Basin collaborative core analysis project in 2015–16 for the wells Theia 1, Olympic 1 and Senagi 1 is still yielding new information. Records for each of the wells on the petrophysical and petrographic assessment of the reservoir and seal quality, including commentary on the CO₂ storage potential, are planned for release in 2022–23. The ternary diagram in Figure 37 shows that mineral assemblage remains unchanged as the grainsize is dramatically reduced moving from sandstone to claystone. This indicates that grainsize is the main control on reservoir quality of the sandstone and claystone facies which have wireline log coverage in the Grant Group at Olympic 1.

Work will commence on a new reference section for the Goldwyer Formation (which was delayed due to the drilling and post-well analysis of Barnicarndy 1).

During 2021–22, two SEEBASE projects were funded by the EIS: the Officer Basin SEEBASE and the Perth Basin SEEBASE. The results of both of these studies will be released through the DMIRS eBookshop and WAPIMS in 2022–23.

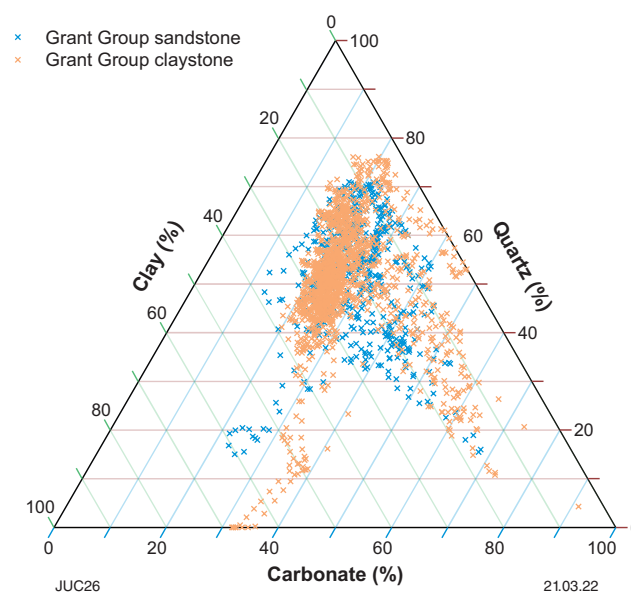


Figure 37. Sandstone and claystone facies have wireline log coverage in the Grant Group at Olympic 1, Canning Basin. This ternary diagram shows that mineral assemblage remains unchanged as the grainsize is dramatically reduced moving from sandstone to claystone, indicating grainsize as the main control on reservoir quality

Planned work program

EIS-funded regional geological and geophysical studies for the Canning and Perth Basins will continue.

Canning Basin

The planned studies in the Canning Basin are to:

- Continue the regional mapping project in the southern Canning Basin incorporating the EIS-funded 2018 reprocessed 2D seismic lines in the Kidson Sub-basin, Cobb Embayment and the northwest portion of the Canning Basin, and the 2D regional deep crustal seismic line across the Kidson Sub-basin
- Commence work on defining a new Goldwyer Formation reference section based on the results of the 2015–16 collaborative core analysis project and the Barnicarndy 1 stratigraphic well.

Northern Perth Basin

Planned multiyear studies in the northern Perth Basin include interpretation of the 2018 EIS-funded, reprocessed 2D seismic lines. The plan is to incorporate the results, along with the 2018 EIS-funded Carnarvon Basin and 2022 EIS-funded Perth Basin SEEBASE products, into a wider interpretation project to improve the definition of the stratigraphy and structure of the basin. The results of this project will be included as new pre-competitive data supporting future acreage releases.

Products planned for release

- Petrophysical and petrographic evaluation of the Permian and Ordovician in Olympic 1, Canning Basin (Report)
- Officer Basin SEEBASE (Report and data package)
- Perth Basin SEEBASE (Report and data package)
- Barnicarndy 1 Digital Core Atlas
- Barnicarndy 1 Interpretative Well Completion Report

Enhanced Geochronology and Isotopic Mapping

Manager: Michael Wingate

Team members: Imogen Fielding, Sarah Gain, Dominique Harmer, Frances James, Yongjun Lu, Marlene Papiccio, Sandra Romano, Tom Scillieri, John Williams

This project complements GSWA's geochronology studies (see Geochronology and Geochemistry work program). We have added Lu–Hf and oxygen isotope and trace element analysis of zircons, Sm–Nd isotope analysis of whole-rock samples, and additional isotope-related techniques (such as whole-rock Lu–Hf and Pb isotopes) conducted in collaboration with university research groups.

Magmatic rocks and crustal evolution

Variations in radiogenic isotope compositions (mainly Sm–Nd and Lu–Hf) provide information on the nature of the sources of magmatic rocks, allowing magmatic rocks derived from the mantle to be distinguished from those derived by reworking of older crust. Knowledge of crustal evolution is also important for understanding mineralization because the addition of juvenile material from the mantle into the crust is commonly associated with mineralizing events. Stable isotopes, mainly oxygen, are used to distinguish material derived from near-surface or supracrustal environments from mantle-derived material. These techniques enable the construction of a range of isotopic maps at different scales, which are powerful in imaging lithospheric and crustal architecture, identifying metallogenic terranes and favourable geodynamic environments, and constraining the 4D evolution of the lithosphere.

Three statewide isotope map layers, Sm–Nd, zircon Lu–Hf, and zircon oxygen, are available via GeoVIEW.WA and DASC. Isotope maps play an increasingly important role in exploration targeting at regional scales, and will be updated with new data as they become available.

This project includes measurement of whole-rock geochemical and zircon, and apatite trace element compositions of granitic rocks in Western Australia. This is to be able to understand water content, pressure, temperature and oxidation state of magmas, all of which control magma fertility for ore formation, and all of which can be used as exploration indicators in remote or covered terrains.

This project is funding the work for the Geochronology and Geochemistry work program. Most analytical work under these two work programs is conducted at the John de Laeter Centre at Curtin University, the Centre for Microscopy, Characterisation and Analysis (CMCA) at UWA, and by several other university laboratories.

Planned work program

The Geochronology and Geochemistry work program will generate U–Pb zircon, baddeleyite and monazite ages in support of GSWA geoscience programs across Western Australia (Fig. 38). The timely release of geochronology results will be maintained, through both rapid, brief, in-house reports and the Geochronology Record series, published online via GeoVIEW.WA, eBookshop and DASC. The laboratory will process samples for geochronology, whole-rock geochemistry and isotope geochemistry as required by GSWA geoscience programs. The Greenstone Geochemical Barcoding Project is the largest single user of whole-rock geochemistry, with more than 1000 samples analysed each year.

This program will continue analyses of Lu–Hf, Sm–Nd, and oxygen isotopes in 2022–23. Isotope data generated by this program will be checked for accuracy and consistency, provided to GSWA projects, and used to update statewide isotope maps available in GeoVIEW.WA (Fig. 39). The results will be integrated with geological and geochemical data and gravity, aeromagnetic, seismic and magnetotelluric datasets, to advance our understanding of crustal architecture, geological evolution and mineralization. Isotope data will be uploaded to the WAGIMS database. Syntheses will be published as Reports or Records and will inform other GSWA and external publications.

A new statewide map layer will present external geochronology results compiled from published sources, and will be available via GeoVIEW.WA and DASC. This product addresses the need for an authoritative compilation of external geochronology that will complement GSWA geochronology results.

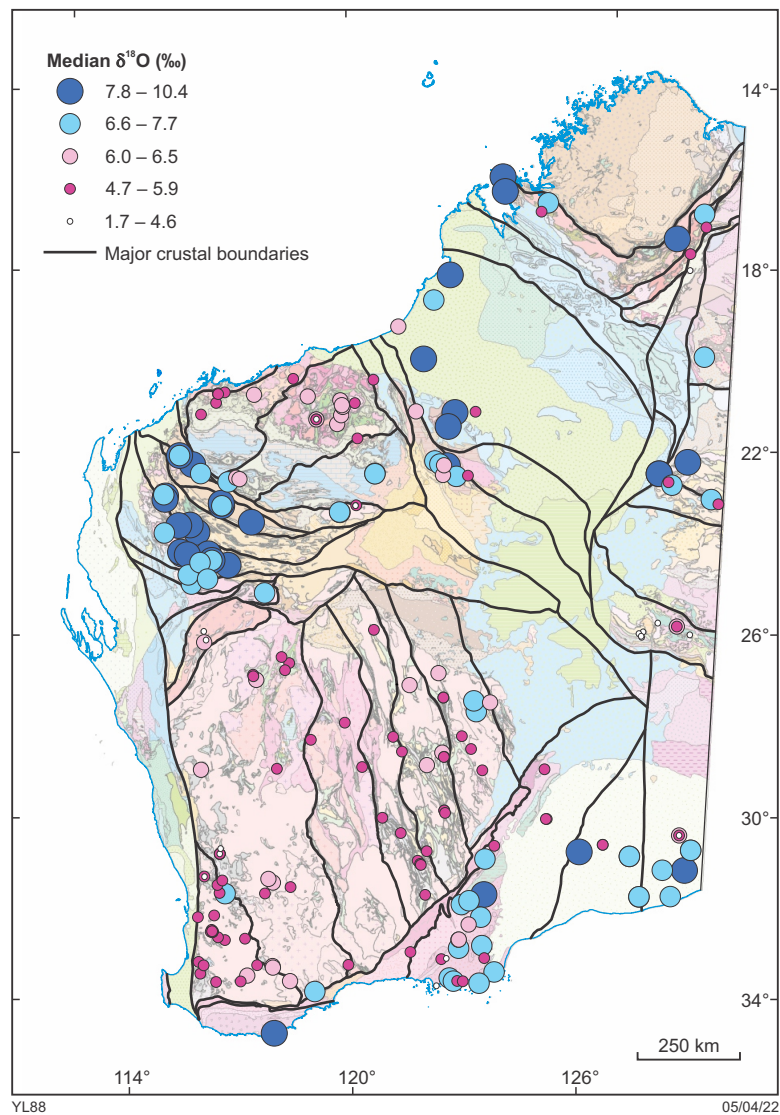


Figure 38. Updated zircon oxygen isotope map for igneous rocks, showing median $\delta^{18}\text{O}$ values of primary magmatic zircons from igneous rock samples. Base map is the 1:2 500 000 interpreted bedrock geology

Collaborative projects

A three-year ARC Linkage project 'New tools for old rocks: first cycle provenance information' is continuing and will enhance stratigraphic understanding of sedimentary sequences through novel provenance fingerprinting using K-feldspar (Pb isotopes) and apatite (U–Pb, Sr isotopes and grain chemistry). This statewide project involves case studies in the Pilbara and Yilgarn Cratons and the Canning and Northern Carnarvon Basins.

