



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

RECORD 2019/1

GEOLOGICAL SURVEY WORK PROGRAM FOR 2019–20 AND BEYOND

2019



Geological Survey of Western Australia



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and **Safety**

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Perth 2019



**Geological Survey of
Western Australia**

MINISTER FOR MINES AND PETROLEUM

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Cover image: Sunset over the Yalgoo Mineral Field. Photograph by T Ivanic, DMIRS

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Geological Survey work program for 2019–20 and beyond

Executive summary

In 2018, the Fraser Institute's Annual Survey of Mining Companies (Stedman and Green, 2018a) saw Western Australia raise its ranking from fifth to second-most attractive mining investment destination worldwide. Our ranking based on geological databases also rose to thirteenth in 2018, from seventeenth in 2017. For petroleum, the Fraser Institute's Global Petroleum Survey for 2018 (Stedman and Green, 2018b) ranked Western Australia as thirty-fifth in the world, which has been fairly consistent over the last 5 years. Petroleum geological databases ranked sixteenth, which is similar to 2017 and significantly better than the 2016 ranking of forty-second. The geological database rankings in both mining and petroleum surveys remains a concern and the Geological Survey of Western Australia (GSWA) is undertaking a data strategy initiative, starting in 2019, that will review how we collect, manage and distribute our data into the future. This strategy will also consider the national data initiatives that are a part of the Resources 2030 Strategy.

The Mineral Exploration Cooperative Research Centre (MinEx CRC) was created in 2018, which includes work on new drilling initiatives (the National Drilling Initiative [NDI]) and the UNCOVER concept for new greenfields exploration. GSWA is committed to working with the MinEx CRC in developing opportunities for research and application of new technologies in future exploration in Western Australia.

In 2019–20, GSWA will have a budget of approximately \$32 million (excluding departmentally funded projects) that is a combination of recurrent and Exploration Incentive Scheme (EIS) funding.

Staffing will comprise:

- ~139 permanent full-time equivalent (FTE)
- 9 permanent part-time in 2019–20
- 8 FTE staff funded from the EIS
- 9 contract full/part-time
- ~37 short-term fee-for-service contractors (as of 1 July 2019)

We anticipate approximately 32 active collaborative research projects partly funded by GSWA.

GSWA plans to publish the following flagship products:

- | | |
|--|----|
| • Reports, Records, Bulletins and non-series books | 38 |
| • Other maps (including State maps & plates) | 12 |
| • Data packages | 17 |

Other headline deliverables for 2019–20 are:

- to develop the mines and mineral deposits information database (MINEDEX) 2018 User Interface
- to develop the geochronology and mineral geochemistry data via an online application
- to implement workflow and product allocation system, Pubstats, using K2
- to develop an electronic lodgement of survey field books
- continue Section 40E reporting.

A major challenge for GSWA, and one that will certainly impact on products delivered in future years, is aligning the work program to obtain maximum leverage from three major external initiatives — the industry-led roadmap of UNCOVER, Geoscience Australia's (GA) Exploring for the Future project in Northern Australia (which finishes in June 2020) and the report of the Resources 2030 Taskforce.

Note: all currencies are Australian dollars unless otherwise indicated.

PART 1

DETAILED WORK PROGRAMS FOR 2019–20 AND BEYOND



GS10 Basins and Energy Geoscience

Manager: Deidre Brooks

Team members: Norman Alavi, Heidi Allen, Iain Copp, Lorraine de Leuw, Louisa Dent, Ameer Ghori, Peter Haines, Sarah Martin, 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 petroleum system frameworks for Western Australia's onshore sedimentary basins. The aim is to encourage increased exploration for energy resources such as petroleum, coal and geothermal energy resources, and thus secure the State's energy future.

The team works in collaboration with other divisions of the Department of Mines, Industry Regulation and Safety (DMIRS) and other organizations, including the Commonwealth Scientific and Industrial Research Organization (CSIRO), Western Australian Energy Research Alliance, The University of Western Australia (UWA), Curtin University, 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 Canning, Carnarvon and Perth Basins. These basins have proven petroleum systems and are underexplored, particularly in the case of the vast Canning Basin. The branch is also contributing to new geological assessment of the Western Australian portion of the Centralian Superbasin, including the Amadeus and Officer Basins, and interpreting results to better understand the petroleum potential of these older basins.

The main operational project the branch is involved with in 2019–20 is the planning, drilling and post-well analysis and interpretation of a stratigraphic well in the Waukarlycarly Embayment, which is an undrilled graben in the western margin of the Canning Basin. This project is funded by the Commonwealth Government Exploring for the Future Program and is operated by DMIRS, in particular the geoscientists within this branch.

During 2019–20, studies will include an expansion on the previous palynological review of the Harvey Ridge. Seismic interpretation and mapping of the Southern Carnarvon Basin will commence and seismic interpretation of the Canning Basin will continue. Both of these projects will incorporate EIS-funded, newly reprocessed vintage 2D seismic data. Other projects during 2019–20 include building 3D depth models of significant geological surfaces in the regions where mapping has recently been completed (southern Perth Basin and western Canning Basin), a compilation and map showing the distribution of hydrocarbon shows in the Canning Basin, compilation of a Digital Core Atlas for Sally May 2 and Nicolay 1 and a review of the Cobb Embayment, Lucas Outlier and Prices Creek Group of the Canning Basin based on fieldwork.

Canning Basin

The main issues and uncertainties in the Canning Basin include:

- unreliable and irregularly distributed geochemical data, creating uncertainties regarding the definition and distribution of petroleum systems
- inconsistent application of stratigraphic nomenclature across the basin, especially in the Paleozoic section, resulting in variations in formation tops between wells
- lack of biostratigraphic data in many wells and intrinsic difficulties of biostratigraphically dating some stratigraphic intervals thereby rendering uncertain correlations
- uncertain validity of the structural and tectonic framework
- lack of good-quality well and seismic data, and issues regarding the quality and distribution of the data, especially in the Kidson Sub-basin, where well and seismic data are sparse.

Southern Carnarvon Basin

The main issues and uncertainties in the onshore to nearshore Southern Carnarvon Basin include:

- questionable stratigraphic correlations due to the lack of biostratigraphic control in wells and poor-quality seismic ties
- paucity of well data to assess Triassic and Permian petroleum source-rock potential
- poor-quality vintage seismic data and sparse/irregular regional coverage.

Perth Basin

The main issues and uncertainties in the Perth Basin include:

- patchy seismic coverage of variable quality
- questionable stratigraphic correlations due to the lack of biostratigraphic control in many wells and poor-quality seismic ties
- paucity of well data to assess shale gas, tight gas and carbon sequestration potential in the Perth Basin
- uncertainty about the tectonic and structural evolution, and depositional history of the basin.

Officer Basin

The main issues and uncertainties in the Officer Basin include:

- extensive surficial cover and deep weathering of outcrops mean that most information must come from sparse drillcores and limited seismic data
- stratigraphic control and correlation across Western Australia, and into South Australia, are in need of refinement
- new mineral cores are available in some areas but have not been assessed for their stratigraphic and biostratigraphic information, or sampled for source-rock evaluation
- the existence of Neoproterozoic source rocks in Western Australia remains problematic despite oil and gas shows in a number of wells in Western Australia and South Australia; a revised source-rock sampling strategy is required.

Amadeus Basin

The main issues and uncertainties in the Amadeus Basin include:

- extensive surficial cover and deep weathering of outcrops; stratigraphic sections are incompletely exposed (particularly shale-prone successions) and source-rock properties cannot be determined
- lack of subsurface data; aircore cuttings from recent mineral company drilling need assessment
- stratigraphic control and correlation with the remainder of the basin; this problem is currently being addressed, although the details remain problematic
- limited biostratigraphic control, apart from stromatolites
- remoteness and difficulty of vehicular access due to the few roads and tracks and extensive sand dunes.

Planned work program 2019–20

Regional geological, geophysical and petroleum geochemical studies for the Amadeus, Canning, Carnarvon, Perth and Officer Basins will continue during 2019–20 and beyond.

Canning Basin

Studies will continue on the Ordovician Goldwyer, Nambett and Willara Formations and the age-equivalent Prices Creek Group; the Devonian – Carboniferous Fairfield Group; the middle Carboniferous–Permian Grant Group and Reeves Formation. Regional seismic interpretation of the southern Canning Basin will be ongoing and results from the study of new cores from industry-drilled wells in the Canning Basin will be incorporated into regional projects such as:

- palynology of the middle Carboniferous – Permian

- publication of the report on seismic interpretation and mapping of the Willara Sub-basin and Broome Platform
- continued seismic interpretation of the Paleozoic in the southern Canning Basin
- commencement of interpretation of new airborne gravity surveys that were acquired over the Canning Basin in 2017 and 2018
- writing of a Record on the Cobb Embayment, southeast Canning Basin to be released in 2019–20
- continued investigation into the age and composition of the basement underlying the Canning Basin
- continued field and petrographic studies into the Ordovician Prices Creek Group and investigation of correlation with the Nambett Formation
- completion of a digital core atlas for Sally May 2, planned for release in 2020–21
- a Record on the Wallal Rift System.

Perth Basin

Studies on biostratigraphy and stratigraphy will continue, including:

- a palynological data review for the southern Perth Basin, excluding the Harvey region
- revision of stratigraphy in Wendy 1 and surrounding wells.

Carnarvon Basin

Studies in the Southern Carnarvon Basin will continue, including:

- source-rock potential of the Triassic and Permian of the onshore and nearshore Carnarvon Basin
- stratigraphy and biostratigraphy of the Permian Byro Group
- commencement of seismic interpretation of the Southern Carnarvon Basin incorporating new EIS-funded, reprocessed seismic data
- new age constraints on the Tumblagooda Sandstone.

Officer Basin

Studies on the petroleum potential of the basin will continue, including:

- a review of new well data with an emphasis on the petroleum potential of the Officer Basin
- new analysis of existing core and other well samples.

Amadeus Basin

Studies on stratigraphy, biostratigraphy, structure and petroleum potential of the Amadeus Basin will continue in collaboration with NTGS, including:

- continuation of writing of a Report on revised stratigraphy of the western Amadeus Basin
- cross-border collaboration with NTGS (which included joint fieldwork) to facilitate better understanding of the evolution and resource potential of the Amadeus Basin
- examination of recently acquired aircore samples from mineral company drilling to assess potential for organic geochemistry and palynology.

Regional studies

Regional studies will include:

- an increase in new, pre-competitive information to assist in assessment of the petroleum prospectivity of proposed State Acreage Release Areas
- continuation of a review of all petroleum source rocks within the basins of Western Australia
- a collaborative project with Curtin University to document the Mesozoic of Western Australia (resulting in a book in the GSWA Western Australia unearthed series)
- external publications where appropriate.

Products planned for release 2019–20

- A seismic interpretation of the Broome Platform, Willara Sub-basin and Munro Arch of the Canning Basin, Western Australia (Report)
- Geology and petroleum prospectivity of the Wallal Rift System (Report)
- Middle Carboniferous – Permian (Grant Group and Reeves Formation) palynostratigraphy (Report)
- Cobb Embayment of the Canning Basin (Record)
- Geology of the northern Perth Basin — a field guide for the Australasian Exploration Geoscience Conference (AEGC) 2019 (Record)
- 3D model of the southwestern Canning Basin (digital product)
- 3D model of the southern Perth Basin (digital product)
- Handbook for the study and description of Microbialites (Bulletin)
- Paleontology reports (ad hoc, as required).

GS12 Land Use Planning

Manager: Warren Ormsby

Land Use Administration: Samantha Carter, Mike Critch, Anjali Epanomitis

Land Use Geoscience: Don Flint, Jordana Gardiner-Haukohl, David Hamdorf, Shane Kenworthy, Lisa Kirby, Kevin Ridge, Sarah Sargent

Land Use Planning plays a key role in providing geological information, advice and approval to assist in government decision making related to the most appropriate use of land. The provision of relevant geological information to State and local government authorities, planners and the community contributes to Western Australia's economic sustainability and helps to ensure that the interests and rights of all parties are recognized.

This combines land use-related geological, regulatory, administrative and policy functions into one branch within DMIRS.

Proposals for land subdivisions and other land use changes are routinely received from State and local government authorities. Each proposal is examined, its implications for access to mineral and energy resources assessed, recommendations, advice and, where necessary, approvals made accordingly.

Roles of the Land Use Planning branch include:

- providing geological input to other government activities such as mapping, and advice to support planning policies, strategies and schemes
- providing approvals and recommendations for proposed land tenure and land use changes throughout the State
- assisting with the development of land use planning policy both within DMIRS and across government
- publishing resource potential for land use planning mapping and the provision of mapping of strategic basic raw materials, and other strategic mineral and petroleum resources, for inclusion into State planning policies, and regional and local planning strategies and schemes
- administering the Western Australian Register of Geoheritage Sites and Geoheritage Reserves.

Planned work program 2019–20

The branch will continue to provide information, advice, assessment and approval in response to routine requests from other government agencies, as well as continue to be involved in the following priority government projects:

- the South West Native Title Settlement and the Geraldton Alternative Settlement Agreement
- the Plan for Our Parks conservation initiative
- carbon farming.

Funding will continue for the South West Native Title Settlement project to fund one additional geologist to facilitate the branch's role in this project. It is anticipated that there will continue to be substantial land approvals and recommendations associated with this project. Funding will also continue into early 2020 for a geologist to carry out further assessments and consultation associated with the Geraldton Alternative Settlement Agreement.

Plan for Our Parks is a major conservation initiative comprising five million hectares of new conservation reserves. A contract geologist will be assisting with the prospectivity assessments and consultation with the resources industry to inform government decision making on these reserves.

The branch will continue to engage collaboratively with other government agencies, including local government to help to clarify roles, streamline administrative arrangements and to provide strategic land use planning advice.

Products planned for release 2019–20

- Aboriginal land, conservation areas, mineral and petroleum titles and geology, Western Australia — 2020 (map).

GS14 Statutory and Resource Information

Manager: Nicole Wyche

Team members: Cecilia D'Ercole, Jodi Dunbar, Amanda Jones, Jutta Pagel, Sarah Sargent (from June 2019), Caroline Strong

The Statutory and Resource Information (SRI) 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 on most mineral commodities. Data users include other DMIRS divisions, other government agencies, research organizations and a range of industries and individuals. The SRI branch also has a regulatory role, performing compliance assessments relating to the *Mining Act 1978* and related legislation.

A key component of this work is the maintenance and enhancement of Western Australia's mines and mineral deposits information 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 use, and is also available registration-free for external users. MINEDEX also generates unique site and project identification qcodes 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 the Data and Software Centre.

The SRI branch produces commodity-related publications. Compliance applications processed by the branch include mineralization and resource reports submitted in support of mining lease applications, applications for expenditure exemptions, extensions of term, retention licences, retention status, combined reporting and special prospecting licences. The group also assesses sterilization reports submitted with mining proposals.

The branch has also submitted a proposal to develop online reporting of Section 40E ('prospecting permit') mineral recovery data, which is funded by the EIS.

In 2019–20, the branch will also focus on the following core tasks:

- population of MINEDEX with current industry activity data
- management of the RMS production report and the data generated by this report
- servicing other DMIRS databases via MINEDEX data
- completion of the Mining Act and related assessments
- providing specialist information to internal and external stakeholders on mining industry activities
- generating specialist publications (see product list below).

Products planned for release 2019–20

- Major resource projects, Western Australia 2020 (map)
- Mines – operating and under development, Western Australia 2020 (map)
- Significant exploration activity in Western Australia (on-demand 'hotspots' map poster available at the GSWA Open Day and at Diggers & Dealers)
- Resource projects – Goldfields region (map).