A collaborative project is underway with the John de Laeter Centre to analyse Re–Os and Pb isotopes and trace element compositions of native gold specimens. The aim is to determine model ages and the provenance of gold mineralization directly from gold and its galena inclusions. The study is focused on 24 small gold nuggets from the Pilbara Craton, Kurnalpi Terrane and Capricorn Orogen. Results will be published as a GSWA Report and journal articles.

GSWA is an ongoing participant in the NCRIS-sponsored AuScope National Argon Map (NAM) program, which aims to generate an open-source locational $^{40}\text{Ar}/^{39}\text{Ar}$ geochronology database for the Australian crust to support resource exploration and increase our geological understanding of the Australian continent. GSWA has submitted samples and nominated a wide variety of additional samples for analysis under this program.



Figure 39. GSWA geologists examining sedimentary structures in Paleoproterozoic sandstone outcrops during geological mapping and geochronology sampling in the Kimberley Basin

Products planned for release

- Geochronology Records and U–Pb datasets released to online applications (GeoVIEW.WA)
- Whole-rock geochemistry analyses released to online applications (GeoChem Extract and GeoVIEW.WA)
- Sm–Nd, Lu–Hf and oxygen isotope datasets released to online applications (GeoVIEW.WA)
- External geochronology results compiled from published sources released to online applications (GeoVIEW.WA)
- Geochronology of the Paterson Orogen, Western Australia (Report)
- Isotopic fingerprinting of native gold from Western Australia (Report)
- Several external publications

Novel Geochronology and Isotope Analysis

Manager: Fawna Korhonen

Team members: Paul Duuring, Klaus Gessner, Peter Haines, Simon Johnson, David Kelsey, Yongjun Lu, Hugh Smithies, Michael Wingate

This project complements GSWA's geochronological and isotopic mapping studies with the addition of 'novel' isotope techniques to date a wider range of rocks and minerals and to isotopically characterize and trace a wider range of geological processes.

Isotopic techniques

An increasing range of available isotopic methods (due to technological advances in, for example spectrometer detection limits, in situ techniques, simultaneous acquisition of trace element chemistry) provides innovative opportunities to expand isotope studies to a wider range of rocks and minerals. These advances include several novel techniques for constraining a wider range of geological processes, and can be applied to date geological events that may not otherwise be possible with traditional U–Pb techniques, including mineralization, alteration, hydrothermal fluid flow, low- to medium-temperature metamorphism, deformation, exhumation, and diagenesis. In many cases, these analyses can be done in situ, preserving the mineralogical relationships in a sample, together with simultaneous measurement of trace elements to assess, for example, fertility, mineral systems footprints, pressure–temperature conditions and paragenesis.

Some examples of 'novel' or 'non-traditional' geochronological systems include: Lu–Hf and Sm–Nd dating of garnet, apatite and calcite, Re–Os dating of sulfides, Rb–Sr dating of micas, glauconite, and shales, and Ar/Ar dating of pyroxene, hornblende, K-feldspar and mica. Similarly, isotopes of S, Fe, Mo, W, Cu, Ti and other elements can provide a range of complementary data on processes up to trans lithospheric scales (Fig. 40).

Planned work program

This program will generate novel geochronological and isotopic data in support of GSWA geoscience programs across Western Australia. These may include but are not limited to in situ measurement of Lu–Hf and Sm–Nd in garnet, apatite and calcite, Re–Os in sulfides and shales, Rb–Sr in micas, glauconite, and shales, Ar/Ar in pyroxene, hornblende, K-feldspar and mica, and multiple sulfur isotope on whole-rock samples.

Collaboration is continuing with Curtin University to use in situ Rb–Sr analysis of biotite, apatite and other minerals to assist with interpretations of low-temperature geological histories of Precambrian rocks and to enhance our geological understanding of previously dated rocks. These studies use recently developed laser ablation collision reaction cell inductively coupled plasma mass spectrometry (LA-CRC-ICP-MS) to date minerals in polished thin sections.

GSWA is involved in a project with researchers at Curtin University to investigate the geochronology of the AK1 lamproite pipe at Argyle, previously dated at c. 1200 Ma by Rb–Sr and K–Ar techniques. This study will employ modern approaches, including U–Pb dating of perovskite, apatite, monazite and xenotime, (U–Th)/He analysis of zircons, and Ar/Ar dating of K-rich phases, such as phlogopite. A better understanding of the timing of eruptions of diamond-bearing lamproites at Argyle will elucidate their relationship to regional and global geodynamic processes, and will inform diamond exploration in Western Australia.

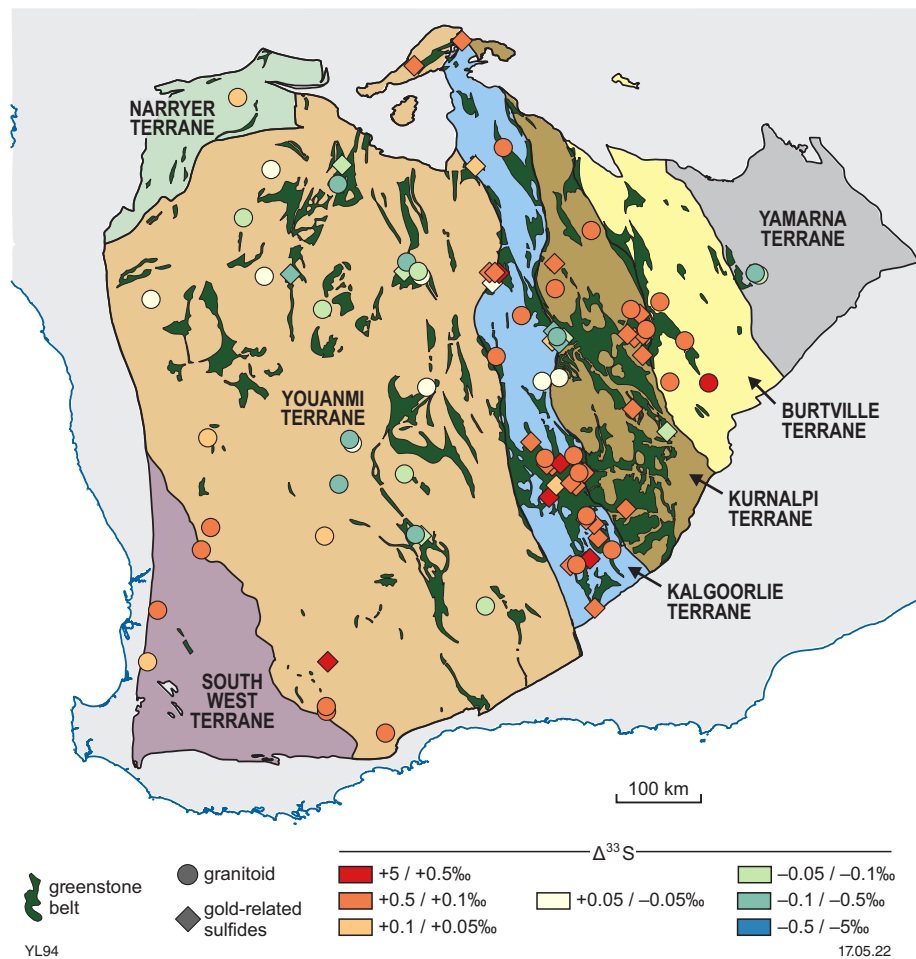


Figure 40. Largely homogeneous sulfur isotope compositions of granitic rocks and sulfide mineralization within different terranes of the Yilgarn Craton mimic the current terrane subdivision based on Nd and Hf radiogenic isotopes. This suggests that mineralizing fluids exsolved from magmas that originated through reworking of material in the lower and middle crust

Products planned for release

- Novel geochronology and isotope data populated in WAGIMS
- Geochronology Records, as appropriate
- Project-specific Records or Reports, and external publications

Greenstone Geochemical Barcoding Project

Manager: Hugh Smithies

Team member: Jack Lowrey

The Greenstone Geochemical Barcoding Project is an initiative under the EIS that aims to geochemically characterize greenstone stratigraphy throughout the EGST. This project will continue to substantially increase the amount of high-quality, multi-element, geochemical data for greenstones, targeting available diamond drillcores that sample the most geologically well-constrained, or best-understood, parts of various greenstone belts. Extensive sampling has already been undertaken in the Kalgoorlie–Kambalda region, as well as in several other smaller regions throughout the EGST, and will ultimately extend throughout the EGST (Fig. 41).

Through detailed geochemical sampling of diamond drillcore, we hope to establish a geochemical ‘barcode’ of the stratigraphy (including local variations) in these better-known sections of greenstone belts.

Project goals

The ultimate goals of this project are to:

- Establish whether local and/or regional greenstone stratigraphies are geologically valid, and understand the geological reasons for any local and regional stratigraphic variations
- Provide a reasonable geochemical proxy for stratigraphy that will allow users to better establish where a particular lithology or lithological association fits in a local or regional stratigraphy
- Provide a data-rich, high-quality geochemical dataset regionally representative of all magmatic rock types that will help develop our understanding of petrogenetic processes in greenstone evolution and associated mineralization.

Planned work program

Work within this project will concentrate in the southern and eastern parts of the EGST, but also support other regional Yilgarn Craton geoscience programs.