Planned work program 2019–20

The major development project for 2018–20 is the MINEDEX user interface redevelopment project. This project will replicate the aging MINEDEX code in software framework .NET.Core, and the new user interface will conform to the standards created by the Office of Digital Government for improved digital service delivery. Key aims of this project include improving search options on MINEDEX data, improved accessibility and compatibility with modern devices (mobile phones and tablets). This project is due for completion in the second half of 2019.

GS20 Mineral Systems Studies

Manager: Trevor Beardsmore

Team members: Lauren Burley, Paul Duuring, Joshua Guilliamse, Lena Hancock, Sidy Morin-Ka, Franco Pirajno (Emeritus)

The Minerals Exploration Geoscience branch focuses on mineral systems in Western Australia, with the objectives of building metallogenic models and improving our understanding of the geodynamic environment of ore formation, thereby assisting with making exploration targeting in greenfields areas more predictive. Such work typically involves fieldwork (mapping, core logging and sampling) and laboratory studies (petrology, geochronology and isotope chemistry), and is supported by and supplements existing databases. The branch makes extensive use of the GSWA HyLogger (project GS95) to assist with detailed studies of alteration assemblages in diamond drillcore and other specimens from mineral deposits. The work in this area has been complemented by projects funded by the EIS (reported herein under ES43 Mineral Systems). All mineral systems knowledge is ultimately made available for the benefit of resource companies, research groups, other government agencies and the wider community. This knowledge is disseminated via Geological Information Series (GIS) packages and internal and external publications.

Planned work program 2019–20

The branch will continue its studies of selected mineral systems and deposits. Outstanding reports from recent projects will be completed and published, including those describing:

- age and alteration at the Browns Range hydrothermal vein- and-breccia-hosted heavy rare earth element (REE) deposits
- nickel sulfide mineralization in the northeastern Yilgarn
- syngenetic gold mineralization at Mount Clement, Capricorn Orogen
- volcanogenic massive sulfide (VMS) mineralization at the Manindi camp, Murchison Terrane
- ‘gold fingerprinting’ techniques in the Kurnalpi region, Yilgarn Craton
- metallogeny of Archean banded iron-formation (BIF)-hosted iron ore in the Yilgarn and Pilbara Cratons.

Work on VMS systems in 2019–20 will involve further field and laboratory studies of the geological settings and metallogeny of deposits in the Manindi camp, Murchison Terrane.

Ongoing studies of REE systems will include laboratory studies of fluid inclusions and alteration at the John Galt deposit, to place constraints on the physical and chemical conditions of mineralization.

Also continuing during 2019–20 will be collaborative studies of gold prospectivity using ‘gold fingerprinting’ techniques developed in the pilot study of the Kurnalpi region. Work will include establishing the depositional context(s) of the gold nuggets in the Pilbara Craton by relating gold nugget characteristics and their distribution to known bedrock-hosted gold occurrences in the Pilbara. Studies of gold provenance and prospectivity using ‘alluvial’ nuggets and ‘bedrock gold’ will begin by negotiation of access to projects and sourcing of suitable sample material.

The study of the Mount Clement gold deposit will be completed and the results published. Outcomes from recent reconnaissance mapping, sampling and laboratory studies of less well-documented deposits in the region will further constrain the metallogeny of the Ashburton Basin.

The branch will also initiate a Mineral Systems study of the South West Terrane of the Yilgarn Craton, particularly focusing on mineralization of gold and ‘battery minerals’. This study will begin with a review of the current knowledge of the metallogeny of this region, followed by initial sampling and laboratory studies of several gold deposits. A collaborative approach will be applied to this project by involving interested company and research organizations.

Field mapping and sampling, and petrological and lithogeochemical studies will continue for the mafic Warakurna large igneous province, including assessment of Cu–Ni–PGE (platinum group elements) prospectivity. The study of regional nickel prospectivity of the northeastern Yilgarn Craton will also continue, in order to understand the tectonostratigraphic evolution of that region.

Following the successful release of GSWA’s online Mineral Systems Atlas and Guide at the GSWA Open Day in 2019 (project ES43), the branch will continue to develop the Atlas. Several significant geological proxy layers for komatiite-hosted nickel and BIF-hosted iron mineral systems will be added, and systematic analyses of other systems will be undertaken to define mappable geological proxies for critical metallogenic processes, assisted, where possible, by subject matter experts in other organizations.

Conceptual design work will begin on a mineral deposit explanatory notes system.

The Minerals Exploration Geoscience branch will continue to manage or monitor — and, where relevant, be involved with — collaborative minerals-oriented research initiatives funded by GSWA.

Products planned for release 2019–20

- Komatiite characteristics of the Fischer East nickel sulfide prospects: implications for nickel prospectivity in the northeastern Kurnalpi Terrane (Report; based on Master of Economic Geology dissertation)
- Geology and nickel mineralization in the Collurabbie greenstone belt, northeast Yilgarn Craton (Report; provisional title)
- Alteration and age of the Browns Range heavy REE deposits (Report; provisional title)
- Origin of rare earth element mineralization at the John Galt prospect, East Kimberley (Report; provisional title)
- Syngenetic gold mineralization at Mount Clement — a potentially unrecognized c. 1820–1770 Ma Capricorn Orogeny mineral system (Report; Provisional title)
- Provenance fingerprinting of gold from the Kurnalpi Goldfield (Report; provisional title)
- A review of known mineral systems in the South West Terrane, Yilgarn Craton (Report; Provisional title)
- Geological setting and alteration characteristics of the Manindi VMS deposits, Murchison Terrane (Report; Provisional title)
- Results of fluid inclusion analysis of samples from the John Galt REE prospect, East Kimberley (Record; provisional title)
- Absolute age constraints for magnetite mineralization at Koolyanobbing and Windarling, Yilgarn Craton (Record)
- Sensitive high-resolution ion microprobe (SHRIMP) U–Pb dating of xenotime from the Wolverine and John Galt REE deposits (Geochronology Records)
- Multiple HyLogger records from Minerals Geoscience branch projects
- External publications as appropriate.

Planned work program and products 2020–21

The branch will continue examining significant Western Australian mineral systems. This work will be done in close collaboration with GSWA's regional mapping section and, as appropriate, with other government and academic institutions, and an expanding network of affiliated exploration and mining companies. The section will continue to engage with collaborative mineral systems-oriented research projects funded by GSWA.

The branch will continue the development of the digital Mineral Systems Atlas, which will deliver mappable, mineral systems-focused geological data layers, drawing upon other in-house and external expertise where required. Future products may include targeted prospectivity studies

GS52 East Yilgarn

Manager: Jyotindra Sapkota

Team members: Matt de Paoli, Melissa Drummond, Stephen Wyche

The Eastern Goldfields Superterrane (EGST) occupies the eastern third of the Archean Yilgarn Craton and is widely considered a typical upper-crustal granite–greenstone terrain. This highly mineralized region contains world-class gold and nickel deposits, and significant deposits of other commodities, including base metals, REE, uranium, gemstones and industrial minerals. The EGST has been divided into four tectonostratigraphic terranes bounded by high-strain zones, from west to east: the Kalgoorlie, Kurnalpi, Burtville and Yamarna Terranes.

The present terrane configuration is traditionally interpreted to reflect accretion of a number of pre-existing ‘continents’ in a series of collisional events between c. 2800 and 2650 Ma. The effects that mantle plumes have had on the magmatic stratigraphy of the greenstones is reflected by the local abundance of komatiites and associated basalts. However, systematic geological mapping and the acquisition of a substantial body of geochronological and geochemical data, indicate that evolutionary models involving rifting of an autochthonous basement also need to be (re)evaluated. These different models can lead to different interpretations on the nature of magma source regions and the evolution of trans-lithospheric structures that form pathways for mineralizing magmas and fluids.

Basalt-dominated greenstone sequences are mapped, intersected in drillcores and recognized in geophysical surveys throughout the EGST. However, linking geological events (e.g. depositional/crystallization or deformation events), stratigraphy or structures within and between individual greenstone belts remains one of the most significant challenges towards a better geological understanding of the region. Only in the Kalgoorlie Terrane, between Norseman and Agnew, has a significant stratigraphic correlation been attempted. Here, most of the exposed greenstones belong to the 2801–2690 Ma Kalgoorlie Group, which comprises the lowermost mafic–ultramafic sequence in most individual greenstone belts. These sequences are not physically contiguous but have a broad similarity in rock types, stratigraphic variations and age, and so have been distinguished as 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). Above the Kalgoorlie Group, the Black Flag Group (2690–2665 Ma, equivalent to the Mount White Group in the Agnew–Lawlers region), comprises mainly turbidite-type deposits, felsic volcanic and volcanoclastic rocks. Younger siliciclastic to felsic volcanoclastic sequences, 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, overlie the Black Flag Group along low-angle unconformities.

Planned work program 2019–20

Current work aimed at generating a seamless bedrock stratigraphic interpretation across the Eastern Goldfields Superterrane at 1:100 000 scale (Fig. 1) will be suspended for a two-year period (2019–21). Within this period, geological studies will focus in the area covered by a high-resolution seismic survey conducted in early 2019 by GSWA between Ora Banda and Kambalda. Detailed structural, metamorphic, geochemical, geochronological and isotopic data will be collected from outcrop and diamond drillcore to support the geological interpretation of the seismic data, together with the formulation of a model for the geological evolution of the area. Available company geological maps and drillhole data will be used to consolidate GSWA’s mapping and stratigraphic interpretation in selected areas, after field verification. The Greenstone Geochemical Barcoding program will continue to work towards a geochemical fingerprint of local to regional magmatic greenstone stratigraphy and support regional correlation. Work has commenced on creating a virtual field guide of important geological localities in the East Yilgarn.

Products planned for release 2019–20

- P–T–t evolution of a suite of layered metamorphosed mafic and sedimentary rocks in the Copperfield area along the Ballard Shear Zone (Record).

Planned work program and products 2020–21

- Geological reinterpretation of the volume covered by the Ora Banda – Kambalda high-resolution seismic survey area will continue, and will include ongoing collection of structural, geochemical, geochronological and isotopic data.
- The Greenstone Geochemical Barcoding program will continue.
- Program of 1:100 000-scale seamless bedrock stratigraphic interpretation across the EGST will continue (2021–22) and move to the area north of Agnew.
- Production of a virtual field guide of important geological localities in the East Yilgarn will be ongoing.

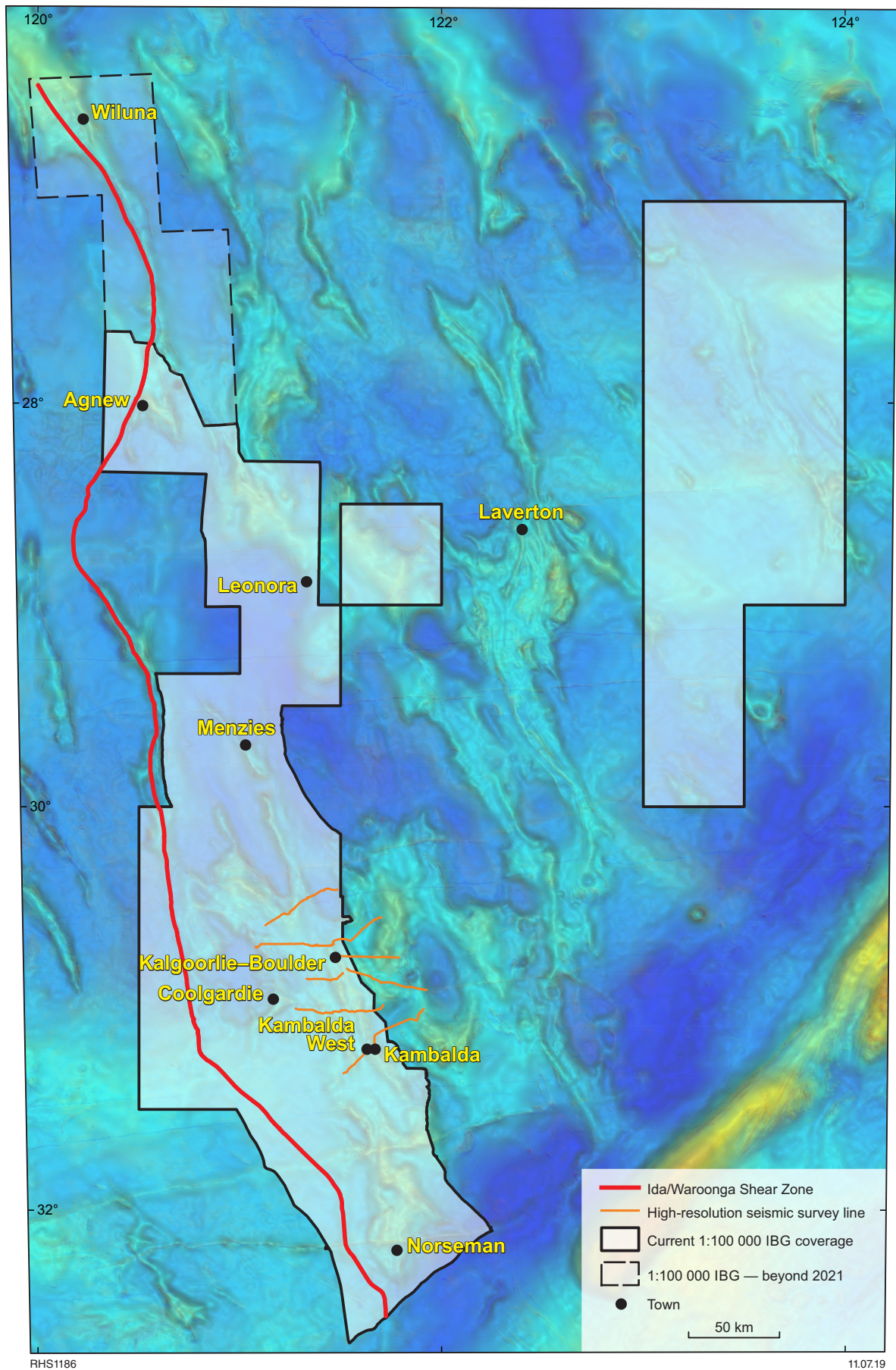


Figure 1. Gravity image of the Eastern Goldfields Superterrane (EGST), to the east of the Ida/Waroonga Shear Zone (after Brett, 2019), outlining areas already covered by 1:100 000-scale interpreted bedrock geology (IBG) mapping and stratigraphic interpretation, and the region where this mapping program will likely concentrate after resumption in 2021–22. Also shown are lines along which high-resolution seismic surveys were conducted in 2019

GS53 Chief Geoscientist and Terrane Custodians

Manager: Simon Johnson

Team members: Huntly Cutten, Terry Farrell, Imogen Fielding, Sarah Goss, Fawna Korhonen, Angela Riganti, Sandra Romano

Terrane custodians: Peter Haines (Basins), Simon Johnson (Proterozoic), Vacant (regolith), Vacant (Archean)

The State Geoscience branch is responsible for maintaining a coherent geological framework for Western Australia and ensuring geoscience information delivered by GSWA is relevant, appropriate and of a high standard. This includes delivering GSWA geoscience as multi-themed products developed and extracted from information stored in GSWA databases, with single-layer datasets, documents and static, printed or downloadable maps only part of the total product. The role of the State Geoscience branch in achieving this is twofold. They work with project teams and groups as appropriate, guiding and overseeing development and population of GSWA databases, coordinating capture of spatial and textual legacy data, contributing to products as appropriate, validating database content, reviewing and approving manuscripts and spatial products, and coordinating work that spans more than one project. They work independently on geological problems not part of current GSWA project work and on statewide geological issues and datasets. The work of the team is thus partly process, with definable standards but no clearly defined outcomes, and partly program, for which there are outcomes. Explanatory Notes System (ENS) content management and monitoring, legacy data capture and management of quality control and product relevance are the processes; whereas outcomes and products arise from delivery of State-level datasets.