Products planned for release

- Greenstone Geochemical Barcoding project data release (Record)

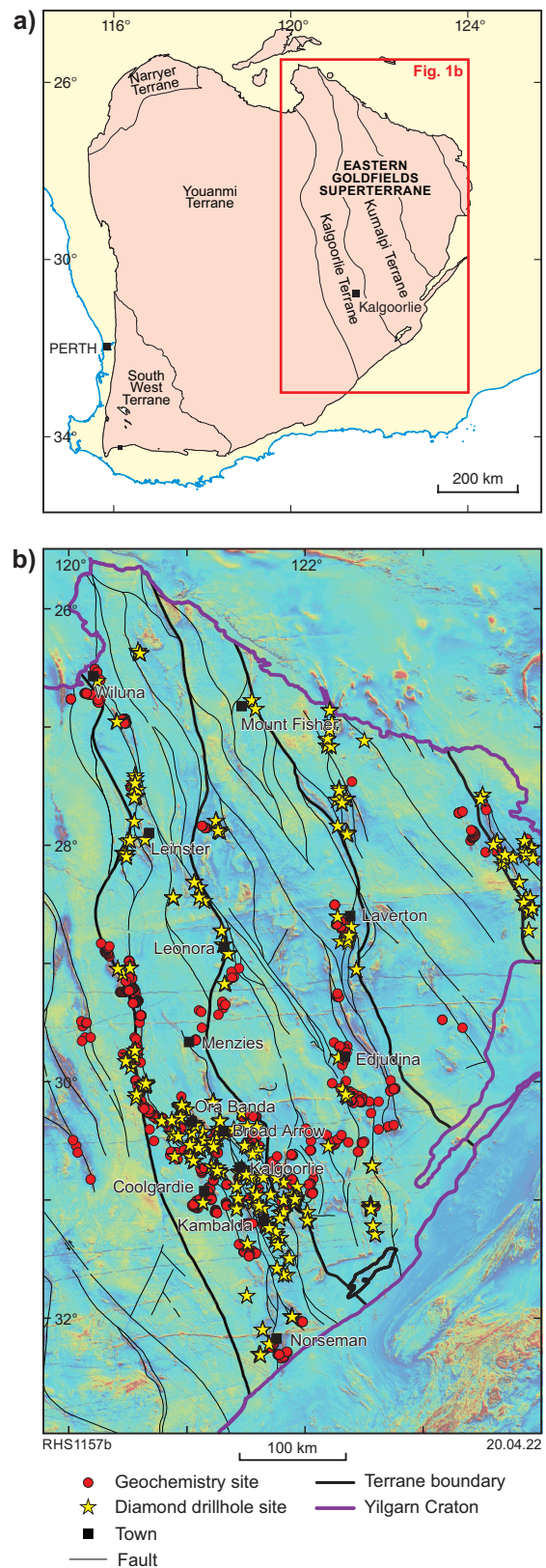


Figure 41. Eastern Goldfields greenstone geochemical barcoding project area: a) overview; b) sample localities

Yilgarn Granite Project

Manager: Hugh Smithies

Team members: David Champion (GA), Jack Lowrey, Yongjun Lu

The Yilgarn Granite Project is an initiative under the EIS that aims to provide complete and detailed coverage of the Yilgarn Craton in terms of modern, high-quality, major- and trace element data (including Li) on granitic rocks, and at the same time, expand the coverage of whole-rock Sm–Nd isotope data. We hope also to identify, within this new dataset, potential proxies for crustal source composition, melting conditions and for fertility in terms of producing precious and strategic mineral deposits (Fig. 42). An extension of this project will involve the trace element and isotopic study of apatite crystals from samples of ‘mafic’ granites (sanukitoids) and lamprophyric rocks from across the craton to identify regional compositional variation in lithospheric source regions (i.e. map the lithospheric mantle). The project will provide interpretation (digital data, GIS layers, Reports) that attempts to place these data within the context of crustal-scale structure, source regions and economic mineral fertility.

Planned work program

Work within this project will concentrate on completing the re-analysis of GA’s archived Yilgarn granite sample suite (~1000 samples remain to be re-analysed) as well as re-analysis of all GSWA legacy granite samples. Work will commence on the trace element and isotopic analysis of apatite crystals from samples of ‘mafic’ granites (sanukitoids) and lamprophyric rocks from across the craton.

Products planned for release

- Yilgarn Granite Project data release (Record)
- Chemical classification of Yilgarn Craton granites (Record)

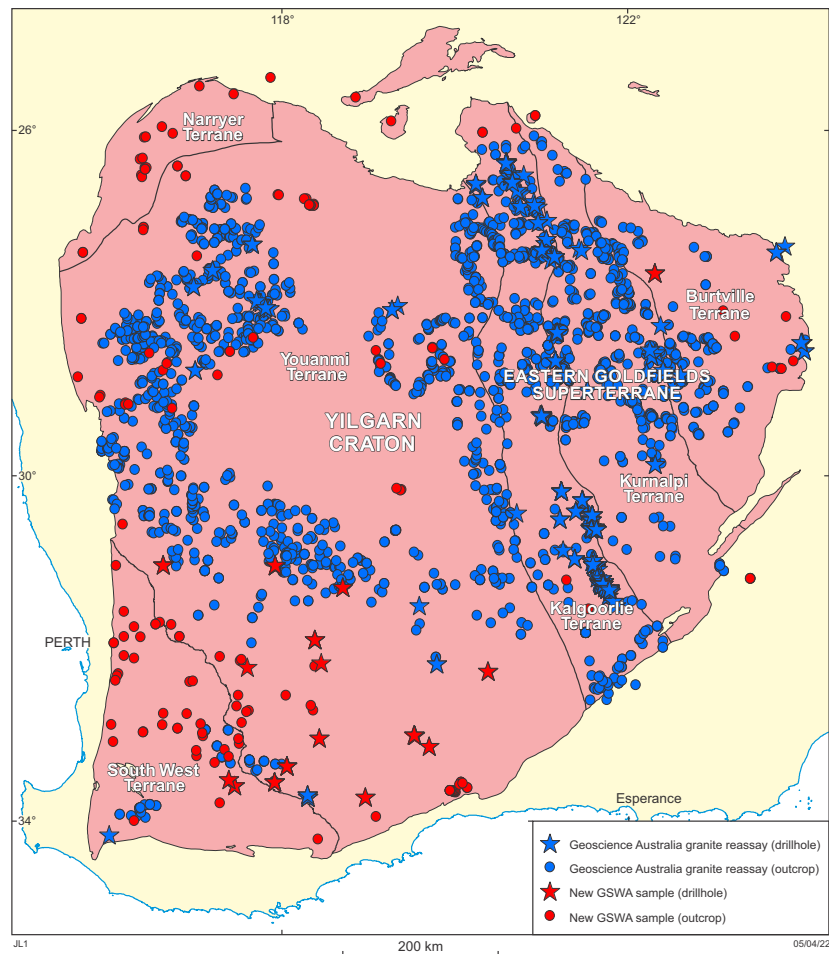


Figure 42. Yilgarn Granite Project area overview and sample localities

Core Scanning and Machine Learning

Manager: Richard Chopping

Team members: ad hoc as required

This program commenced in 2020–21 to understand, enhance and promote the role of machine learning or other data analytical techniques in providing additional and detailed geological context around GSWA-managed drill samples, e.g. from EIS core. This work is to assist with the Greenstone Geochemical Barcoding Project and will integrate new, non-destructive analyses with more traditional geochemical analyses through the use of modern data analytical techniques (Fig. 43).

Planned work program

Pending funding, the work program of this project is to acquire non-destructive geochemical analyses on core from key drillhole(s) as a trial to compile data appropriate for application in machine learning approaches to augment other analyses on drillholes.



Figure 43. Modern data analytical techniques can use artificial intelligence to interrogate and interpret data

STRATEGIC RESEARCH WITH INDUSTRY

Strategic Industry Research Program

Manager: Charlotte Hall

Team members: MRIWA

This program supports the Minerals Research Institute of Western Australia (MRIWA) under the MRIWA project theme of **Find more viable resources** (Fig. 44). Under a 2021 MoU, the EIS contributes \$350 000 per annum. The selection of projects submitted under the theme to receive support is at the discretion of the MRIWA board. This funding is in addition to projects where GSWA is a partner in a project such as M0554 and M0470a.

All projects sponsored under **Find more viable resources** can be found on the [MRIWA website](#).

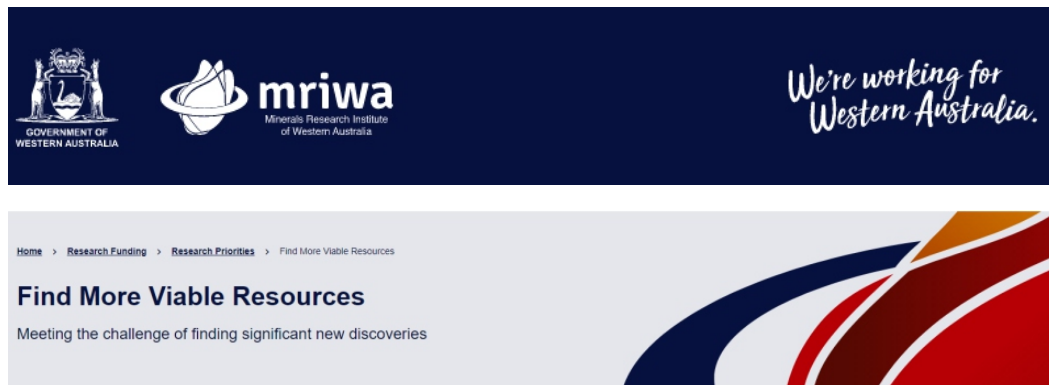


Figure 44. MRIWA's project is funded by the EIS

PART THREE

Specific Limited Term Projects
– detailed work programs



WA-Array

Manager: Ruth Murdie

Team members: John O'Donnell, Huaiyu Yuan

The global transition to a low carbon economy will support ongoing high demand for critical minerals to keep pace with investment in renewable energy generation and storage technologies. Western Australia's future requires optimal strategic planning which balances the competing land uses required for the State's transition to a low carbon economy; locations for renewable energy projects must be balanced against exploring, and developing future mines and associated potential downstream processing operations. The WA-Array program will see the implementation of passive seismic data across Western Australia to find areas of higher prospectivity under deep cover, which will assist in evaluating future competing land uses.

The program will involve the deployment of an 'array' of 165 seismometers arranged in a grid pattern spaced at 40 km intervals, with the entire State mapped over a period of 10 years by relocating the instruments on an annual basis between nine regional areas (Fig. 45). The program is a major logistical undertaking, representing one of the largest of its type completed anywhere in the world, and has been designed to complete passive seismic mapping at an optimal level of station spacing across Western Australia.

The first phase of deployment of WA-Array will be in the southwest of the State and planning for the second deployment area will begin with cultural heritage surveys. All sites will be cleared for both passive seismic and MT. The MT will follow the passive seismic and be conducted by GA as part of the AusLAMP project.

Computing infrastructure will be installed to facilitate processing of the data at GSWA. Raw data will be made available one year after each area has finished recording. Products, such as the depth to Moho and lithosphere/asthenosphere boundary, local seismicity (Fig. 46) and seismic hazard, will be released through GeoVIEW.WA.