Planned work program 2019–20

Work during 2019–20 will focus on the update of online data delivery systems and on progress towards the update and delivery of new, key data layers to GeoVIEW.WA, including the southern half of the seamless 1:500 000 regolith–landform layer. Updates are also planned to the 1:500 000 interpreted bedrock geology layer to ensure the data are current. Work will continue on the implementation and progressive attribution (dip, age and reactivation events) of the current State 1:500 000 linear structure layer.

Work has begun on developing an in-house, bespoke database to hold and deliver geochronology, isotope, mineral chemistry and thermobarometric data. The data will be delivered through the GeoVIEW.WA platform and will increase the way such data can be interrogated and downloaded. This work will coincide with the continued development of a State metamorphic map (at various scales) and the production of individual, sample-based metamorphic Records.

Population of ENS, monitoring of the style and quality of GSWA geoscience, and overseeing GSWA database capture and validation will continue. Work will commence on the population of regolith–landform units as well as the continued population and updates to lithostratigraphic and tectonic units and orogenic events. The branch will investigate whether it is possible to deliver the statewide Western Australian field observation database (WAROX) dataset online through the GeoVIEW.WA platform.

Work will continue on the fourth (Mesozoic) and fifth (Archean) parts of the concise geology of Western Australia (Western Australia unearthed series) as well as several geotourism products including a book on the geology of the Kalbarri area.

Products planned for release 2019–20

- Compilation of WAROX data, 2020 update, with potential delivery through GeoVIEW.WA
- Update of attribution table (dip, age and reactivation events) of 1:500 000 State linear structures digital map layer and begin data population
- Update of 1:500 000 State interpreted bedrock geology digital map layer
- Release of 1:100 000 project geology regolith–landform layer in GeoVIEW.WA
- Release of seamless 1:500 000 regolith–landform layer in GeoVIEW.WA for the southern half of the State
- Updates to the 1:100 000 interpreted bedrock geology digital map layer
- Extended ENS content (including regolith)
- ENS for State impact structures and associated lithostratigraphic units
- Geology of the Kalbarri area.

Planned work program and products 2020–21

Work will continue to focus on the maintenance, upgrade and population of spatial and textual datasets, extension of the Western Australia unearthed products to layperson's guides and region-by-region guides, and quality assessment of GSWA products and data.

GS54 Geochronology and Geochemistry

Manager: Michael Wingate

Team members: Imogen Fielding, Frances James, Jack Lowrey, Yongjun Lu, Ed Mikucki, Marlene Papiccio, 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 contribute to enhancing the prospectivity of the State. 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.

Geochronological techniques are applied to constrain the timing of magmatism, metamorphism, deformation and mineralization, using a range of isotope systems (mainly U–Pb, Ar/Ar and Re–Os) and a variety of minerals (zircon, baddeleyite, monazite, titanite, hornblende, feldspars and micas). The SHRIMPs in the John de Laeter Centre at Curtin University are used extensively by GSWA for U–Pb geochronology. GSWA also uses laser ablation inductively coupled mass spectrometry (LA-ICP-MS) instruments in the John de Laeter Centre to date detrital zircons, to date monazite and xenotime in thin sections in support of metamorphism and pressure–temperature–time (P–T–t) studies, and to measure the trace element compositions of minerals.

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 WACHEM database and made available through the online GeoChem Extract application.

Geochronology and geochemistry results and derivative materials are used extensively in GSWA's isotope geology studies, led by Yongjun Lu (ES46 Enhanced Geochronology and Isotopic Mapping). These include specialized isotope geochemistry studies, including whole-rock Sm–Nd, Lu–Hf and Pb-isotope analyses, zircon Lu–Hf and oxygen isotope analyses, and Re–Os mineral analyses. These investigations are conducted in collaboration with external university laboratories.

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 the Perth Core Library at Carlisle. The laboratory also manages archiving and retrieval of materials in GSWA's extensive sample collection to support numerous in-house and external research projects, and coordinates petrographic services for geologists.

The project work for GS54 is funded through ES46. Accordingly, details of the work program are discussed within ES46.

GS55 Geophysics Acquisition and Processing

Manager: David Howard

Team member: John Brett

The role of the Geophysics Acquisition and Processing section is to plan and manage regional geophysical data acquisition projects, to prepare datasets for delivery to the public and internal users, and to provide processing, interpretation services and advice as required.

The section will continue to manage the airborne geophysics index data repository (MAGIX) and the submission, archive and release of airborne and some ground survey datasets supplied by the exploration industry.

Planned work program and products 2019–20

The planned work program for 2019–20 and beyond is described separately under programs ES30 (Airborne and Ground Geophysical Surveys) and ES37 (Eastern Goldfields Seismic Survey). All new data acquired will be included in updates to the relevant statewide compilation datasets.

GS58 West Yilgarn

Manager: Tim Ivanic

Team member: Jack Lowrey

The Youanmi Terrane in the western part of the Archean Yilgarn Craton comprises an extensive Archean granite–greenstone terrain that contains significant deposits of gold, iron ore, nickel, copper, lead, zinc, tungsten, molybdenum, bismuth, vanadium, titanium, beryllium, lithium, tin, tantalum and uranium. The region clearly has the potential for more discoveries of these commodities. The Youanmi Terrane has a long and complex geological history. An understanding of the tectonic evolution of the region, including its structure and stratigraphy, is essential to understanding the controls on formation and distribution of mineralization.

Youanmi Terrane greenstones were deposited between 2990–2700 Ma and can be subdivided into four main time intervals: 1) 2.99 – 2.91 Ga, for example the Madoonga and Gossan Valley Formations; 2) the 2.82 – 2.80 Ga Norie Group; 3) 2.80 – 2.74 Ga Polelle Group; and 4) the 2.74 – 2.71 Ma Glen Group and Marda Complex. Felsic plutonic rocks intruded during each of these time periods followed by voluminous plutonism from 2.7 – 2.6 Ga, which led to cratonization of the Yilgarn Craton.

Much of the geoscientific work conducted so far in the Youanmi Terrane has concentrated on its Neoarchean greenstone sequences. However, there is a large temporal gap in the understanding of the crustal evolution of the proto-Yilgarn Craton and its architecture during the Mesoarchean from 3.1 – 2.9 Ga. Most rocks of this age within the Yilgarn Craton are in less well-known portions of the Youanmi Terrane, typically where data density is low and map coverage relatively poor.

Thus, the main objective of the West Yilgarn project is not only to expand the existing understanding of Neoarchean rocks but also add a new level of interpretation to the Mesoarchean history of the Youanmi Terrane. This new interpretation will offer a wider appreciation of the configuration of the protocraton onto which the voluminous Norie, Polelle and Glen Groups were deposited, and through which the giant layered intrusions at 2.8 Ga were channelled. An expanded temporal framework with documentation of new magmatic suites will allow for an improved context for exploring terrane endowment by VMS, Ni, Fe and Au mineral systems.

Planned work program 2019–20

Mapping at a 1:100 000 scale will target areas of undated stratigraphy, which will greatly advance our understanding voluminous greenstones, initially in the Sandstone area (Fig. 2). Mapping will be accompanied by targeted sampling for high-precision geochemical, isotopic and geochronological analysis, which will be obtained from outcrop and diamond drillhole samples. Areas previously mapped between 1995 and 2005, such as Sandstone, will be augmented by interpreted bedrock geology mapping

utilizing more detailed geophysical coverage, geochemical data, geochronological control and drillhole observations. This will allow an expansion of our ongoing stratigraphic categorization of the terrane. Spatial data will seamlessly merge into existing Murchison Geological Information Series (GIS) data layers and form the new Youanmi GIS with wider coverage.

We will also begin geochemical and geochronological sampling in the southern and western Youanmi Terrane in order to target and characterize 3.1 – 2.9 Ga geology (Fig. 2). The aim is to understand the petrogenesis and geodynamic history of these rocks in relation to the existing stratigraphic and magmatic framework developed in the northern Youanmi Terrane.

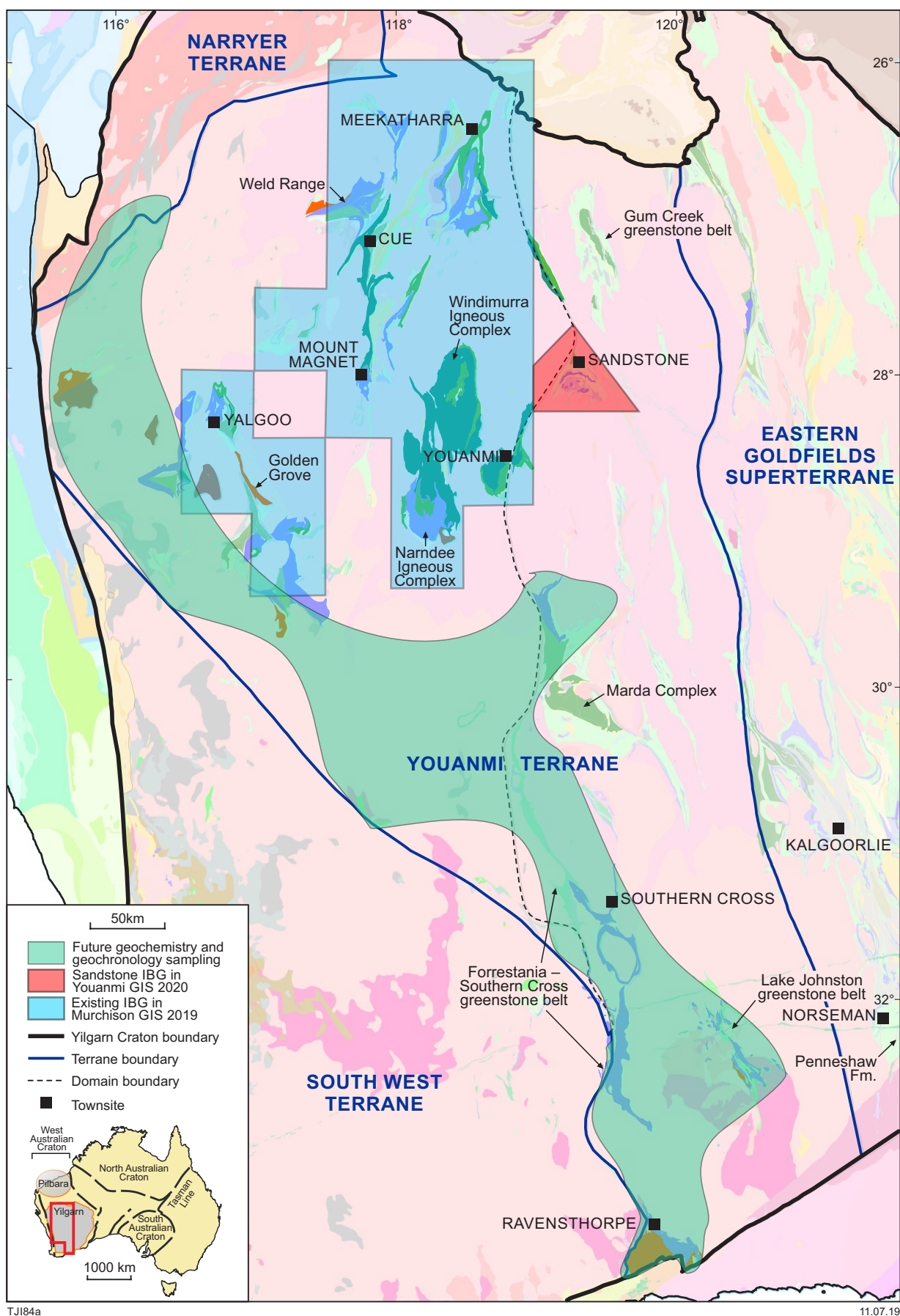
Cooperative projects will continue, including geochemical, metamorphic and structural studies in the northern Youanmi Terrane, 3D modelling in the western Youanmi Terrane and structural and isotopic studies in the Narryer Terrane.

Products planned for release 2019–20

- Youanmi GIS 2020 update to include:
 - interpreted bedrock geology of the Sandstone greenstone belt
 - updated 1:500 000 State interpreted bedrock geology layer
- Youanmi Terrane stratigraphy and explanatory notes update
- Volcanic geochemistry of the northern Murchison Domain (Report)
- The 3.0 – 2.9 Ga history of the Youanmi Terrane (Record).

Planned work program and products 2020–21

- Continued mapping and sampling of the western and southern Youanmi Terrane (e.g. areas around Gullewa and Ravensthorpe) to be published in future Youanmi GIS updates
- ENS update, including the Gossan Hill Formation
- Records and Reports relating to advances in stratigraphic and geodynamic understanding, based on new mapping and sampling
- Records deriving from collaborative studies.



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Figure 2. Geological map of the Youanmi Terrane in the western part of the Yilgarn Craton showing the present extent of 1:100 000-scale IBG map coverage, the Sandstone region (including the Sandstone greenstone belt), for which a 1:100 000 IBG map will be produced in 2019–20, and the broad region (green) where it is hoped that additional geochronological and geochemical data will significantly add to our understanding of the geological evolution of the older greenstone sequences within the terrane

GS62 3D Geoscience

Manager: Ruth Murdie

*Team members: Klaus Gessner, Lucy Brisbout, Ivan Zibra,
Huaiyu Yuan (Macquarie University)*

The 3D Geoscience section aims to increase the knowledge of Western Australia's subsurface through the integration of geophysical, geological and geochemical data in 3D structural models. The objective of GS62 activities is to employ targeted structural mapping and 3D structural modelling techniques to allow the extension of knowledge from exposed and well-understood areas to inaccessible or data-poor parts of the Earth's crust in Western Australia. An important aspect of GS62 is to develop the capability to build, manage, analyse and store 3D models according to GSWA quality standards and stakeholder needs. The workflow to generate 3D models involves data acquisition, processing, visualization, interpretation, publication and archiving. Input data include geological observations, active and passive source seismic data, and measurements of mineral spectra, radiation, magnetization, density and electrical properties.

EIS-funded collaborative projects with leading research institutions that complement GSWA's capabilities in data acquisition, analysis and modelling, form the core part of the section's activities. 3D Geoscience activities often involve data acquired and processed under EIS (ES31 Deep Seismic Survey Program), and products are generated in collaboration with external research partners, as listed under ES42 3D Lithosphere Visualization Project.

Planned work program 2019–20

The 3D Geoscience section will continue to contribute to regional mapping project teams, specifically in the area surrounding the Canning Basin and the Yilgarn Craton. Geophysical sections and detailed structural mapping will complement the seismic data acquired in the Eastern Goldfields (ES37).

The Yalgoo–Singleton 3D model, showing the granite–greenstone regional geometries, will support continued mapping, metamorphic and mineralization studies in the area. A 3D model of the Yangibana paleochannel in the Capricorn Orogen will quantify depth to bedrock and support regolith studies.

Continuation of the field acquisition and production of preliminary results from the Canning Basin passive seismic campaign will form a large component of the fieldwork, with most of the data analysis done at UWA and the Institute of Geology and Geophysics, Chinese Academy of Sciences (IGG-CAS).

3D Geoscience will be actively involved in the interpretation of the 18GA-KB1 deep seismic survey, including modelling of the gravity data.

Planned products for release 2019–20

- Yangibana 3D geomodel
- Yalgoo–Singleton 3D geomodel
- 3D fault model of the northern Youanmi Terrane
- Yalgoo structure and isotopes (Report or Record)
- 3D fault model of the northern Murchison
- External publications as appropriate.

Planned work program and products 2020–21

Acquisition of passive seismic data will continue in collaboration with Macquarie University and IGG-CAS in the area surrounding and including the Canning and Kimberley Basins.

Mapping and modelling will focus on the Eastern Goldfields and northern Yilgarn Craton; with all activities expected to result in publications.

GS63 Pilbara and Hamersley

Manager: Heather Howard

Team members: Olga Blay, Arthur Hickman, David Martin

The Pilbara Craton, northwest Australia, provides the world's best-preserved geological record of late Eoarchean to Neoarchean crustal evolution. The Eoarchean to Mesoarchean 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 1:1 00 000 scale was completed in 2005, along with a major revision of the stratigraphy, structure 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 2630–2445 Ma Hamersley Group of the Mount Bruce Supergroup. This supergroup incorporates the world's best-preserved sequence of Archean ultramafic to felsic volcanic deposits, arguably the world's most continuous transect across the Archean–Proterozoic boundary. The prominent BIF, and deposits reworked from them, are amongst 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. A collisional setting for BIF and mafic and felsic rocks in the upper part of the Hamersley Group has been proposed, but the debate on stratigraphic definition, tectonic setting and evolution of the Mount Bruce Supergroup remains largely unresolved.

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, and more recent work in the Capricorn Orogen. The project seeks to use significant stratigraphic and structural data 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 2019–20

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

Products planned for release 2019–20

- **Geology of the Hardey Syncline** — the key to understanding the northern margin of the Capricorn Orogen (Record)
- **A geochemical traverse through the Fortescue Group near Paraburdoo** (Record)
- **East Pilbara Craton: Archean crustal evolution 3800–2830 Ma** (Report; provisional title)
- **Explanatory notes to accompany the 1:500 000 interpreted bedrock geology digital map layer for the Pilbara Craton**
- **Northwest Pilbara GIS, 2020** (includes 1:100 000-scale geology layers)
- **The Archean–Proterozoic boundary: out with the old, in with the new** — a field guide through the Mount Bruce Supergroup (Record; provisional title)
- **Pilbara Craton: evolving Archean tectonic styles** — a field guide (Record; provisional title).

Planned work program and products 2020–21

Work will continue towards new releases of GIS packages along with new geochemistry data. New Records will be produced, focusing on a reassessment of the tectonic setting and geological evolution of the Fortescue and Hamersley Groups. Interpretation of the part of the Kidson Seismic line covering the region between Gregory Range and Marble Bar is also planned.

GS64 Geoscience Mapping Through Cover

Acting manager: Richard Chopping

Team members: Nadir de Souza Kovacs, Sara Jakica

GS64, which commenced in 2018–19, is linked to ES34 Mapping Through Cover and ES36 Participation in the Mineral Exploration Cooperative Research centre (MinEx CRC). It also is aligned with the work of GS65 Proterozoic Margins, which contributes to understanding of the MinEx CRC project area for Western Australia ('The Gap' – see GS65 work plan). The majority of activities for this project will be conducted through ES34, with support for the National Drilling Initiative (NDI) within the MinEx CRC conducted through ES36. Accordingly, activities for this work are discussed within ES34 and ES36.

GS65 Proterozoic Margins

Manager: Catherine Spaggiari

Team members: Dave Kelsey, Chris Phillips, Raphael Quentin de Gromard

Proterozoic Margins is a new section that was designed to amalgamate the activities of GS56 North Australian Craton and GS61 Albany–Fraser Orogen and Eucla Basement Project, and resides within the 4D Geodynamics branch. The project work is primarily funded through ES38, and details of the work program can be found under that section. 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 borders, informally known as ‘The Gap’, and provide essential data and knowledge towards GSWA’s commitment to the NDI of the MinEx CRC (see GS64 and ES36).

GS80 Editing and Publishing

GS81 Mapping and Events

GS82 Graphics

GS83 GIS Services

GS84 Spatial Systems

GS87 Data Capture

GS88 Data Integrity

GS89 Spatial Projects

GS90 Native Title

General Manager: Stephen Bandy

Team members: Ireen Akter, Matt Aravidis, Ryan Aston, Paul Backhouse, John Bennett, Dennis Bettesworth, Xavier Bezu, Robin Bower (Manager GS80), Derek Canham, Shaun Coldicutt (Manager GS81), Neil Dinnison, Sean Doherty, Greg Dutkiewicz, Bhumita Fadadu, Darlene Fox, Annick Francois, Kiran Gavni, June Graham, Isabel Granado, Erin Gray, Kay Greenberg, Gary Hartley, Bec Hitchings, Joe Hogen-Esch, Dean Hubbard, Stewart Jefferys, John Kirk, Irena Lesiak, Annabelle Lopez, Frank Matera, Sue Mulligan, Andrew Murphy, Sreedhar Nallan, Lucio Pallotta, Joyce Peng, Andrew Pollard (Manager GS90), Michael Prause (Manager GS82), Tanya Quaglia, Amanda Roscoe, Tanya Rose, Phil Sinagra, Martin Stephen, John Stevens, Bernd Striewski, Adam Symonds, Dale Rayner, Daniel Then (Manager GS83), Brad Tapping, Craig Wainwright (Manager GS87 and GS88), Darren Wallace (Manager GS84), Stephen White, Graham Wyles

Experienced, well-qualified staff are critical to the quality and delivery of geoscience and titles information. These staff members include geoscience editors, cartographers, graphics officers, product designers, desktop publishers, database managers, geospatial officers, online coordinators, business analysts and GIS specialists.

These program areas reside in the Geoscience and Titles Information branch, which is responsible for:

- the production of all GSWA products, including geoscientific maps, Reports, Records and data packages for delivery as digital media and via the internet; in addition, the team creates high-quality graphics for display and promotion, and prepares pamphlets, catalogues, flyers and other exhibition materials
- the acquisition and integrity of both mineral and petroleum titles information within Tenagraph and DMIRS Spatial Data Infrastructure environment; that role includes managing the system for survey of mining leases, precise capture and integration of survey leases within the Landgate Spatial Cadastral Database (SCDB), maintaining the integrity of tenements surveyed and unsurveyed, supporting the National Native Title Tribunal with the supply of precise information, producing GIS special purpose maps
- the development and maintenance of quality assurance processes that align with national and international standards; in cooperation with internal and external geoscience groups, the branch develops the data models and standards required for spatial geoscience information management; the Branch's data specialists manage GSWA spatial geoscience databases and develop web-based applications to deliver these data.

Planned work program and products 2019–20

The team will continue to produce geoscientific maps, manuscripts, digital datasets and promotional materials as follows:

- 38 manuscripts
- 12 geological maps at other scales
- 17 digital products.

The following online geoscience and titles information will be released:

- MINEDEX 2018 user interface
- Geochronology and mineral geochemistry data via an online application
- Electronic lodgement of survey field books
- Section 40E reporting
- Decommissioning of NORM2 data file.

GS85 Resource Investment Information

Manager: Gaomai Trench

Team member: Richard Bruce, Jenna Meehan

The objective of GS85 Resource Investment Information is to facilitate the provision of resource-related information to investors for mineral and petroleum investment in Western Australia, to accelerate mineral exploration and discovery. This involves providing geoscientific, policy and regulations information to assist with attracting new resource investment, while at the same time, nurturing relationships with existing investors.

Activities are undertaken proactively, individually through GSWA's own direct efforts, and in cooperation with Australia Minerals, the collective name given to joint facilitating activities overseas with other geological surveys across Australia. Activities undertaken by the branch include the following:

- delivering high-impact presentations and funding of exhibition booths at major investment conferences and seminars
- conducting geoscientific, government policy and regulations-focused investment workshops and seminars for small groups
- publishing geoscientific and new discoveries materials, including maps, posters and flyers
- responding to ad hoc investor requests for geoscience information, information and advice relating to policies and regulations
- supporting the Minister for Mines and Petroleum on official travel overseas
- liaising with Chinese State-owned enterprises with offices in Western Australia
- coordinating the China Geological Survey – GSWA Technical Cooperation Program.

In 2019–20, the project will fund Western Australia's presence at a number of key national and international events including:

- RIU Explorers Conference
- Diggers and Dealers Mining Forum
- GSWA Open Day
- DMIRS Petroleum Day
- RIU Good Oil Conference
- AMEC Convention
- NAPE Summit
- Prospectors and Developers Association of Canada Annual Convention, Trade Show and Investors Exchange (PDAC)
- China Mining Conference and North Asia Mining Seminar, including China and Japan in 2019 and Korea in 2020 (in cooperation with Austrade and Australia Minerals)
- India–Australia Mineral Resources Investment Forums in Mumbai, Hyderabad and Kolkata (in cooperation with Austrade and Australia Minerals)
- Mines and Money Asia in Hong Kong.

Planned work program 2019–20

Similar opportunities to those mentioned above will continue to be the focus of future work programs, some of which will be undertaken in cooperation with Australia Minerals and Austrade.

GS91 Mineral Exploration Information Management

Acting manager: Julia Thom

Team members: Monique Brouxhon, Subashni De Biran, 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 — and 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 previous data, which minimizes duplication of exploration effort and enables more efficient exploration.

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

The Mineral Exploration Information section also 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.

Planned work program and outcomes 2019–20

Planned activities and outcomes are to:

- review and release surrender reports and their associated annual reports as they are received, together with the thirteenth 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
- amend the Guidelines for Mineral Exploration Reports on Mining Tenements to include: program of works number (POW) and whether a drillhole has been rehabilitated in the collar table of drillholes, adoption of a unique sample ID for mineralogical samples, encouraging digital submission of reports
- test the new html version of Western Australian mineral exploration index (WAMEX), drillholes and geochemistry, ensuring that the SQL server reporting services reports are included in the search criteria
- test functionality of Adobe to convert multiple documents to Optical Character Recognition (OCR) and, if successful, convert all non-OCR reports in WAMEX
- continue training in the use of the WAMEX and mineral drillhole and surface geochemistry databases in both Perth and Kalgoorlie
- develop a core library database 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 of 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.

GS92 Statutory Petroleum Exploration Information

Manager: Felicia Irimies

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

The Petroleum Exploration Information 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.

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, and 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 very close links to Western Australian petroleum and geothermal information management system (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.

Priorities for transcribing and scanning legacy data are set in part by the future activities of GS10 Energy Geoscience and Carbon Strategy and the Specific Area Gazettes conducted by the Resource Tenure Group.

Planned work program and outcomes 2019–20

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/ NOPIMS in collaboration with NOPTA and GA
- collaborate with NOPTA/GA in regards to better integration of our systems (WAPIMS, NOPIMS, National Electronic Approvals Tracking System [NEATS], Petroleum Geothermal Register [PGR]):
 - CIMS– create one sampling approval system for all material stored at the Perth Core Library at Carlisle (mineral, State and Commonwealth petroleum)
 - implement a publicly available ‘Data by Depth’ functionality in WAPIMS
 - upload the scanned seismic sections in WAPIMS
 - load the well deviation data
 - create forms and public reports to release online all the public geoscientific data captured in WAPIMS (State and Commonwealth)
- assist the Petroleum Compliance branch in capturing data submitted for the Gorgon CO₂ injection project and Tubridgi gas storage project
- assist the Energy Geoscience and Carbon Strategy branch in creating the Digital Core Atlas and other projects as required (Kingdom data packages, geochemical data capture, reprocessing, etc.)
- publish a new Guidelines for petroleum data submission and release based on Part 8 and Part 9 of the Mines and Petroleum Regulation Amendment Regulations 2018
- start digitizing all the onshore line sections without digital data to SEG-Y; priorities based on work done by Energy Geoscience and Carbon Strategy branch
- 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.

GS94 and GS96 Core Library Services

Manager: Paul Stephenson

Team members: Bill Anderson, Debbie Caple, Matt Chappell, Joel Coulter, Fiona Dodd, Peter Drobek, Simon Fanning, Jackie Fleming, Mark Harrison, Andy Leighton, Ben Rooney, Josh Williams

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 Perth Core Library is also now the western hub of the National Offshore Petroleum Data and Core Repository (NOPDCR), and 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 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.

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

Planned work program and outcomes 2019–20

At the core libraries in 2019–20, work will continue to maintain the same level of service to stakeholders. Developments include:

- adding new line markings at Carlisle to indicate loading zones inside the main site
- 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 outdoor viewing area at Kalgoorlie due to be completed in October 2019
- installation of shade sails in the outdoor processing area at Carlisle, due July 2019.

GS95 HyLogger and the National Virtual Core Library

Manager: Lena Hancock

Team members: Edward Rogers, Michael Wawryk

The GSWA 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 and interpretations from drillcore (and other rock samples), thereby improving our understanding of the composition of the Australian crust. HyLogger 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. High-definition digital images of the core are simultaneously obtained. The data are processed and posted to a dedicated national website (the NVCL) and to GeoVIEW.WA, where they can be viewed using open-access software. Full datasets are also available upon request.

Planned work program 2019–20

The facility will continue to collect and interpret spectral data from drillcore that contributes directly to increasing the knowledge of Western Australian geology and mineral and petroleum systems (Fig. 3). 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). Priority of scanning is determined by a GSWA committee in order to balance the competing objectives, demands and priorities of users.

Other regular activities for 2019–20 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. Short GSWA reports of data processing and interpretation will be included in the final products. In addition, links to other related publications will be available through the GeoVIEW.WA HyLogging layer.

HyLogger staff will collaborate and lead several special projects in 2019–20 to:

- develop procedures for using the portable/desktop X-ray diffractometry (XRD) and scanning electron microscope (SEM) to systematically and rapidly validate mineral identifications made by visual and hyperspectral logging of core and hand specimens
- provide technical support to GSWA geological staff using this facility
- deliver to GSWA, academic and industry personnel another two workshops in the Perth and Kalgoorlie Core Libraries promoting the use of the hyperspectral technology.

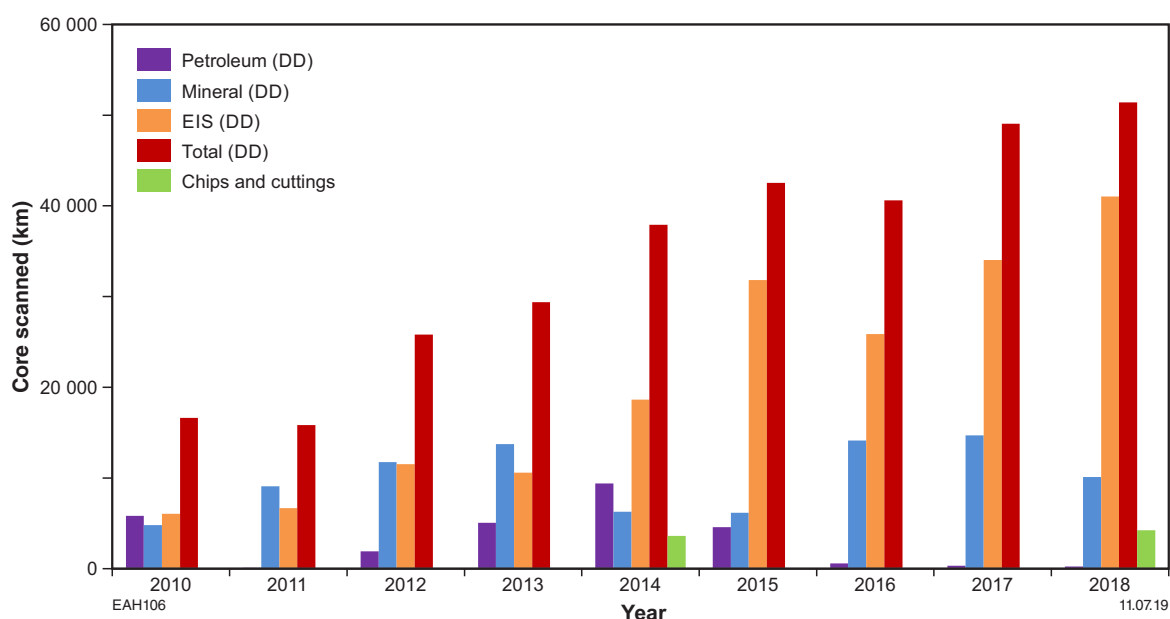


Figure 3. GSWA HyLogger facility usage statistics 2010–19. A total of 309 171 m of core from 1071 drillholes was scanned and analysed in this period. Abbreviation: DD, diamond drilling

Products planned for release 2019–20

- HyLogging data processing and interpretation for assorted drillcores (numerous HyLogger Records)
- Portable XRD: applications to mineral identification in core (Record)
- Application of the HyLogger data to mineral system projects (GSWA Open Day poster)
- Application of the HyLogger data to petroleum core (DMIRS Petroleum Day poster).