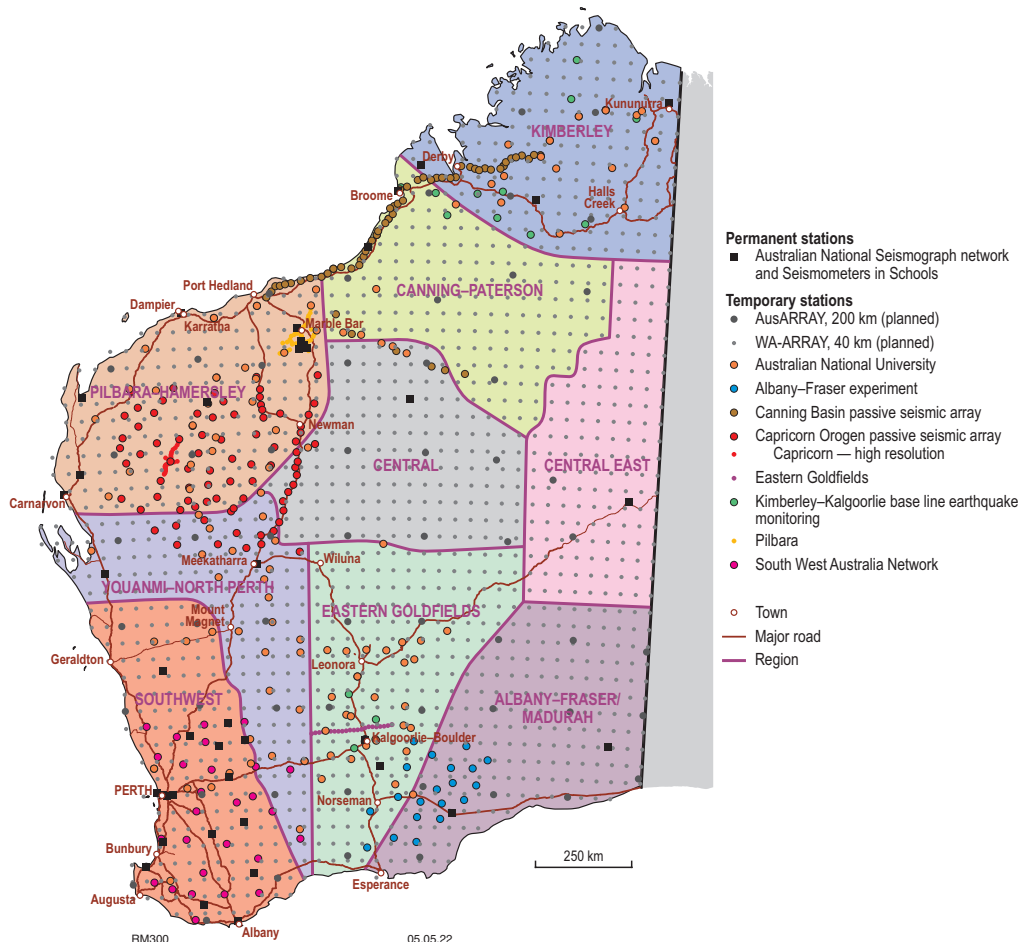


Figure 45. Planned location of the WA-Array 40 km grid across the State. It will take nine deployments over the next 10 years to complete

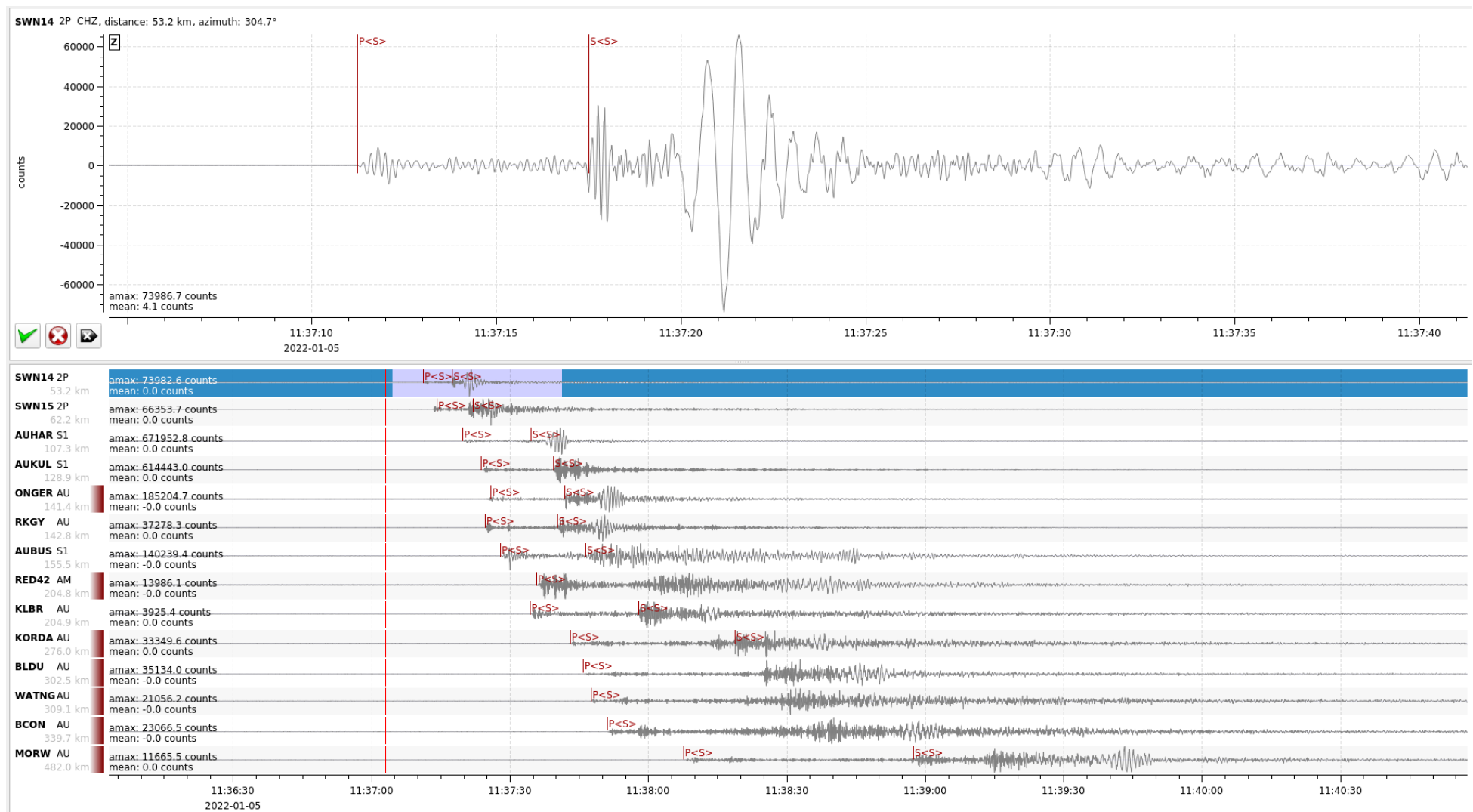


Figure 46. Seismogram from the SWAN stations recording the M4.8 earthquake on 5 January 2022 near Wagin

Geoscience Data Transformation Strategy

Manager: Deavi Purnomo

Team members: Sabrina Bednarski, Sean Breadsell, Betsy Bush, Sharon Ingram, Yanrong Li, Chee Ng, Tony Perry, Mark Taylor

A core business function for GSWA is to provide pre-competitive geoscience data at no cost, to reduce the financial risk to explorers, attract new investment into the State, and to provide guidance to government policy and land use decisions. The division 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 (Fig. 47).

The GSWA Geoscience Data Transformation Strategy is a five-year plan that will place the department at the forefront of pre-competitive geoscience data delivery, greatly increasing the attractiveness of the State of Western Australia for exploration of its vast and untapped mineral and petroleum resources.

The plan identifies the following 15 direct actions, which also address resourcing, and outlines priorities and timelines for completion:

1. All data to be spatially intelligent and in a machine-readable format at the point of generation or collection
2. All GSWA data to be hosted in a cloud-based, data lake storage system
3. Early phase of stakeholder consultation to assess existing database functionality
4. Agile database population, maintenance and upgrades performed regularly
5. Review current database functionality and modify with common keys to allow data interoperability and assignment of appropriate metadata before upload to the cloud
6. Provide access to raw and reduced datasets; this will build accountability by enabling transparency of workflows
7. Identify and deploy a single platform for the visualization, interrogation and delivery of all 3D and spatial data products
8. Release quality assured and approved data in a near-to-real time frame
9. Phase out all hard products, with new, fully quality-assured data releases direct to the cloud
10. Text and image-based data products must be spatially attributed, be released in a multimedia enabled format and be machine readable
11. All physical assets must be catalogued, scanned and made available to the public
12. Release the mineral drillhole and surface geochemistry database to the cloud as soon as possible, in a human- and machine-readable format, in its current 'uncleaned' state
13. In a second phase, data within the mineral drillhole and surface geochemistry database should be cleaned and quality assured for delivery as a new GSWA dataset
14. Promote closer ties to the Strategic Spatial Services Branch, by leveraging the similarity in vision and implementation in data strategy policies
15. To ensure accountability for data action, a position of Chief Data Officer should be created.

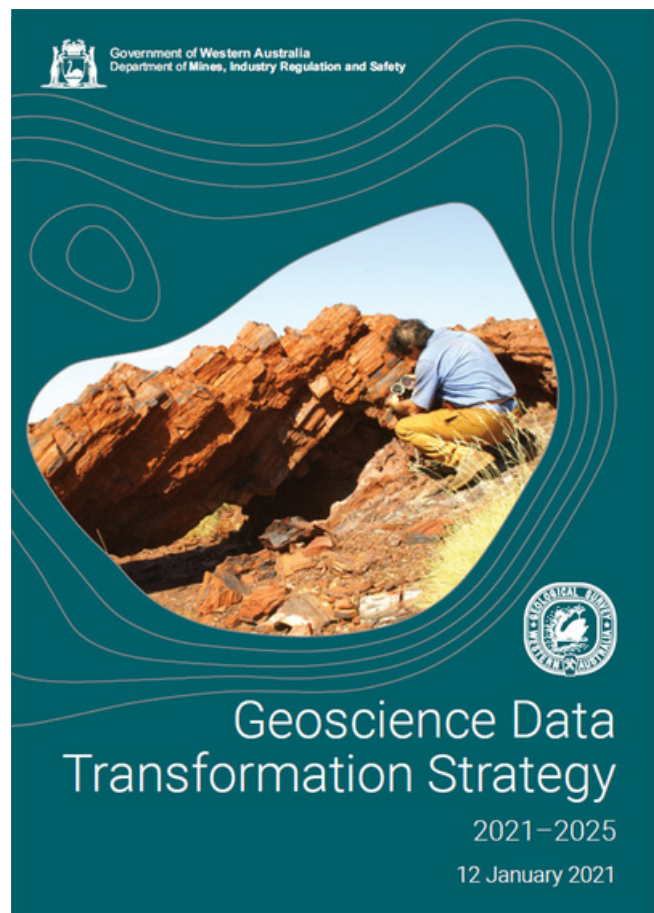


Figure 47. Geoscience Data Transformation Strategy document

The Geoscience Data Transformation Program is currently in the Initiate Phase focusing on early discovery, resourcing and planning. Activities have included:

- Development of activity streams:
 - Data optimization (data validation and digitization)
 - Data integration (Data Lake)
 - Sustainable storage for big data
 - Lodgement portal (external data capture and submission)
 - Discovery portal (internal and external data catalogue and search)
 - My Geology portal (internal data capture and management)
- Defining resourcing requirements and onboarding of the program team
- Developing a Stakeholder Engagement and Change Management strategy
- Establishing program reporting protocols to align with portfolio operations compliance obligations
- Implementation planning for the lifecycle of the Program
- Visual elements planning including:
 - Program identity design
 - Activity stream graphics
- Current state discovery analysis of technology and data.