Planned work program and products 2020–21

Maintenance of the HyLogging facility, collection and interpretation of hyperspectral data from mineral and petroleum core will continue. HyLogger staff will continue to collaborate with GSWA colleagues and other researchers to undertake and publish outcomes from research projects that use the HyLogger facility to collect significant fundamental data.

PART 2

EXPLORATION INCENTIVE SCHEME — DETAILED WORK PROGRAMS



ES20 Government Co-funded Exploration Drilling

Manager: Charlotte Hall

Team member: Monique Brouxhon

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.

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.

A formal advisory committee, chaired by the Deputy Director General of the Resource and Environmental Regulation Group of DMIRS and consisting of representatives from the main industry representative groups and research sector, provides advice to DMIRS on program guidelines. The committee, which meets twice yearly, also ensures that the program is relevant to the exploration industry.

The Co-funded Exploration Drilling program also undergoes a transactional and probity audit twice yearly by an external auditor. The probity audit ensures the selection process for any round is transparent, impartial and defensible. 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 program refunds up to 50% of direct drilling costs capped at \$30 000 for genuine prospectors, \$150 000 for multi-hole projects and \$200 000 for deep single-hole projects.

As a result of feedback from applicants in Rounds 1 (2009) and 2 (2010), and industry representatives, there are now two rounds of co-funding per year, which started in 2011, across either a financial or calendar year. This resulted in an increase in the number of offers made in a financial year and in the number of projects completed (Fig. 4a). Successful applicants are required to complete the proposed drilling project within 12 months. Interim and final drilling reports plus core, where cored drilling is undertaken, are submitted to DMIRS before refunds are paid. Final reports and core are released to open file after a six-month confidentiality period, which begins at the time the first invoice is approved for payment.

Planned work program 2019–20

During 2019–20 drilling from three rounds will be undertaken by exploration companies. As can be seen highlighted by the red rectangle in Figure 4b, three rounds overlap the reporting year. Successful applicants of Rounds 18 and 19 are currently in the process of drilling. Round 18 applicants have until December 2019 to complete drilling, while Round 19 applicants will be required to drill by 30 June 2020.

The 2019–20 financial year will see the following work undertaken:

- Round 17 will undergo final closure, 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.
- Rounds 18 and 19 drilling periods will be completed, including receipt of interim and final reporting requirements.
- Applications for Round 20 will be opened in late August 2019 and Round 21 in late February 2020 (Fig. 4b).
- Co-funded Drilling reports will be released, out of confidentiality, to the DMIRS open-file database, WAMEX.
- The Royalties for Regions 2019–20 financial year progress report (for the final year of Royalties for Regions funding) will be prepared and submitted to the Department of Primary Industries and Regional Development (DPIRD).
- An independent body will be employed to undertake an economic review of the EIS as a final reporting requirement to DPIRD for Royalties for Regions.
- Audits will be undertaken by an external auditor on the probity of the selection process for Rounds 20 and 21, and transactions for the last 12 months.
- The success rates of projects that have received co-funded drilling over the last 10 years will be reviewed and assessed.
- A summary of 2019–20 Co-funded Drilling will be prepared for inclusion in the GSWA annual review.

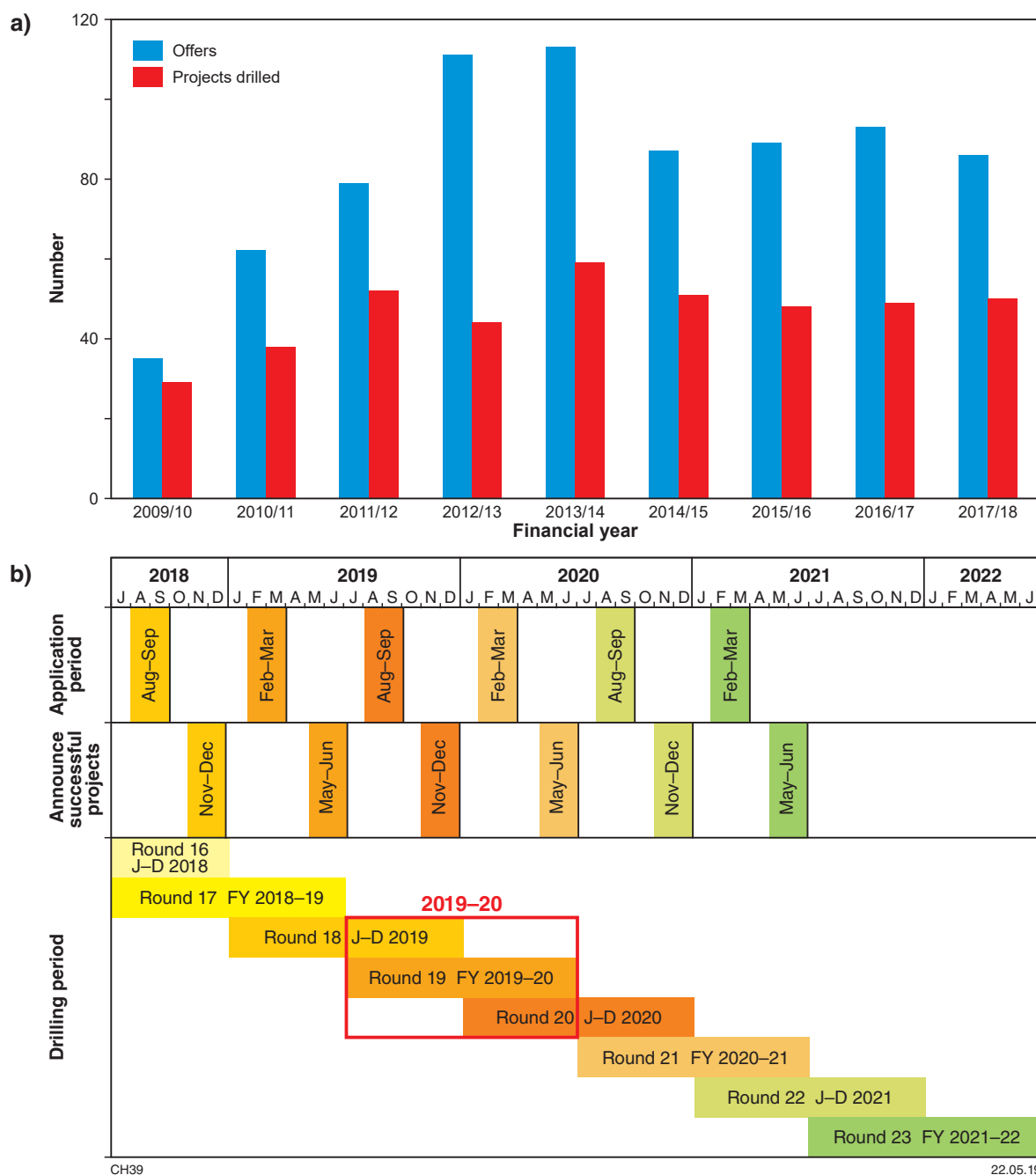


Figure 4. EIS Co-funded Exploration Drilling program statistics and timeline: a) number of projects offered funding vs projects actually drilled, by financial year; b) schedule of Rounds 16–23. Red box indicates the three rounds which are part of the 2019–20 financial year. Abbreviations: J–D, January–December; FY, financial year

ES30 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 Agreements.

Medium-resolution (200–400 m line-spacing) aeromagnetic and radiometric coverage of the State was completed by June 2013. The current focus of activity is completion

of ‘second-generation’ gravity coverage of the State at a 5–8 km wavelength resolution and broad-scale AEM surveys to complement GA’s nationwide AusAEM project.

Planned work program 2019–20

ES30 activities in 2019–20 and beyond will include:

- continuation of the Pilbara airborne gravity survey, which commenced in 2018–19 (Fig. 5)
- area prioritization and planning for new surveys.

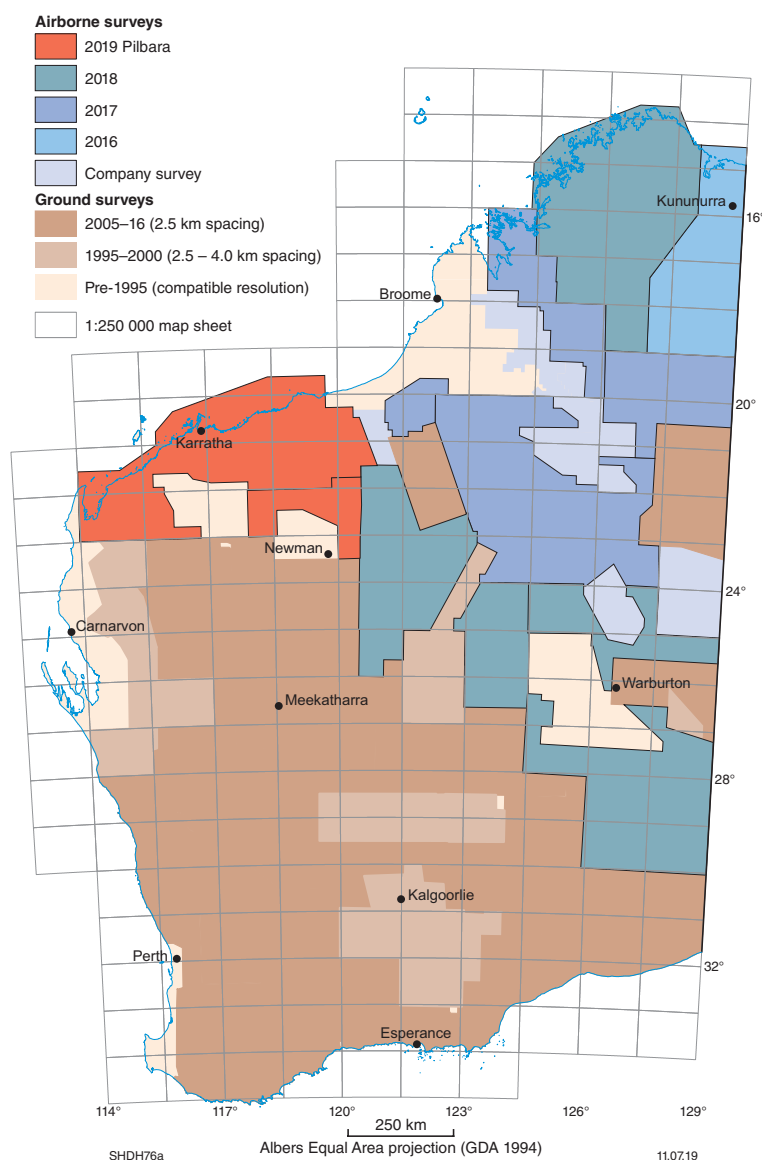


Figure 5. GSWA ‘second-generation’ gravity survey coverage

ES31 Deep Seismic Survey Program

Manager: Ian Tyler

Team members: Lucy Brisbout, Klaus Gessner, Ruth Murdie

The aim of the Deep Seismic Survey program is to obtain 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 objective of ES31 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, The Australian National University (ANU) and UWA, particularly on passive source seismology and magnetotelluric surveys. GSWA activities that derive from the data acquired and processed in ES31 are also described under GS62 3D Geoscience and ES42 3D Lithosphere Visualization Project.

Planned work program 2019–20

Passive source seismic and magnetotelluric data will continue to be acquired in the Eastern Goldfields in a collaborative project with UWA led by Mike Dentith. This three-year research project commenced in July 2018 to complement the high-resolution seismic survey in the Eastern Goldfields described in the ES37 section of this document.

The basement portion of the 18GA-KB1 deep crustal seismic survey acquired across the remote Kidson Sub-basin of the Canning Basin will be interpreted in collaboration with GA and prepared for preliminary release at the AEGC in Perth in September 2019.

GSWA is in the planning stage of coordinating future acquisition of passive source seismic and magnetotelluric data with GA under the Australian Passive Seismic Array project (AusARRAY) and the Australian Lithospheric Architecture Magnetotelluric project (AusLAMP) initiatives. Funds have also been committed to support a collaborative passive source seismic study in the southwest of the State, with ANU, GA and the Department of Fire and Emergency Services (DFES).

Products planned for release 2019–20

- Kidson deep seismic survey basement interpretation – to be released at AEGC in Perth (September 2019)
- Southern Yilgarn Craton magnetotelluric data
- Western Musgrave magnetotelluric data
- External publications as appropriate.

Planned work program and products 2020–21

Future activities and products will focus on obtaining, processing and releasing deep geophysical data from the basement underlying and flanking the Canning Basin, from the Eastern Goldfield and the southwest Yilgarn Craton.

ES34 Regolith and 3D Paleosurface Mapping

Manager: Richard Chopping

*Team members: Nadir de Souza Kovacs, Sara Jakica,
UniSA Embedded Researcher (MinEx CRC; TBA)*

ES34 commenced in 2018–19 and is linked to GS64 Geoscience Mapping Through Cover and ES36 Participation in MinEx CRC. 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.

Over the past decade, GSWA has demonstrated the application of single-station passive seismic (using Tromino instruments) 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 2019–20 will be to continue applying 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. 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.

An ongoing collaborative project with the John de Laeter Centre at Curtin University is the development of the (U–Th)/He technique for geochronological analysis of secondary iron oxides in weathering systems. Iron oxide-rich duricrust and pisolithic material form a suitable geochronological proxy that provides a time-integrated record of the weathering processes that have shaped regolith formation. The results are being used to determine if the age of this material varies significantly on a regional scale, and how this relates to landscape evolution and past climatic conditions. Combined with regolith mapping, these data and their interpretations will help detect the distribution of economic mineral signatures in the cover.

Planned work program 2019–20

- With the northern half of the 1:500 000 State regolith–landform digital map completed, work is focused on releasing the southern half of the map. Documentation of the methods developed and used will also be released.

- 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.
- Regolith mapping and landscape evolution analysis within the MinEx CRC drilling project areas, including field-based studies, legacy drillcore analysis and satellite imagery interpretation; this work will be aligned with MinEx CRC project work and will contribute to State regolith map updates and ENS.
- 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 geochemistry sampling, will be utilized during regolith mapping and regolith profile studies. This will provide information about paleoweathering patterns and local geochemical dispersion patterns from bedrock.

Products planned for release 2019–20

- Release of the southern half of the 1:500 000 State regolith–landform digital map
- State 1:500 000-scale digital regolith map – new compilation methodologies (Record)
- Regolith–landform mapping classification scheme (Record)
- Data entry for units in the new regolith module in ENS
- Assessment of the Kimberley ASTER Version 2*: geoscience products for regolith–landform mapping (Record)
- Geochronology records for 10 duricrust samples from the Capricorn Orogen and Yilgarn Craton.

Planned work program and products 2020–21

Work in 2020–21 and beyond will focus more intently on regolith mapping and landscape evolution analysis within the MinEx CRC drilling project areas. This will lead to a broader understanding of the distribution of mineral footprints in cover sequences. A key component will also be in understanding regolith landforms to inform drilling site selection as required. The work will include field-

based studies, legacy drillcore analysis, satellite imagery interpretation and analysis of AEM and other geophysical data, where available. The collaborative nature of the MinEx CRC will allow substantial skills and knowledge transfer to GSWA staff. The broader outlook for GS64 is to use the research conducted within MinEx CRC for the development of methods to efficiently map undercover terranes using drilling technology and geophysics in lieu of outcrop, as per more traditional geological mapping was undertaken.

The following products and outcomes are planned for release in 2020–21:

- Step back in time to the Yangibana paleochannel: a 3D model using passive seismic data (Record)
- The application of passive and active seismic methods to estimate cover thickness (Record)
- Data compilation pre-drilling for ‘The Gap’ region.

ES36 Participation in MinEx CRC

Acting manager: Richard Chopping

Team members: Nadir de Souza Kovacs, Sara Jakica

ES36 commenced in 2018–19 and is linked to GS64 Geoscience Mapping Through Cover. The MinEx CRC was granted by the Commonwealth Government in March 2018 and brings together industry, government and research organizations, and represents a 10-year investment in the next generation of mineral systems discovery research. The CRC, which commenced in January 2019, comprises three programs: Drilling Technologies, Data from Drilling and the NDI. GSWA is a participant in Program 3, the NDI.

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
- reanalysis of regolith geochemistry for the West Arunta region using the CSIRO Ultrafine process.

Further information about the MinEx CRC can be found at <http://minexcrc.com.au>.

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. There are three projects that encompass the NDI: Project 7 — maximizing the value of data and drilling through cover; Project 8 — geological architecture and evolution; and Project 9 — targeting mineral systems in covered terranes.

The aims of Project 7 are to:

1. develop a web platform and data management system that can operate in near real time
2. develop advanced mineral system data analytics so that the maximum amount of geoscientific information can be extracted from the legacy and NDI drilling programs
3. maximize the efficiency and value of drilling by developing algorithms and tools that can optimize

drill program design and provide drill target rankings relative to the key science questions.

This streamlined approach to managing and integrating the many layers of complex drilling data will enable objective analysis and result in significant efficiency gains as well as the ability to modify drilling programs in real time.

The main aim of Project 8 is to provide new pre-competitive geoscience data in the NDI case study areas to increase data confidence and improve geological understanding. Understanding the relationships between regolith, basin cover and basement, through new knowledge of mineralogy, geochemistry, petrophysics, hydrology and geochronology, will be used to reconstruct landscape evolution through time and to map the depths to key boundaries and cover thickness. Determination and development of the most rigorous methods for characterizing and mapping buried geology will be a key feature, and will enable predictions of buried geology through novel drilling techniques and by understanding its expression in cover sequences and geophysical data.

The aim of Project 9 is to develop methodologies to detect and understand the footprints of buried mineral systems using the extensive datasets generated through Project 8. This will involve establishment of a new generation of multiscale (province, district and links to deposit scale) exploration targeting models for selected mineral systems that represent and quantify the spatial variations in architectural/structural, stratigraphic, geophysical, geochemical, mineralogical and isotopic (collectively geological) characteristics of each mineral system type.

Project 9 will provide advice on the most valuable data types, sampling media and sampling densities to map footprints of relevant mineral systems. It will also integrate temporal and spatial geoscientific data for specified regions with existing understanding of ore-forming processes to create maps of mineral potential, using improved knowledge- and data-driven prospectivity mapping techniques, and test exploration targeting models and mineral potential maps by utilizing MinEx CRC drilling technology and research.

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 (Fig. 6). This area is informally defined as ‘The Gap’. This work will align with other project work including GS10, GS64, GS65 and external collaborative projects through the Minerals Research Institute of Western Australia (MRIWA).

Planned work program 2019–20

Drilling within the NDI will be undertaken in two parts, with the first presently scheduled for the 2021 field season. This will be subject to land access and drill rig availability. Work within the 2019–20 financial year will involve data compilation and establishing foundations for a mineral systems analysis of the region.

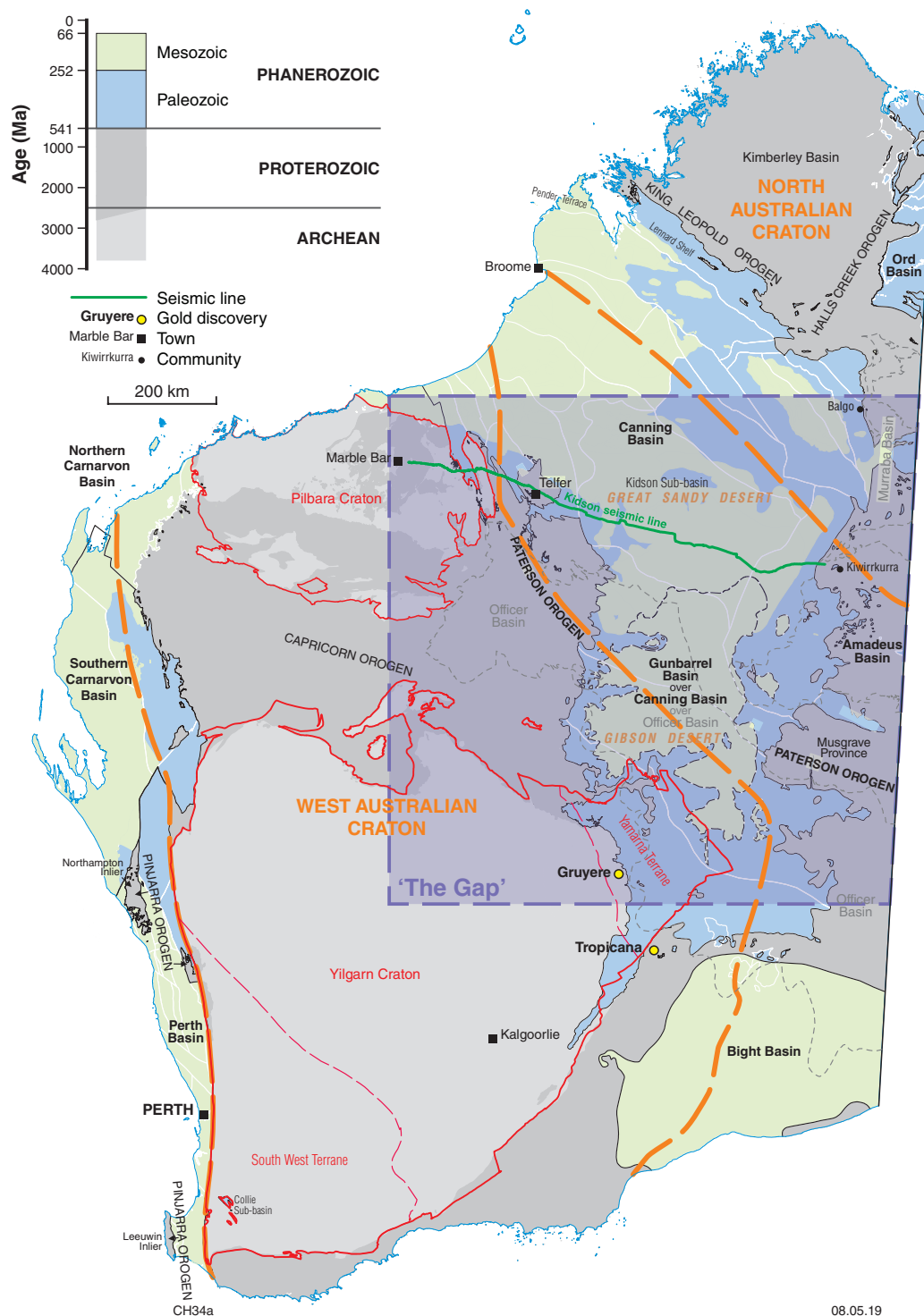


Figure 6. ‘The Gap’, as outlined by the blue box, is an informal area representing a region with the largest degree of geological uncertainty (base map modified after Martin et al., 2016). MinEx CRC NDI activities for Western Australia will focus their attention in this region, including the application of two phases of drilling to map under cover geology. Dashed orange lines delineate the extent of the West and North Australian Cratons; red lines delineate the extent of the Yilgarn and Pilbara Cratons; and white lines represent tectonic units within the Phanerozoic basins

ES37 Eastern Goldfields Seismic Survey

Manager: David Howard

*Team members: Melissa Drummond, Klaus Gessner, Sara Jakica,
Hugh Smithies, Ivan Zibra*

The objective of ES37 Eastern Goldfields Seismic Survey is to provide mineral explorers in the region with subsurface information in a depth range from about 300 to 5000 m to complement information from other sources, and to delineate areas that might be suitable for 3D seismic surveys for mineral exploration and targeting.

Planned work program 2019–20

In the 2019–20 financial year, work will include the completion of processing and interpretation of data acquired in 2018–19 (Fig. 7).

Products planned for release 2019–20

- Eastern Goldfields seismic survey data package consisting of:
 - raw acquisition data and acquisition report
 - processed data and processing report
 - interpretation products and report.

Planned work program and products 2020–21

The Eastern Goldfields Seismic Survey project will be completed in 2019–20.

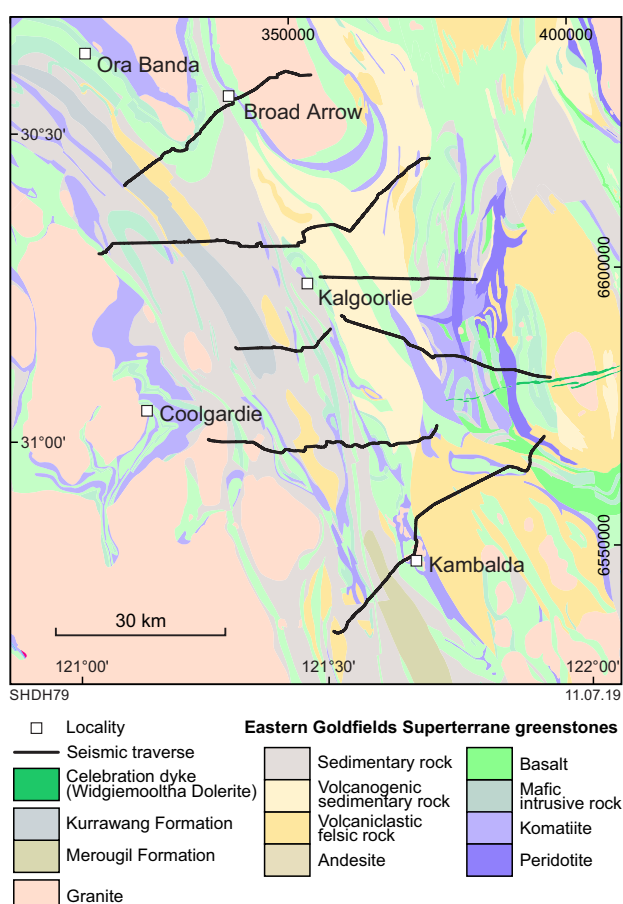


Figure 7. Location of seismic traverses across the Eastern Goldfields on regional geology base map

ES38 Proterozoic Margins

Manager: Catherine Spaggiari

Team members: Dave Kelsey, Chris Phillips, Raphael Quentin de Gromard

Proterozoic Margins is a new section within the 4D Geodynamics branch that operates predominantly under ES38, but with links to GS65. The section was designed to amalgamate the activities of GS56 (North Australian Craton) and GS61 (Albany–Fraser Orogen and Eucla Basement Project), and resides within the 4D Geodynamics branch. The primary objective of ES38 is to investigate and map the geology of the remote greenfields regions in the vicinity of the Northern Territory and South Australian borders (Fig. 8). The work will contribute essential knowledge towards GSWA's commitment to the NDI of the MinEx CRC (see GS64 and ES36). Much of the region is covered by younger basins and regolith, and a major component of the work program of ES38 will be to interpret geophysical data and produce interpreted bedrock geology maps. This work will incorporate knowledge gained from field mapping and drillcore analysis, with particular emphasis on utilizing EIS Co-funded drillcore housed at the Perth Core Library. The project builds on the successful approach developed in the Albany–Fraser Orogen and Eucla Basement Projects. Initially, the Paterson Orogen and the West Arunta region will be 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 will provide fundamental information to enable exploration teams to evaluate prospectivity and potential targets.

Planned work program 2019–20

In the east Albany–Fraser Orogen, detailed structural and metamorphic analysis will continue, with emphasis on defining and understanding the events of the Albany–Fraser Orogeny and their links to mineralization, and the kinematic and magmatic history of crustal-scale shear zones. This work links with the collaborative MRIWA M470 project (Curtin University), which is due for completion in late 2019.

Detailed work on the Eucla Basement drillcore is complete and interpretations of geophysical data are well advanced. The first release of a pre-Mesozoic, 1:250 000-scale digital interpreted bedrock geology map of the Madura and Coompana Provinces is planned.

The progressive extension of the digital 1:250 000 Geological Series mapping and examination of the age, character and correlations of Paleoproterozoic to Neoproterozoic sedimentary basin outliers in the Kimberley region will continue, but with emphasis on connections with basins in the Tanami region.

New work will focus on examining and sampling drillcore from the West Arunta and Paterson Orogen. This work

will link with the MinEx CRC NDI and include new workflows, such as the collection of petrophysical data. A new field program is planned for the Rudall Province in the Paterson Orogen or the West Arunta in August. The work will also link with the collaborative deep crustal Kidson Seismic Line interpretation project and complement the MRIWA M521 Paterson Orogen project (Centre for Exploration Targeting [CET]/UWA), which is focusing on basin evolution, and geophysical data and numerical modelling.

Products planned for release 2019–20

- Stratigraphic and co-funded drilling of the Eucla Basement — the Proterozoic geology beneath the Nullarbor Plain (Report)
- Outcrop model records from drone photography (new product of short records for each 3D outcrop model, including model results, outcrop sketch map and structural interpretation)
- Pre-Mesozoic, GIS data package of the east Albany–Fraser Orogen
- Pre-Mesozoic, GIS data package of the Madura–Coompana (Eucla Basement)
- ENS entries for selected units of the east Albany–Fraser Orogen, Madura and Coompana Provinces
- Results from the MRIWA M470 project (GSWA and MRIWA Reports)
- Kimberley GIS package update, including:
 - MONTAGUE SOUND second edition 1:250 000 Geological Series map
 - Population and publication of ENS for units of the Eastern Zone of the Lamboo Province, including updates to the 1:500 000 layers
- ENS entries for the Kimberley Basin
- Sedimentology and stratigraphy of the Kimberley Basin (Report)
- Geodynamic setting of the Lamboo Province (Report; incorporating age data from metasedimentary and meta-igneous rocks across all three zones in the Lamboo Province)
- Interpretation of the basement geology imaged in the Marble Bar to Kiwirrikura Kidson Seismic Line (collaborative project)
- External publications, particularly from the MRIWA M470 PhD work.

Planned work program and products 2020–21

Work will continue on field mapping and drillcore analysis from the West Arunta and Paterson Orogen, which will greatly assist with planning GSWA's drilling program in the MinEx CRC NDI.

Entries in the ENS database for both the West Arunta and Paterson Orogen will require updating and expansion. Entries in the ENS database for the Albany–Fraser Orogen, Madura and Coompana Provinces will continue.

The MRIWA M521 Paterson Orogen project will continue, and GSWA will provide input and assistance where required.