Execution phases of the program are scheduled to commence during the 2022–23 financial year.

PART FOUR

Active Collaborative Research Projects
— detailed work programs



ARC collaborative agreements



ARC Centre of Excellence for Core to Crust Fluid Systems — CE11E0070

Project manager: Suzanne O'Reilly (Macquarie University)

Partner researchers/institutions: Simon Wilde (Curtin University), Campbell McCuaig (CET, UWA), Chris Kirkland (CET, Curtin), Huaiyu Yuan (Macquarie University, CET)

GSWA contacts: Simon Johnson, Klaus Gessner, Michael Wingate

Duration of project: 2011–17 (extended to 2025)

Project description

A world-leading **Centre of Excellence** driving innovative interdisciplinary research towards a new understanding of Earth's origins, fluid budgets and evolution, and delivering outcomes of tangible benefit to society. Seismology work continues with projects in the Canning Basin looking at deep crustal structure. Seismology will wrap up by the end of 2022.

GSWA sponsored projects

- 3D crustal architecture of Western Australia
- Zircon Lu–Hf constraints on Precambrian crustal evolution in Western Australia

Outputs – planned or actual

In 2021, this program delivered outputs that combine geological, geochemical and geophysical techniques to constrain structural models of Archean lithosphere in Western Australia.

- Selway, K, Dentith, M and Gessner, K 2021, Lithospheric-scale magnetotellurics over the Eastern Goldfields Superterrane, Yilgarn Craton: Australian Earth Science Convention, Geological Society of Australia Abstract Volume 133, p. 6.
- Pickle, RC, Miller, MS, Murdie, R, Allen, T, Yuan, H, Gessner, K and Kennett, BLN 2021, Preliminary earthquake catalogue for an ongoing temporary seismic network in SW Australia derived using machine-learning phase picker and an automated workflow: AGU Fall Meeting.
- Gessner, K, Calvert AJ, Doublier, MP, Brisbourn, L, Yuan, H and Murdie, RE 2021, Seismic imaging of layered crust in the Pilbara Craton: A challenge for Paleoarchean crustal overturn?: AGU Fall Meeting.
- Lin, X, Yuan, H, Dentith, MC, Murdie, R, Gessner, K and Nayak, A 2021, Improved full waveform moment tensor inversion of Cratonic intraplate earthquakes in southwest Australia: Geophysical Journal International 227, p. 123–145.

ARC Discovery project DP200101104 — Deciphering the tectonic record of the early Earth

Project manager: Fawna Korhonen

Partner researchers/institutions: Curtin University

GSWA contacts: Fawna Korhonen, Simon Johnson

Duration of project: 2020–25 (delayed due to COVID-19) commenced in 2021

Project description

This project aims to decipher how and why plate tectonics emerged, and how any precursor tectonic system modulated planetary heat loss. The project expects to generate new knowledge regarding the tectonic record of the early Earth using pressure–temperature–age constraints from truly ancient (2.8 – 4.0 billion years old) metamorphosed rocks in the Pilbara Craton and the Narryer Terrane, as well as other localities worldwide. Expected outcomes of this collaborative international project include the development of a conceptual geodynamic model for the early Earth. This should provide significant benefits in permitting a better understanding of the where and why of Australia's natural resources, in training a new generation of Earth system scientists, and in broadening public awareness of fundamental Earth science.

Outputs – planned or actual

- Metamorphic History Records for each metamorphic sample (once these are published).

ARC Linkage project LP130100722 — Earth’s best-preserved Archean boninites: do they finally resolve the Archean mantle plume–plate controversy?

Project manager: Derek Wyman (University of Sydney)

Partner researchers/institutions: Jack Lowrey (PhD candidate, University of Sydney / GSWA)

GSWA contact: Tim Ivanic

Duration of project: 2014–18 (extended to 2022)

Project description

This study will look at the geochemistry of mafic rocks in the Murchison Domain of the Yilgarn Craton. Subduction typically starts in the modern Earth with the eruption of chemically distinctive rocks known as boninites. This project will study remarkably well-preserved 2.8 billion-year-old boninites from Western Australia that may finally establish whether modern-style plate tectonics operated in the first half of Earth’s history.

Outputs — planned or actual

- Peer-reviewed journal papers, conference proceedings, GSWA Open Day posters, PhD thesis; GSWA Report
- Lowrey, JR, Ivanic, TJ, Wyman, DA and Roberts, MP 2017, Platy pyroxene: new insights into spinifex texture: *Journal of Petrology*, v. 58, no. 9, p. 1671–1700.
- Lowrey, JR, Wyman, DA, Ivanic, TJ, Smithies, RH and Maas, R 2020, Archean Boninite-like Rocks of the Northwestern Youanmi Terrane, Yilgarn Craton: *Geochemistry and Genesis: Journal of Petrology*, doi:org/10.1093/petrology/egaa002.



ARC Linkage project LP170100985 — Enabling 3D stochastic geological modelling (LOOP)

Project manager: Klaus Gessner

Partner researchers/institutions: Monash University

GSWA contact: Klaus Gessner

Duration of project: 2018–23

Project description

We will develop a new open-source 3D implicit geostructural simulator and modelling platform that will address the entire 3D geological modelling workflow, from guiding efficient observations and field sampling to the production of a series of consistent 3D geological models with uncertainty assessment and characterization.

Outputs — planned or actual

- Six software and data packages: **The Loop Interface**, Map2Loop, Loop Structural, Tomofast-x, GeoSwarm agents, Geoscience Ontology Dataset
- **Presentations**
- Open-source **technical publications**
- Report on stochastic modelling of Kalgoorlie cube.



ARC Linkage project LP180100199 — New tools for old rocks: first cycle provenance information

Project managers: Simon Johnson, Michael Wingate, Hugh Smithies

Partner researchers/institutions: Chris Kirkland (Curtin University)

GSA contact: Simon Johnson, Hugh Smithies

Duration of project: 2020–23

Project description

The aim of this research is to enhance stratigraphic understanding of sedimentary sequences in Western Australia through application of novel provenance fingerprinting tools in K-feldspar (Pb isotopes) and apatite (U–Pb, Sr isotopes and mineral chemistry). While much stratigraphic characterization has been based on detrital zircon ages and their correlation to basement sources, two major limitations are apparent:

1. zircon may be multicycle, blurring source–sink relationships
2. zircon may be absent in mafic lithologies thus biasing investigations.

In this work, K-feldspar and apatite provenance investigation will be undertaken on a statewide basis and include case studies in the Yilgarn Craton and Canning and Northern Carnarvon Basins.

Outputs — planned or actual

- Johnson, SP, Kirkland, CL, Evans, NJ, McDonald, BJ and Cutten, HN 2018, The complexity of sediment recycling as revealed by common Pb isotopes in K-feldspar: *Geoscience Frontiers*, v. 9, p. 1515–1527, doi:10.1016/j.gsf.2018.03.009.
- Zametzer, A, Kirkland, CL, Hartnady, MIH, Barham, M, Champion, DC, Bordorkos, S, Smithies, RH and Johnson, SP 2022, Applications of Pb isotopes in granite K-feldspar and Pb evolution in the Yilgarn Craton, *Geochimica et Cosmochimica Acta*, v. 320, p. 279–303.
- Hartnady, MIH, Kirkland, CL, Smithies, RH, Johnson, SP and Johnson, TE 2022, Pb isotope insight into the formation of the Earth's first stable continents: *Earth and Planetary Science Letters*, v. 578, doi:10.1016/j.epsl.2021.117319.
- Numerous high-quality, open-access journal articles at various stages throughout the project, some probably published six months to one year after project end.



ARC Linkage project LP180101118 — Enhanced 3D seismic structure for southwest Australia (SWAN)

Data acquisition is in the final stages up to mid-2022 before proceeding to data analysis and Report compilation in 2023.

Project manager: Klaus Gessner

Partner researchers/institutions: ANU, GA, DFES

GSA contact: Klaus Gessner

Duration of project: 2020–23 (delayed and extended for additional six months due to COVID-19)

Project description

The objective of this work is to delineate the 3D structure of the crust and lithosphere located in the southwestern part of Western Australia, using a full range of seismic imaging techniques. Work is ongoing – fieldwork was started Q2 2020 and will run until Q4 2022. Initial results with AI earthquake detection successfully detecting lots of smaller earthquakes than are reported by GA with interesting trends being observed. Initial depth to Moho under the stations has been included in the AGP. Work is continuing with DFES on communicating and integrating the results into DFES planning and activities.

Outputs — planned or actual

- External publications, Report
- An information article on the Arthur River earthquake was published in Preview.

ARC Linkage project LP190100146 — Evolution of Proterozoic multistage rift basins – key to mineral systems**Project manager:** Mark Jessell (UWA)**Partner researchers/institutions:** UWA, Monash, University of Sydney, CSIRO, Independence NL, BHP Billiton, Anglo American PLC, MRIWA**GSWA contact:** Klaus Gessner**Duration of project:** 2020–24 (four years from signed agreement)**Project description**

This project will deliver a new quantitative and integrated exploratory framework for the mineral industry in Australia's frontier sedimentary basins by integrating the latest advances in laboratory experimental tectonics with thermo-mechanical numerical, surface process and geophysical modelling. The project will use northern Australian basins as a natural laboratory to address the fundamental processes involved in the development of sedimentary ore systems. The project will investigate how they can be detected by modern exploration techniques using a multidisciplinary approach with a team of experts with backgrounds in mineral and petroleum systems. The project started in February 2021. It employs a postdoctoral student and two PhD students at Monash University, and a part-time software developer and PhD student at the University of Sydney. Activities include benchmark analogue and numerical models at Monash and Sydney and, at UWA, the creation of a tectonic database that enables automatic time–space plots for the North Australian Craton.