The following products are planned for release in 2020–21:

- Structural and metamorphic evolution of the southeast Albany–Fraser Orogen (Report)
- Kimberley GIS package, with updated digital map layers and ENS entries
- Tanami–Arunta GIS package, with updated digital map layers
- Paterson Orogen GIS package, with updated digital map layers
- Proterozoic geology of the West Arunta region, incorporating new results from drillcores (Record)
- Proterozoic geology of the Paterson Orogen, incorporating new results from field mapping and drillcores (Record).

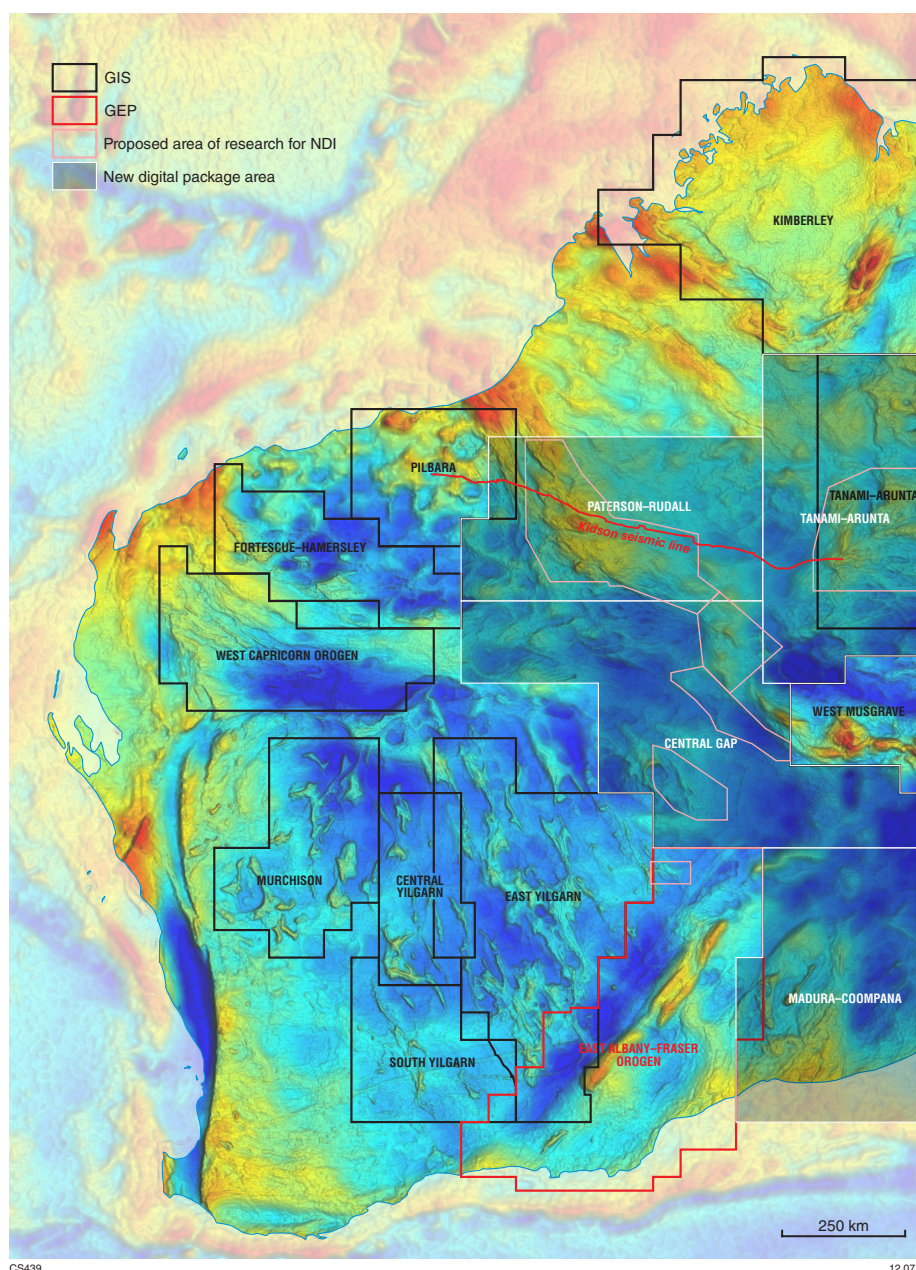


Figure 8. Gravity image (after Brett, 2019) overlain by the project areas covered by ES38, informally defined as ‘The Gap’, reflecting the basement regions between the North, West and South Australian Cratons. The diagram also shows proposed areas of research for the NDI of MinEx CRC and areas covered by planned GIS data packages. Abbreviations: GEP, Geological Exploration Package

ES40 Geology Online

Manager: Darren Wallace

Team members: Stephen Bandy, Derek Canham, Bhumita Fadadu, Terry Farrell, Kiran Gavni, Frank Matera, Angela Riganti

In addition to better integration of GSWA's online data, the Geology Online project will develop and facilitate the population of new databases and data services to GSWA clients and support the production of geoscience reports and derivative maps on demand.

These databases will be complemented by the development of data entry and query interfaces with reporting functions. The online interface will allow clients to generate customized geoscience reports derivative maps on demand.

Planned work program and outcomes 2019–20

The following outcomes are due by June 2020:

- Enhancements of publication management tool, PubStats (K2)

- Development of a new user interface for WAMEX
- Stage 2 enhancements of geochemistry database, WACHEM
- Upgrade of the MINEDEX user interface
- Section 40E reporting
- Development of interface to thin section and polished slide collections.

Planned work program and outcomes 2020–21

The following are subject to funding approval:

- ENS for Mineral Systems
- Redevelopment of WAMEX.

ES42 3D Lithosphere Visualization Project

Manager: Klaus Gessner

*Team members: Lucy Brisbout, Ruth Murdie,
Huaiyu Yuan (Macquarie University), Ivan Zibra*

The aim of the 3D Lithosphere Visualization Project is to visualize and model relevant portions of the solid Earth in Western Australia. The objective is to extend knowledge from exposed and well-understood areas of the Earth's crust and lithosphere to inaccessible or data-poor parts using 3D structural analysis, modelling and numerical simulation techniques. These techniques also test the validity of conceptual models and interpretations. An important aspect of ES42 is cooperation with leading research institutions that complement GSWA's capabilities in data acquisition, analysis and modelling. In addition to collaborating with GA, GSWA engages with Macquarie University, IGG-CAS, ANU, the Department of Fire and Emergency Services (DFES), Monash University and UWA on passive source seismology and magnetotelluric surveys. These activities are described in detail under GS62 3D Geoscience.

Planned work program 2019–20

Acquisition and analysis of passive seismic data will continue in collaboration with Macquarie University and IGG-CAS in the Pilbara Craton, Paterson Province, King Leopold Orogen, and Canning and Kimberley Basins. As part of a collaboration with ANU, GA and DFES for Australian Research Council (ARC) project LP180101118 'Enhanced 3D seismic structure for southwest Australia', the planning and deployment of passive seismic stations will commence for the southwest Yilgarn Craton.

Modelling work will focus on outcomes from passive seismic work carried out in collaboration with UWA, including the Capricorn Orogen passive array (COPA), the Perth Basin project, and the Distributed Acoustic Sensing project.

Following the release of high-resolution seismic data (ES37) and the acquisition of passive seismic and magnetotelluric data from the Eastern Goldfields (ES31), GSWA will initiate a project to integrate these products with results from the geochemical barcoding and regional mapping activities (GS52), with the ultimate goal to generate a 3D model of the Kalgoorlie area. These activities will be carried out in close collaboration with 'Yilgarn 2020', a MRIWA-sponsored, four-year project led by the CET at UWA.

As part of Australian Research Council (ARC) project LP170100985 Enabling 3D stochastic geological modelling (3D-LOOP), a large Monash University-led international project for reducing risk for the resources industry, GSWA will engage in developing 3D stochastic modelling for the next generation of 3D modelling software.

Products planned for release 2019–20

- Capricorn Orogen Passive Array (COPA) project (Report)
- Distributed Acoustic Sensing in the Perth Basin (Record)
- Perth Basin passive seismic (Report)
- X-ray microtomography (Record)
- The Precious Earth (book)
- Crustal structure beneath the southern Pilbara Sub-basins (Report)
- External publications as appropriate.

Planned work program and products 2020–21

Analysis and integration of passive seismic data into models and products will continue in collaboration with Macquarie University and IGG-CAS in the area surrounding and including the Canning and Kimberley Basins, and with ANU, DFES and GA in the southwest of Western Australia.

Modelling and production will focus on the Eastern Goldfields, utilizing tools developed by the 3D-LOOP project. The focus of publications will be on the Capricorn Orogen work.

ES43 Mineral Systems

Manager: Trevor Beardsmore

Team members: Olga Blay, Paul Duuring, Lena Hancock, Sidy Morin-Ka, Michael Wingate

Under this program, GSWA collaborates with other government, university and/or industry partners to study specific aspects of Western Australian mineral systems. These projects are partly to fully funded by the EIS, with the Minerals Geoscience branch managing in-house participation. Projects underway or pending for 2019–20 include:

- Pilbara gold fingerprinting (\$25 000 per annum over two years)
- rare earth resource potential of northern Australia (\$25 000 per annum over three years)
- MRIWA M532 — Geology, mineralogy and metallurgy of eMaterial resources in Western Australia (\$50 000 per annum over two years).

Planned work program 2019–20

The Pilbara gold fingerprinting project aims to characterize the provenance and metallogenesis of gold mineralization across the Pilbara Craton, using morphometry, microstructure, associated minerals and trace element composition of bedrock-hosted and placer gold grains/nuggets. Gold-bearing specimens provided by industry partners are visually inspected, then mounted in resin, cut and polished, and analysed quantitatively for a suite of trace elements using LA-ICP-MS and SEM-EDX (energy dispersive X-ray spectroscopy) and calibrated using certified gold standards. With the assistance of John Watling (TSW Analytical), this project will provide a world-first database of gold trace-element chemistry. Results are expected to assist in identifying the type and origin of basement-hosted gold deposits, the sources of paleoplacer gold in Fortescue Group rocks, and an evaluation of the prospectivity of the Pilbara for significant undiscovered gold deposits.

GSWA will collaborate in the ARC Linkage project 'Rare earth resources of northern Australia' with James Cook University, ANU, GA and the Geological Surveys of New South Wales and Queensland, and a number of REE-focused resource companies (pending a successful grant application). A detailed research program is yet to be completed, but university researchers propose to 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.

GSWA is also sponsoring the new MRIWA project M532 — Geology, mineralogy and metallurgy of eMaterial resources in Western Australia — in collaboration with Curtin University, Lithium Australia NL, Galaxy Resources Limited, Rio Tinto Limited and AXT Pty Ltd. The project will be largely operated by the John de Laeter Centre at Curtin University, and is intended to provide a comprehensive understanding of the geology and mineralogy of Western Australian lithium–cesium–tantalum (LCT) pegmatite-hosted lithium deposits, develop practical geometallurgical models to optimize the sustainable development of these deposits, and verify the suitability of field portable analytical devices for determining lithium abundance and distribution during exploration.

The project comprises three modules:

1. classification and geology of LCT pegmatites
2. mineralogy and deportment of economic and deleterious elements
3. physical and chemical processing behaviour.

GSWA will collaborate most closely in module 1, assisting with the development of a database documenting the geological setting of LCT pegmatite mineral systems in Western Australia (age, isotope geodynamics, degree of mineral fractionation, petrological, geochemical variations, post emplacement histories), and comparing Western Australian eMaterial deposits with global counterparts.

Products planned for release 2019–20

- Several short GSWA Records relating to gold characteristics
- Pegmatite geochronology records.

Planned work program and products 2020–21

All Mineral Systems projects will continue through 2020–21. For the Pilbara gold fingerprinting project, data collection and analysis will be completed, the geochemical database will be developed, and the final report(s) documenting the study will be drafted. Results from the REE (ARC Linkage) and LCT pegmatite (MRIWA) projects are likely to begin being published in GSWA and external publications.

ES45 Mapping Geodynamic Settings Program

Manager: Simon Johnson

Team members: Fawna Korhonen; part time fee-for-service staff

The Yilgarn Craton metamorphic data capture project documented the metamorphic patterns and thermobarometric evolution of the Yilgarn Craton in order to facilitate geological research, as well as to aid mineral exploration in the region. Although the data were delivered to GSWA in 2015, they were incompatible with current GSWA databases. This six-month project aims to capture that data into the WAROX database, and will include the capture of attributes such as metamorphic facies, diagnostic minerals, new petrographic descriptions and new structural measurements. This data will also form the core dataset to build a metamorphic map and further investigate the thermal evolution of the Yilgarn Craton.

Products planned for release 2019–20

- Specific data layers in the Compilation of WAROX data
- 2020 digital product.

Planned work program and products 2019–20

Capture of metamorphic, structural and petrographic data for the Yilgarn Craton, totalling about 60 000 sites across the Yilgarn Craton.

ES46 Enhanced Geochronology and Acquisition of Isotope Data

Manager: Michael Wingate

Team members: Frances James, Yongjun Lu, Ed Mikucki, Marlene Papiccio, Tom Scillieri, John Williams

This project enhances GSWA's geochronology studies (see GS54 Geochronology and Geochemistry) with the addition of 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–Pb isotopes) conducted in collaboration with university research groups.

Variations in radiogenic isotope compositions (mainly Sm–Nd and Lu–Hf) provide information on the nature of the sources of magmatic rocks, allowing magmas 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.

The ES46 project also includes measurement of whole-rock geochemical and zircon trace element compositions of Archean granitic rocks in Western Australia, to understand water content, pressure, temperature and oxidation state of magmas, all of which control magma fertility for ore formation, and can be used as exploration indicators in remote or covered terrains.

The ES46 project is funding the work for GS54. Accordingly, the work program for GS54 is included below. The majority of analytical work under ES46 and GS54 is conducted at the John de Laeter Centre at Curtin University, and the Centre for Microscopy, Characterisation and Analysis (CMCA) at UWA.

Planned work program 2019–20

The GS54 program will generate U–Pb zircon, baddeleyite and monazite ages in support of GSWA geoscience programs across Western Australia. The timely release of geochronology results will be maintained, through both rapid, in-house, brief reports and the Geochronology Record Series, published online via GeoVIEW.WA, eBookshop and the Data and Software Centre. The laboratory will process samples for geochronology,

whole-rock geochemistry and isotope geochemistry as required by GSWA geoscience programs. The Greenstone Geochemical Barcoding Project (ES49) is the largest single user of whole-rock geochemistry, with >1000 samples analysed each year.

The ES46 program will continue analyses of Lu–Hf, Sm–Nd and oxygen isotopes in 2019–20. Isotope data generated by this program will be checked for accuracy and consistency, provided to GSWA projects and published on the DMIRS website as they become available. Existing and new zircon oxygen isotope data will be released in tabulated form via GeoVIEW.WA and in the annual compilation of geochronology information. 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. Syntheses will be published as Reports or Records and will inform other GSWA and external publications.

GSWA is a supporting partner, with the John de Laeter Centre, AuScope, Australian Research Data Commons (ARDC) and UWA, in a 2018–20 project to secure, digitize and make publicly available sample materials and associated data records in the McNaughton SHRIMP sample mount collection. GSWA will play a key role as custodian of physical specimens, which will be made available to the public via GeoVIEW.WA.

Following the success of a pilot project in which (U–Th)/He techniques were used to date iron oxide minerals in lateritic duricrust at the Boddington gold mine (GSWA Record 2018/13), a new two-year project with the John de Laeter Centre will start in late 2019 to expand the applications and extend regolith dating across Western Australia.