**ARC Linkage project LP190100635 — Realising Australia's rare earth resource potential****Project manager:** A/Prof Carl Spandler (University of Adelaide)**Partner researchers/institutions:** A/Prof John Mavrogenes (ANU), Dr Rhodri Davies (ANU), Dr Teresa Ubide (UQ), Dr David Huston (GA), Prof Nicholas Rawlinson (University of Cambridge), Dr Phillip Blevin (GSNSW), Dr Helen Degeling (GSQ) and resource companies**GSWA contacts:** Trevor Beardsmore, Sidy Morin-Ka**Duration of project:** 2020–23**Project description**

Combine experimental petrology, numerical modelling of lithosphere architecture and magma evolution, and petrological and geochemical studies of prospective or known areas of unconformity-related and peralkaline volcanic REE mineralization across northern Australia, to develop comprehensive metallogenic models and exploration tools. Case studies will include the Browns Range and John Galt REE deposits in the East Kimberley – West Tanami region of northern Western Australia. It is with these studies that GSWA is most closely affiliated.

Outputs – planned or actual

External publications.

ARC Grant (DP200103208) — Testing continental growth models with calcium and strontium isotopes**Project manager:** Tony Kemp (Chief Investigator, UWA)**Partner researchers/institutions:** Simon Wilde (Curtin University), Martin Van Kranendonk, (UNSW), Tim Elliott (University of Bristol), Matilda Boyce (PhD candidate)**GSWA contact:** Tim Ivanic (co-supervisor to PhD)**Duration of project:** 2020–23**Project description**

Testing the relationship between atmospheric and magmatic records in Ca and Sr isotopes during Mesoarchean crustal growth. Fresh plagioclase and calcite will be collected from the best-preserved Eo-mesoarchean layered mafic intrusions and stromatolites to provide a window into the crust–mantle–atmosphere system in early Earth history.

Outputs – planned or actual

- Journal articles and conference abstracts.



MinEx collaborative agreements

MinEx CRC Program 3: National Drilling Initiative

Project manager: Richard Chopping

Partner researchers/institutions: Multicollaborative project

GSA contact: Richard Chopping

Duration of project: 2018–28

Project description

MinEx CRC will create new opportunities for mineral discovery by delivering more productive, safer and more environmentally friendly drilling methods. It will include new technologies for collecting data while drilling, and exploration data on never-before-sampled rocks that are hidden but prospective for minerals. A key component of this CRC is the NDI, linking State and federal geological surveys with researchers in drilling and deriving meaning from data to develop new methodologies to map under cover. The NDI will focus on drilling in each partner state, and will conduct three major research streams:

- Project 7: Maximizing the value of data and drilling through cover
- Project 8: Geological architecture and evolution
- Project 9: Targeting mineral systems in covered terranes.

GSA involvement in MinEx CRC includes additional involvement in Project 6 (discussed below). GSA will house an embedded researcher from the University of South Australia in 2019–22 who will contribute to this research.

Outputs – planned or actual

- Compilation of geoscientific data for ‘The Gap’ region (Paterson Orogen – Canning Basin – west Arunta Orogen – west Musgrave Province)
- New geological, geochemical, geochronological and petrophysical samples/data obtained through MinEx CRC drilling techniques.

MinEx CRC Project 6 — Automated 3D Geology Modelling

Project manager: Mark Jessell (UWA)

Partner researchers/institutions: Mark Lindsay (Supervisory), Ranee Joshi (PhD candidate) / CSIRO, UWA

GSA contact: Tim Ivanic (co-supervisor to PhD)

Duration of project: 2019–23

Project description

Integrate multiscale datasets into one model wherein data could be subsampled and dynamically visualized in a particular scale optimal for solving multiple multiscale geologic problems. To answer this, existing subsampling methodologies are tested against different types, dimension and resolution of geological data. The specific aim of building a multiscale model in the Yalgoo–Singleton area is to combine multiscale datasets to take advantage of the full value of the data available and provide new knowledge of the stratigraphy, crustal architecture and underlying geodynamic process that may have led to today’s 3D geometry of the region. Since the modelling will be performed as an iterative process, we expect to find new geologic indications, point to areas that need more detailed modelling or data and raise new geological questions as the model is upscaled and downscaled. The type of data considered in this research focuses on lithological, structural and geophysical vector and grid data. Publicly available data from GSA emphasizes maximizing available pre-competitive datasets and consequentially assessing the ease-of-access of the existing data formats.

Outputs – planned or actual

- Joshi, R, Lindsay, M and Jessell, M 2019, Multiscale 3D Geological Model of the Yalgoo-Greenstone Belt Area through Subsampling of Stratigraphic Vector Maps, Oral presentation at SGTSG Biennial Meeting, Port Lincoln, South Australia, 22 November 2019.
- Joshi, R, Jessell, M and Lindsay, M 2019, Going Multiscale and Estimating Uncertainty on 3D Geological Models, Oral presentation at GeoCon 2019: Geoscience for a resilient and sustainable Philippines, Manila, Philippines, 4–5 December 2019.

MinEx CRC PhD project — Thermal history of the Gap and Madura–Forrest areas

Project manager: Stijn Glorie (University of Adelaide)

Partner researchers/institutions: Alejandra Bedoya Meija (PhD candidate),
Chris Kirkland (Curtin University)

GSWA contact: David Kelsey (co-supervisor to PhD)

Duration of project: 2022–24

Project description

This project will investigate the thermal history of three study areas within Western Australia ('The Gap' NDI area of MinEx CRC, southwest Albany–Fraser and Madura–Forrest areas), with the aim to map the low-temperature exhumation level using apatite separates from existing GSWA samples as well as newly drilled NDI samples, when they become available. The apatite fission track method records the cooling history of study areas between ~60 and 120 °C, which enables the evaluation of (differential) exhumation throughout the Phanerozoic. The method can establish the timing of fault (re-)activation and the associated relative exhumation level of the crust. This has great importance to mineral exploration as it allows us to evaluate the preservation potential of mineral deposits. In addition, the newly developed in situ Lu–Hf dating method will be applied to phosphates and garnets to help establish the geochronological framework of the study areas. Garnet Lu–Hf dating is powerful in rapidly revealing the metamorphic history of the study areas, where apatite Lu–Hf is powerful in establishing the formation age of mafic rocks (in absence of zircons).

Outputs — planned or actual

- GSWA Geochronology Record/s (publication/s) of sample batches including data tables (raw + processed data tabulated; data for standards tabulated), detailed analytical methodology, figures, sample images, sample description and interpretation
- Publication of PhD thesis as a GSWA Record
- At least one publication in an international peer-reviewed scientific journal.

MRIWA collaborative agreements



MRIWA project M470a — A multiscale approach to controls on mineralization in the Fraser Zone, Western Australia

Project managers: Katy Evans, Chris Kirkland (Curtin University)

Partner researchers/institutions: MRIWA, Independence Group NL, MG Creasy, Legend Mining, Curtin University

GSWA contact: Raphael Quentin de Gromard

Duration of project: Originally 2020–23 but was put on hold because of the delayed arrival of PhD students in Australia due to COVID-19 travel restrictions. Project has resumed in 2021 and has been extended to 2024.

Project description

This program of research will focus on the partially covered and highly prospective Fraser Zone, Western Australia.

The project will consist of four modules:

1. Architecture and stratigraphy: cutting-edge split stream LA-ICP-MS instrumentation and new mineral isotope systems will produce a reliable chronostratigraphic and tectonothermal framework, in the context of a well-constrained lithospheric architecture
2. The tectonothermal evolution of the Fraser Zone: application of new thermodynamic models with high-resolution, high-throughput, element maps of mineralized and unmineralized samples to quantify variations in pressure, temperature, time and space in the Fraser Zone
3. Controls on tenor: process-based conceptual models of crust–magma–fluid interactions based on detailed site data from our partner organizations. A data science approach will be necessary to optimize information from the large existing datasets. The outputs will be a quantitative understanding of the processes that control the grade of mineralization, and tools to recognize the presence of mineralization from indirect evidence
4. Regolith from the Silver Knight deposit will be used to develop a gossan/alteration model for the Fraser Zone deposits with predictive capacity.

This MRIWA-funded research program will build on existing investment by GSWA and Western Australia's research institutions to provide an exceptional value proposal.



MRIWA project M521 — Lithospheric and crustal-scale controls on multistage basin evolution: impacts on mineralizing systems

Project managers: Weronika Gorczyk, Mark Jessell (CET, UWA)

Partner researchers/institutions: MRIWA (UWA/First Quantum Minerals / Fortescue Metals Group)

GSWA contact: David Kelsey

Duration of project: 2018–22

Project description

This project will use an integrated basin studies approach, combining interpretation of multiple regional datasets (e.g. new seismic reflection, drillcore, gravity, magnetics) with numerical modelling to investigate multiscale (lithospheric and crustal) and multistage deformation processes. These will provide insight into the link between basement and basin evolution, and subsequent mineralization processes. The 'natural laboratory' used for this study is primarily the Paterson Orogen, in central Western Australia.

Outputs — planned or actual

- The project will produce six-monthly reports and comprehensive MRIWA reports.



MRIWA project M532 — Geology, mineralogy and metallurgy of eMaterial resources in Western Australia

This project work is completed and a Report is in preparation for publication.

Project manager: Trevor Beardsmore

Partner researchers/institutions: John de Laeter Centre, Curtin University; AXT Pty Ltd

GSWA contact: Trevor Beardsmore

Duration of project: 2020–23

Project description

To develop a geometallurgical framework for Western Australian lithium pegmatite deposits that will lead to improved efficiencies in exploration, mineral beneficiation and processing techniques.

Outputs — planned or actual

- Report, digital data package, external publications.



MRIWA project M10433 — Detection of distal footprints in the Southwest Yilgarn: linking basement and cover

Project manager: Ignacio Gonzalez-Alvarez

Partner researchers/institutions: MRIWA, CSIRO and resource companies

GSWA contact: Paul Duuring

Duration of project: 2021–24

Project description

Re-evaluating the gold prospectivity of the southwest Yilgarn through the application of recent advances in geochemical technologies, targeting chemical and isotopic anomalies in cover rocks that have been proven to provide vectors to mineralization in the more thoroughly explored central and eastern terranes of the Yilgarn.

Outputs — planned or actual

Report and GIS datasets.

Other collaborative agreements



Critical minerals (Li, Ta, Nb, W, REE) in the western Yilgarn Craton

This project is completed, but the Report and accompanying data will be published in 2022–23.

Project manager: Trevor Beardsmore

Partner researchers/institutions: CSIRO

GSWA contacts: Trevor Beardsmore, Paul Duuring

Duration of project: Completed

Project description

CSIRO will re-analyse about 3200 laterite samples from the western Yilgarn Craton using modern analytical techniques, to determine lithium and several other critical metals (i.e. tin, tungsten and REE) that could not be reliably measured in previous analytical campaigns using older technologies. The study will combine conventional geochemical analysis with the UltraFine+ methodology, indicator mineral chemistry, and studies of regolith characteristics and deportment of critical metals in primary critical mineral deposits. The intent is to understand the formation of critical metal anomalies in the regolith, and their significance as indicators of the size and quality of potential underlying mineralization. Hence, there is a need to assess critical metal potential value in the region, and provide a tool that might be applied to critical metals exploration at the regional scale.

Outputs – planned or actual

- Joint CSIRO–GSWA Report, western Yilgarn laterite geochemistry database, external publications.



CWAS Canning passive seismic deployment — Phase 3

Project manager: Klaus Gessner

Partner researchers/institutions: Huaiyu Yuan (Macquarie University)

GSWA contact: Klaus Gessner

Duration of project: 2021–23

Project description

The project will provide seismic velocity data for the active-source seismic model of the Kidson line and will provide depth information to constrain the architecture of the central Canning Basin, and its margins. The project will be essential to arrive at a better understanding of the basement of the Canning Basin and its potential for mineral systems. The CWAS project moved to the Pilbara where we are looking at deep crustal structure. The array was in place to capture the 2021 M 5.8 earthquake at Marble Bar. It is now in its second stage and has rolled southwards where it will remain until March 2023.

Outputs – planned or actual

- Seismic models of the western margin and central part of the Canning Basin, including crustal thickness maps, crustal shear wave velocity model and body-wave tomographic model down to 400 km depth.



Deep learning identification of anomalous data in geochemical datasets

This project is completed and a Report will be published in 2022–23.

Project manager: Trevor Beardsmore

Partner researchers/institutions: Vladimir Puzyrev (Curtin University)

GSWA contact: Paul Duuring

Duration of project: Completed in 2021

Project description

The study applied deep learning models to identify spurious geochemical data within the five WAMEX geochemical datasets. Spurious geochemical data are defined as those samples that have predicted analyte values that are very different to their measured values.

Outputs – planned or actual

- Report.

Do the mineral systems in the southern Kalgoorlie Terrane have a camp-scale geophysical signature?

Project manager: Michael Dentith (UWA)

Partner researchers/institutions: UWA

GSWA contact: Klaus Gessner

Duration of project: 2018–19 (extended to 2022)

Project description

Geophysical data will be collected, processed and interpreted from the region between Kalgoorlie–Kambalda–Norseman. This experiment will research whether there is a distinctive crustal-scale geophysical signature of the mineral systems in this area, which is notable for its numerous large mineral deposits. Identifying such a signature will demonstrate a means for identifying other, as yet unknown, camps in Western Australia, and hence encourage greenfields exploration in the State.

Outputs – planned or actual

- Broadband MT data and the operations report have been released in the **MAGIX** data repository under registration number 72154.

In situ mica Rb–Sr geochronology and experimental Lu–Hf garnet — Batch 2

Project partner: Chris Kirkland (Curtin University)

GSWA contact: Fawna Korhonen

Duration of project: 1 March 2022 to 28 February 2023

Project description

This project follows that for Batch 1 (2021–22) given the success of the method, workflow and product delivery. Sample selection will be carried out by GSWA with input from the Timescales of Mineral Systems Group, Curtin University, to help select the most appropriate material to address the geological question of interest for GSWA. A new textural screening tool may be used to assist in sample selection as developed in Rb–Sr Batch 1. Experimental Lu–Hf garnet will be performed on a select number of samples. Sixteen biotite Rb–Sr samples and four garnet Lu–Hf samples will be run.

Outputs – planned or actual

- Geochronology records for all samples, including data tables (raw + processed data; data for standards), figures, images of analytical spot locations, stage file of analysis spots, and interpretation. Sample thin sections returned. Research partners (GSWA and Curtin University) recognize that a key performance indicator for academic staff is the ability to publish (collaboratively with GSWA) peer-reviewed outputs. Curtin University staff involved in this work shall be permitted to publish results in symposia and journal outputs of their choosing.

Apatite geochronology for constraining salt stratigraphy

Project manager: Chris Kirkland (Curtin University)

Partner researchers/institutions: Chris Kirkland (Curtin University) / Andrew Feitz (GA)

GSWA contacts: Deidre Brooks, Peter Haines, Michael Wingate

Duration of project: 2022–25

Project description

Thick salt deposits are targeted for energy storage (hydrogen, hydrocarbon gas, compressed air). Salt caverns made by drilling and dissolving salt offer unique injectivity and sealing properties, with fast deliverability. Local thick salt diapirs near shores, are recognized in the Canning Basin, Northern Carnarvon Basin and Southern Carnarvon Basin, in the southern part of the Bonaparte Basin (Northern Territory) and in the Arrowie Basin (South Australia). However, the age and local environmental conditions of salt formation for many of Western Australia's salts are unknown or indirectly constrained. Recent work by the Timescales of Mineral System Group, Curtin University has highlighted the potential of using apatite (or other uranium-bearing minerals) within salt to directly constrain the timing of salt deposition or modification. Such geochronology may provide an important tool for stratigraphic constraint across the State and indeed Australia.

Outputs – planned or actual

- The final project report will be provided to all clients in a format suitable for public release via systems as may be provided by GA, GSWA, or Curtin University. The system chosen for release will be determined at time of completion and may include release on various platforms including, but not limited to, Curtin University's theses repository. Interim progress reports at 12 and 24 months from PhD commencement. Final project report to be provided on PhD completion.
- Isotopic and geochemical data collected during the course of this work will be provided to the partners in a format consistent with national guidelines on geoscience measurements.

Interferometric processing

Project partner: Juerg Hauser (CSIRO)

GSWA contact: Klaus Gessner

Duration of project: Completed – March 2021 to August 2021

Project description

Develop and apply a methodology to:

- Reconstruct long offset (<100 km) data from short offset (<10 km) batches of seismic reflection survey data
- Potentially enhance the signal to noise ratio
- Establish the feasibility of direct inference of the interfaces and velocity (Vp) from the data reprocessed by CSIRO.

Outputs – planned or actual

- Reports, white paper, seismic interferometric reconstruction method
- A 'white paper' progress report and a presentation of results were delivered to GSWA in November 2021.

K–Ar dating of fault rocks

Project manager: Huntly Cutten

Partner researchers/institutions: Horst Zwingmann (Kyoto University); Tonguc Uysal, Andrew Todd (ARRC, CSIRO)

GSWA contacts: Huntly Cutten, Michael Wingate

Duration of project: 2015–24

Project description

This project will involve K–Ar (and possibly Rb–Sr) dating of fault rocks, fault gouge and slickenside surfaces, to determine the ages of the most recent fault movements in low-grade rocks of the Edmund and Collier Basins, in which deformation events could previously be dated only indirectly. The project is planned to be expanded to include the eastern Capricorn Orogen basins, and additional Western Australian terranes.

Outputs – planned or actual

- Cutten, HN, Johnson, SP, Thorne, AM, Wingate, MTD, Kirkland, CL, Belousova, EA, Blay, OA and Zwingmann, H 2016, Deposition, provenance, inversion history and mineralization of the Proterozoic Edmund and Collier Basins, Capricorn Orogen: Geological Survey of Western Australia, Report 127, 74p.
- Cutten, HN, Zwingmann, H, Uysal, T and Todd, A 2021, Dating Proterozoic fault movement using K–Ar geochronology of illite separated from fault gouge: Geological Survey of Western Australia, Report 214.
- Cutten, HN, Zwingmann, H, Uysal, T and Todd, A 2022 Proterozoic activation of the Mount Vernon Fault, Edmund Basin, Capricorn Orogen, Western Australia – external publication.

Narryer Terrane isotopes project

Project manager: Hugh Smithies

Partner researchers/institutions: Tony Kemp (UWA)

GSWA contacts: Hugh Smithies

Duration of project: Ongoing

Project description

Field inspection/sampling of the Narryer gneisses, zircon isotope work (geochronology, oxygen isotopes and hafnium isotopes, both whole grain and laser ablation) and whole-rock hafnium, neodymium, and lead isotope studies.

Outputs – planned or actual

- Kemp, AIS, Wilde, SA and Spaggiari, CV 2019, The Narryer Terrane, Yilgarn Craton, Western Australia: review and recent developments, *in* Earth's Oldest Rocks, second edition *edited by* M van Kranendonk, V Bennett and E Hoffmann: Chapter 18, p. 401–433, Elsevier, doi:org/10.1016/B978-0-444-63901-1.00018-6.
- Rowe, ML 2016, Petrology and geochemistry of the Eoarchaeon Manfred Complex: origin and components: Geological Survey of Western Australia, Record 2016/22, 150p.
- Rowe, ML, Kemp, AIS, Wingate, MTD, Petersson, A, Whitehouse, MJ and van der Riet, C, 2022, Cratonisation of Archaean continental crust: Insights from U-Pb zircon geochronology and geochemistry of granitic rocks in the Narryer Terrane, northwest Yilgarn Craton, Precambrian Research 372, 106609, doi:10.1016/j.precamres.2022.106609.

National Virtual Core Library — Western Australian node

Project manager: Lena Hancock

Partner researchers/institutions: AuScope with NCRIS funding, CSIRO

GSWA contact: Lena Hancock

Duration of project: Ongoing

Project description

GSWA houses, manages and operates a HyLogger-3 semi-automated core logging facility as part of the NVCL project. GSWA owns the HyLogger, maintains it and provides operational staff as a co-investment in the project. The aim is to systematically capture hyperspectral data for all mineral and petroleum drillcore in its Perth and Kalgoorlie Core Libraries. GSWA provides data and interpretations to the NVCL, GeoVIEW.WA and other third parties.

Outputs – planned or actual

- Geoscience publications using HyLogger data; procedural publications.

Drill cuttings dataset acquisition, digitalization, and AI/ML-based lithology quantification

Project manager: Lena Hancock

Partner researchers/institutions: Dr Marina Pervukhina and Dan Hills, CSIRO

GSWA contact: Lena Hancock, Deidre Brooks

Duration of project: 2022–25

Project description

DMIRS and CSIRO will undertake work for the acquisition of high-resolution (HR) digital images of drill cuttings, processing, and development of artificial intelligence/machine learning (AI/ML) technologies for automatic lithology quantification. DMIRS and CSIRO will discuss and select cuttings from Western Australian basins that best represent agreed lithological types. The HR images and corresponding hyperspectral data will be collected for the agreed number of cuttings samples by DMIRS using HyLogger technology. The images will be used by CSIRO to train different types of neural networks including Deep Convolutional Neural Networks (DCNN) to distinguish between different lithologies, that is, to recognize mineralogy, grade, and angularity of the grains.

Outputs – planned or actual

- HR images of the cuttings accompanied with the corresponding spectral information
- Detailed written report on the development of an AI/ML technology and its application to selected cuttings datasets.



Oxygen isotope analyses of zircons

Project manager: Michael Wingate

Partner researchers/institutions: UWA, CMCA

GSWA contact: Michael Wingate

Duration of project: Ongoing

Project description

This project will add value to zircon Lu–Hf analyses by using zircon oxygen isotopes to distinguish material derived from near-surface or supracrustal environments from material derived from the mantle.

Outputs – planned or actual

- Contributions to GSWA publications and journal articles.



Paleoproterozoic mafic magmatism of the Kimberley Basin, Western Australia

Project manager: Fawna Korhonen

Partner researchers/institutions: Karin Orth (University of Tasmania)

GSWA contacts: Chris Phillips

Duration of project: Completed – final Report to be submitted

Project description

The main aims are to:

- Map the distribution and relationships of the extrusive mafic rocks and sedimentary interbeds
- Constrain the spatial and temporal relationships of the different magmatic phases within the Hart Dolerite Sill
- Search for the plumbing and drivers that lead to the eruption and intrusion of 300 000 km³ of magma
- Understand the role of mafic volcanism in the development of Australia and in particular the North Australian Craton.

Outputs – planned or actual

- Orth, K, The Hart–Carson Large Igneous Province, Kimberley Region, northwestern Australia: Report (planned, with a contribution from Susan Belford).



Pilbara gold fingerprinting

Project manager: Michael Wingate

Partner researchers/institutions: Source Certain International Pty Ltd (former TSW Analytical)

GSWA contact: Lena Hancock

Duration of project: 2019–21 (extended to 2024)

Project description

To characterize the provenance and metallogenesis of gold mineralization across the Pilbara Craton using morphometry, microstructure, associated minerals and trace element composition of bedrock and placer gold grains.

Outputs – planned or actual

- 67 Mineralogy Records
- GSWA Report.

Isotopic fingerprinting of native gold from Western Australia

Project manager: Michael Wingate

Partner researchers/institutions: Svetlana Tessalina, Bryant Ware, Neal McNaughton (John de Laeter Centre, Curtin University)

GSWA contact: Lena Hancock

Duration of project: 2021–22

Project description

Analysis of Re–Os and Pb isotopes and trace element compositions in native gold specimens from the Pilbara Craton, Kurnalpi Terrane, and Capricorn Orogen will determine model ages and the provenance of gold mineralization directly from gold and its galena inclusions.

Outputs – planned or actual

- GSWA Report and journal articles.



Tectonostratigraphic evolution and significance of the boundary between the Youanmi and the South West Terrane in the Archean Yilgarn Craton of Western Australia

Project manager: Nicolas Thébaud (UWA)

GSWA contacts: Raphael Quentin de Gromard, Tim Ivanic (co-supervisors to PhD)

Duration of project: March 2022 – September 2025

Project description

The aim of this PhD research project is to collect new geoscientific data, to test the validity of the recently revised boundary separating the South West Terrane from the Youanmi Terrane of the Yilgarn Craton through a multidisciplinary approach aimed at developing the lithostratigraphic, magmatic, structural and metamorphic evolution of the region. Collectively, the data acquired will help refine the tectonic understanding of this boundary but will also peer into the tectonic evolution of both terranes with reference to their respective metallogenic endowment.

Outputs – planned or actual

- Digital geological map layers
- GSWA Report and journal articles.

Seismic acquisition using distributed acoustic sensing in an urban environment

Project manager: Mike Dentith (UWA)

Partner researchers/institutions: UWA

GSWA contact: Klaus Gessner

Duration of project: 2017–20 (extended to 2022)

Project description

The project uses passive seismic, ambient noise-based methods to map large-scale structure, especially depth to basement. Concurrently, the seismic monitoring data will also be used as a comparative study that aims to demonstrate that instead of using seismic instruments, seismic monitoring can be undertaken using existing fibre-optic cable infrastructure. Distributed acoustic sensing is an emerging technology for seismic wavefield measurement that relies on conventional optical fibre cables to create 'virtual' strain-rate sensors at every few metres along the cable. Delivery of the project data and a final report are delayed, but expected later in 2022.

Outputs – planned or actual

- GSWA Report.

National Collaborative Framework (NCF) agreements

AusAEM–WA Project Agreement Western Australian component of Australian 20 km airborne electromagnetic surveys, GA Ref: 004495

Falls under the NCF CMCG40003A PA4

Project manager: David Howard

Partner researchers/institutions: GA

GSWA contacts: David Howard, John Brett

Duration of project: 2019–23

Project description

The project is a continuation of previous agreements NCF CMCG40003A PA4 and CMCG4003A 000668-1 – GA Ref 003995, described below.

The current focus of national geophysics has shifted to very widely spaced, broadscale AEM surveys, extending GA's 2017–20 EFTF AusAEM surveys, as part of a collaborative, national goal of the Commonwealth, State and territory geological survey agencies to acquire AEM data at 20 km line-spacing or less across the Australian continent. AusAEM–WA is the Western Australian component of this Australian 20 km Airborne Electromagnetic Survey objective (AusAEM). AusAEM–WA Stage 1 commenced in 2020–21 over the southwest and southeastern parts of Western Australia, and was completed with release of the Murchison area dataset in March 2022. Survey of the two small remaining areas in the Kimberley and in the east of the State has been funded by the EIS and will be completed as part of the GA EFTF Western Corridor program currently in progress. It is anticipated that Western Australia will have complete AusAEM 20 km coverage by June 2023.

Outputs – planned or actual

- Survey datasets including point data, grids, images and inversion products
- Released in 2021–22: Eastern Goldfields, East Yilgarn, Earaheedy–Desert TEMPEST surveys; Southwest–Albany and Murchison blocks SkyTEM datasets
- Planned for 2022–23: Kimberley and Eastern Border datasets.

Australia Minerals Project Agreement GA Ref: 003938

Falls under head agreement CMC G40003A – 000668-1

Project manager: Anthony Budd

Partner researchers/institutions: GA

GSWA contact: Executive Director, GSWA

Duration of project: 2018–23

Project description

Australia Minerals is a collaborative group of Australian state and territory government geological surveys that is an outworking of the Geoscience Working Group (GWG) under the Energy Council of the Council of Australian Governments. Australia Minerals promotes minerals investment in Australia by participating in international and domestic conferences, mining trade shows and investment seminars. GA coordinates the participation of Australia Minerals at events.

The project:

- Promotes Australia to make it the preferred destination for minerals investment, particularly at the exploration stage
- Advocates opportunities in greenfields areas, mineral provinces and commodities revealed by new geoscience information or changes in market demand
- Targets all market segments responsible for guiding investment decisions in minerals
- Committees included: GWG.

*Land access in Western Australia project agreement, GA Ref: 004637
(AUSLAMP and AUSARRAY)*

Project managers: Klaus Gessner, Ruth Murdie

Partner researchers/institutions: GA

GSWA contacts: Klaus Gessner, Ruth Murdie

Duration of project: 2019–25 (six years initial term with option for two 12-month extensions)

Project description

Australian Lithospheric Architecture Magnetotelluric Project (AUSLAMP) is a magnetotelluric survey acquiring long-period magnetotelluric data at ~3000 sites across Australia to map the electrical conductivity of the continent in 3D.

*Management of National Offshore Petroleum and Greenhouse Gas Data Repository —
National Offshore Petroleum Data and Core Repository CMCG4003A – P3*

Open-file data

Partner researchers/institutions: GA (two-way agreement)

GSWA contact: Paul Duncan

Duration of project: 2020–23

Project description

NOPIMS manages both confidential and open-file data. Confidential data is restricted to NOPTA (CMCG4003A – P1) and GA. Open-file data (CMCG4003A – P3) is available to the public to query and download offshore petroleum data.

NCF Collaborative Head Agreement Ref: CMCG40003A – 000668-1

Project managers: Director Regional Geoscience; Executive Director, GSWA

Partner researchers/institutions: GA

GSWA contacts: Director Regional Geoscience; Executive Director, GSWA

Duration of project: 2017–22 (ongoing 2021–24)

Project description

The primary objective of this Head Agreement is to facilitate collaboration between governments through various projects for integrated service delivery in order to improve:

- Agency's delivery of services to customers
- Efficiency and effectiveness of government services.

This Head Agreement describes the process and limits for forming a project with GA.

Committees include:

- Chief Government Geologist Committee
- Head Agreement Management Committee.

*NOPIMS — National Offshore Petroleum Information Management System Project
Agreement CMCG4003A – P4*

Information and communication technology (ICT) development

Partner researchers/institutions: NOPTA and GA (three-way agreement)

GSWA contact: Paul Duncan

Duration of project: Ongoing

Project description

Under the agreement, DMIRS provides services to the Commonwealth (GA and NOPTA) to deploy a petroleum information management system using DMIRS infrastructure with functionality comparable to WAPIMS. This agreement is for the ongoing development and maintenance of the system with all costs associated related to ICT Common Use Agreement personnel.

NOPTA — Offshore Petroleum and Greenhouse Gas Data Management Project Agreement – National Offshore Petroleum Data and Core Repository CMCG4030 – P1

Confidential data

Partner researchers/institutions: NOPTA and GA (three-way agreement)

GSWA contact: Paul Duncan

Duration of project: Ongoing

Project description

NOPIMS manages both confidential and open-file data. Confidential data is restricted to NOPTA (this agreement) and GA. Open-file data is available to the public to query and download offshore petroleum data including:

- Well activity and completion reports, and data
- Survey reports and data
- Titles reports and general study reports.

Some key aspects of the agreement are:

- DMIRS will host NOPIMS using DMIRS ICT infrastructure
- NOPIMS delivers capabilities for:
 - industry data discovery and delivery
 - data management
 - physical sample management
 - confidential information (CMCG4003A – P1) and open information (CMCG4003A – P3) metadata management.

NOPIMS will contain confidential and open information on wells, geophysical surveys and other related exploration and production data.



Geochronology of the Argyle diamondiferous lamproite

Project manager: Fawna Korhonen

Partner researchers/institutions: Denis Fougere and others, Curtin University, John de Laeter Centre

GSWA contact: Michael Wingate

Duration of project: 2022

Project description

This project will investigate the emplacement age of the Argyle diamondiferous lamproite pipe using a range of geochronology techniques, including U–Pb dating of perovskite and phosphate minerals, Ar/Ar dating of K-bearing minerals, and (U–Th)/He dating of zircon.

Outputs – planned or actual

- Journal articles and contributions to GSWA publications.

RECORD 2022/1

GSWA WORK PROGRAM 2022–23

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Fieldnotes

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