GSWA contributed to the success of two ARC grants at Curtin University, which will benefit GSWA in 2019–20 and the years ahead. The Western Australian ThermoChronology Hub (WATCH) grant provides the Perth science community with a world-first triple-dating capability, combining fission track dating, in situ (U–Th)/He dating and U–Pb dating by LA-ICP-MS. A three-year ARC Linkage project 'New tools for old rocks: first cycle provenance information' 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 will include case studies in the Yilgarn Craton and the Canning and Northern Carnarvon Basins.

GSWA has also committed support to two multi-institutional ARC Large Infrastructure and Equipment Fund (LIEF) grant applications, the results of which will be announced in late 2019. These are:

- an Australian-first collision-reaction-cell/multicollector ICP-MS, which will provide isotope analyses at unprecedented precision
- a new thermal ionization mass spectrometry (TIMS) facility for high-precision geochronology.

Products planned for release 2019–20

- Compilation of geochronology information, 2020
- Geochronology Records, U–Pb datasets and whole-rock geochemistry analyses released to online applications (GeoChem Extract and/or GeoVIEW.WA)
- Whole-rock geochemistry analyses released to online applications (GeoChem Extract and GeoVIEW.WA)
- Lu–Hf, Sm–Nd and oxygen datasets released as part of the Compilation of geochronology information, 2020 (data package)
- Lu–Hf, Sm–Nd and oxygen datasets released to online applications (GeoVIEW.WA and GeoChem Extract)
- Zircon trace element datasets released to online applications
- GSWA publications and external publications as appropriate.

Planned work program and products 2020–21

Future geochronology and geochemistry work (GS54) will continue to support GSWA's mapping and geoscience programs. Geochronology results and publications will be informed by a range of additional data, including the results of Sm–Nd, Lu–Hf and oxygen isotope studies.

The Geochronology and Geochemistry branch will continue to expand its range of geochronological and isotopic techniques through in-house research and external scientific collaborations.

Currently under construction is a new geochronology and mineral chemistry database (WAGIM), which will organize and deliver geochronology, isotope and mineral chemistry, and metamorphic data. New Geochronology Records will be produced 'on-the-fly', together with the most up-to-date geological context information, by a module in ENS within GeoVIEW.WA. The WAGIM database will also facilitate publication of 'external' geochronology data, via a dedicated layer in GeoVIEW.WA.

The work program for 2020–21 and beyond will be similar to that for 2019–20. New samples for isotope and trace element studies will be collected during the normal course of GSWA fieldwork to address specific geological problems.

The following publications are planned for release in 2020–21:

- Compilation of geochronology information, 2021
- Geochronology Records, U–Pb datasets and whole-rock geochemistry analyses released to online applications (GeoChem Extract and/or GeoVIEW.WA)
- Whole-rock geochemistry analyses released to online applications (GeoChem Extract and GeoVIEW.WA)
- Lu–Hf, Sm–Nd and oxygen datasets released as part of the Compilation of geochronology information, 2021 (data package)
- Lu–Hf, Sm–Nd and oxygen datasets released to online applications (GeoVIEW.WA and GeoChem Extract)
- Zircon trace element datasets released to online applications
- GSWA publications and external publications as appropriate.

ES47 Petroleum Systems

Manager: Deidre Brooks

Team members: Norman Alavi, Heidi Allen, Lorraine de Leuw, Louisa Dent, Ameer Ghorri, Peter Haines, Sarah Martin, Arthur Mory, Leon Normore, Charmaine Thomas, Yijie (Alex) Zhan

The objective 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 a number of distinct subprograms.

Collaborative core analysis projects with the petroleum industry are contributing to research on the reservoir quality and hydrocarbon source-rock potential of the Canning and northern Perth Basins.

The results from the Canning Basin project, which commenced in 2015 when the three industry exploration wells Theia 1, Olympic 1 and Senagi 1 were drilled, include:

- recognition of a new potential petroleum source-rock in the Ordovician Nambear Formation
- improved correlation of conodont age dating with international time scales using new geochronology (chemical abrasion isotope dilution thermal ionization mass spectrometry [CA-ID-TIMS]) and chemostratigraphy (carbon isotope curves) results
- better estimation of thermal maturity combining geochemistry and several methods of converting organic petrology of bitumen, graptolites and other bioclasts to an equivalent vitrinite reflectance
- the development of a new digital product, called the Digital Core Atlas, to interactively display large datasets from core analysis results; the first Digital Core Atlas was for the Olympic 1 well has received wide acclaim from industry, academia and international geological surveys; a Digital Core Atlas for Theia 1 well was released at the end of June 2018, and the Senagi 1 well Digital Core Atlas was released in April 2019. This new digital product type is now being utilized in other regions of the state.

Assessment of the parameters influencing reservoir quality in the Permian sandstones of the northern Perth Basin, particularly in the region of the significant Waitsia gas discovery, are progressing and include ichnology, XRD, petrography, HyLogger spectral analysis, influence of temperature and depositional environment on distribution of clays and detailed core logging.

Geophysical projects in 2019–20 that incorporate new EIS-funded, pre-competitive data and aim to improve the structural and stratigraphic definition of the Canning and Carnarvon Basins include:

- seismic interpretation of Kidson Sub-basin and Crossland Platform, utilizing the EIS Co-funded Kidson seismic survey and EIS-funded, newly reprocessed 2D seismic lines in the Kidson Sub-basin, Cobb Embayment and northwestern Canning Basin

- seismic interpretation of the Southern Carnarvon and northern Perth Basins, utilizing 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 recently released EIS-funded Carnarvon Basin SEEBASE product
- planning for a joint DMIRS–GA stratigraphic well in the western Canning Basin (Waukarlycarly Embayment) utilizing the data from the new Kidson seismic survey.

Following on from the seismic acquisition, stratigraphic drilling is planned for mid-2019 on a location along the new seismic line, to improve understanding of the stratigraphy and petroleum potential of the Waukarlycarly Embayment and the underlying basement. The drilling costs are not funded by EIS.

A Record reviewing the exploration history and coal resources of the Canning Basin is planned for publication in 2019–20, which is associated with two Records released in 2018–19 that review the exploration history and estimated lignite resource volumes in southwestern Western Australia, including the Eucla Basin, and the Mesozoic coal seams of the northern Perth Basin. A data package associated with these Records will be published in 2019–20.

Finally, the need for CO₂ geosequestration sites near the major emitters requires further geological studies and data acquisition. The collaborative core analysis projects in both the Canning and Perth Basins include potential reservoir and seal studies, and the Canning Basin project is funded jointly by the Commonwealth and EIS.

Planned work program 2019–20

In 2019–20 and beyond, regional geological and geophysical studies for the Canning, Perth and Carnarvon Basins will continue, including EIS-funded studies for petroleum systems, coal and CO₂ geosequestration.

These projects include the:

- publication of a review of significant coal resources of Western Australia within three published Records and a GIS package of the coal-related drillholes relevant to the areas covered by the Records
- continuation of reservoir studies and CO₂ geological storage, in collaboration with GA and petroleum companies, in the Perth and Canning Basins; this includes cooperation on core analysis with Mitsui (formerly known as AWE) of the core from the

Waitsia Field wells drilled in the northern Perth Basin, and publication of a petrophysical review of CO₂ geological storage potential of the reservoir quality units intersected in the Olympic 1, Theia 1 and Senagi 1 wells in the Canning Basin

- commencement of interpretation of newly reprocessed legacy seismic data mainly in the Canning Basin and the area between the northern Perth and Southern Carnarvon Basins, which can also be included as new pre-competitive data supporting future acreage releases
- commencement of interpretation of the new 2D regional deep crustal seismic line across the Kidson Sub-basin and incorporation of the results in a regional mapping project
- publication of a Digital Core Atlas for each of the Harvey wells (1–4) in the Perth Basin.

Canning Basin

The planned outcomes from studies in the Canning Basin in 2019–20 are to:

- commence interpreting the newly reprocessed 2D seismic lines in the Kidson Sub-basin, Cobb Embayment and the northwest portion of the Canning Basin
- continue investigating regional correlations and hydrocarbon potential of the lower to middle Ordovician Goldwyer and Nambeet formations
- define the Nambeet Formation reference section and finalize and release a Record based on the results of the collaborative core analysis project
- commence work on defining the Goldwyer Formation reference section based on the results of the collaborative core analysis project
- release a Record of the results of the assessment of the CO₂ geosequestration potential of the Ordovician intersected in Theia 1 and Olympic 1 wells, and the Devonian in Senagi 1 well in the Canning Basin, based on the results from the collaborative core analysis project
- release a Record documenting the coal resources of the Canning Basin.

Perth Basin

The planned outcomes from studies in the Perth Basin in 2019–20 are to:

- continue the core analysis project of the Waitsia area core with results feeding into regional studies
- release a Digital Core Atlas for each of the four Harvey wells.

Southern Carnarvon Basin

The planned outcome from studies in the Carnarvon Basin in 2019–20 is to commence interpretation of the EIS-funded, newly reprocessed 2D seismic lines and incorporate the results, along with the new EIS-funded SEEBASE product, into a wider interpretation project to improve the definition of the stratigraphy and structure of the onshore portion of the basin.

Products planned for release 2019–20

- Digital Core Atlases, Harvey 1–4, Perth Basin (interactive digital products)
- CO₂ geosequestration potential of Ordovician reservoirs intersected in Olympic 1, Canning Basin (Record)
- CO₂ geosequestration potential of Ordovician reservoirs intersected in Theia 1, Canning Basin (Record)
- CO₂ geosequestration potential of Devonian reservoirs intersected in Senagi 1, Canning Basin (Record)
- Coal resources of the Canning Basin: exploration and evaluation history (Record)
- Digital GIS package of coal drillholes related to the coal Records.

ES49 Greenstone Geochemical Barcoding Project

Manager: Hugh Smithies

Team members: Lauren Burley

The Greenstone Geochemical Barcoding Project is an initiative under the EIS that aims to geochemically characterize greenstone stratigraphy throughout the EGST. This project will 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. This has initially been undertaken in the Kalgoorlie–Kambalda region, but will ultimately extend throughout the EGST. 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. The ultimate goals of this project are:

- to establish whether local and/or regional greenstone stratigraphies are geologically valid, and establish the geological reasons for any local and regional stratigraphic variations
- to 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

- to provide a data-rich, high-quality geochemical dataset regionally representative of all magmatic rock types that will help further develop our understanding of petrogenetic processes in greenstone evolution and associated mineralization.

Planned work program 2019–20

Work within ES49 will continue to concentrate in the western part of the EGST (i.e. the Kalgoorlie Terrane). This work will assist with and complement the interpretation of the high-resolution seismic survey that was conducted in early 2019 by GSWA, between Ora Banda and Kambalda.

Products planned for release 2019–20

- Greenstone Geochemical Barcoding Project data release (Record)
- Greenstone Geochemical Barcoding Project (Record).

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Appendix

Current GSWA collaborative research projects — 1 July 2019

Current and new projects

Ar/Ar dating of pyroxene



Project Manager: Michael Wingate

Partner researchers/institutions: John de Laeter Centre, Curtin University

GSWA contact: Michael Wingate

Duration of project: 2017–20

Project description

To test whether Ar/Ar analysis of pyroxene can be used to date mafic and ultramafic rocks that cannot be dated by other methods.

Outputs — planned or actual

GSWA publication and journal article (planned)

ARC Centre of Excellence CE11E0070: core to crust fluid systems



Project Manager: Suzanne O'Reilly (Macquarie University)

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

GSWA contacts: Ian Tyler, Klaus Gessner, Michael Wingate

Duration of project: 2011–17 (extended to 2022)

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 (<http://ccfs.mq.edu.au/>).

GSWA sponsored projects

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

Outputs — planned or actual

Co-branded GSWA Reports and international journal papers; GSWA geochronology records

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.

Gorczyk, W, Gessner, K, Lu, Y and Thébaud, N 2016, 2nd lithosphere workshop, 19–20 November 2015, The University of Western Australia: Geological Survey of Western Australia, Record 2015/16, 43p.

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Johnson, SP, Sheppard, S, Wingate, MTD, Kirkland, CL and Belousova, EA 2011, Temporal and hafnium isotopic evolution of the Glenburgh Terrane basement: an exotic crustal fragment in the Capricorn Orogen: Geological Survey of Western Australia, Report 110, 27p.

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Kirkland, CL, Smithies, RH, Woodhouse, A, Howard, HM, Wingate, MTD, Belousova, EA, Cliff, JB, Murphy, RC and Spaggiari, CV 2012, A multi-isotopic approach to the crustal evolution of the west Musgrave province, Central Australia: Geological Survey of Western Australia, Report 115, 47p.

Kirkland, CL, Spaggiari, CV, Smithies, RH, Wingate, MTD, Sweetapple, MT, Watkins, R, Tesselina, S and Creaser, RC 2015, Temporal constraints on magmatism, granulite-facies metamorphism, and gold mineralization of the Hercules Gneiss, Tropicana Zone, Albany–Fraser Orogen: Geological Survey of Western Australia, Record 2015/5, 33p.

Kirkland, CL, Spaggiari, CV, Wingate, MTD, Smithies, RH, Belousova, EA, Murphy, R and Pawley, MJ 2011, Inferences on crust-mantle interaction from Lu–Hf isotopes: a case study from the Albany–Fraser Orogen: Geological Survey of Western Australia, Record 2011/12, 25p.

Spaggiari, CV, Kirkland, CL, Smithies, RH and Wingate, MTD 2014, Tectonic links between Proterozoic sedimentary cycles, basin formation and magmatism in the Albany–Fraser Orogen, Western Australia: Geological Survey of Western Australia, Report 133, 63p.

Yuan, H 2016, Secular change in Archean crust formation recorded in Western Australia, *in* GSWA 2016 extended abstracts: promoting the prospectivity of Western Australia: Geological Survey of Western Australia, Record 2016/2, p. 18–20.

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: 2014–20

Project description

This study will look at the geochemistry of mafic rocks in the Murchison Domain of the Yilgarn Craton. Subduction typically starts on 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 as a 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.

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: 3 years (2018–21)

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 sampling in the field to the production of a series of consistent 3D geological models with uncertainty assessment and characterization.

Outputs — planned or actual

Open-source 3D geological simulator and modelling software package.

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

Project Manager: Simon Johnson, Michael Wingate, Hugh Smithies

Partner researchers/institutions: Chris Kirkland (Curtin University)

GSWA contact: Simon Johnson

Duration of project: 2019–23

Project description

The aims of this research are 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: a) zircon may be multicycle, blurring source–sink relationships; b) 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, 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.

Numerous high-quality, open-access journal articles at various stages throughout the project, some probably published six months to one year after the end of the project.

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

Project Manager: Klaus Gessner

Partner researchers/institutions: ANU, GA, DFES

GSWA contact: Klaus Gessner

Duration of project: 2019–22

Project description

To improve understanding of both 3D seismic structure in southwest Australia and the nature of the earthquake behavior in this seismically active region, a network of 25 broadband seismometers (SWAN) will be installed. All classes of seismic data will be exploited to generate 3D seismic models of the continental lithosphere. The enhanced seismic coverage and structural control will enable better location and characterization of seismic events that will allow prediction of the ground motion patterns in the 3D models from earthquakes with assigned location and magnitude, which is fundamental to earthquake hazard assessment. These developments will allow Australia to move to the forefront of 3D ground motion studies.

Outputs — planned or actual

Journal articles and GSWA Reports, and potentially maps, datasets and 3D models.

Crustal evolution of Western Australia

Project Manager: Chris Kirkland

Partner researchers/institutions: Curtin University

GSWA contact: Michael Wingate

Duration of project: 2015–20

Project description

The project aims are to:

- produce contoured, time-dynamic hafnium isotopic maps from selected regions of Western Australia
- implement secondary ion mass spectroscopy oxygen analyses of GSWA mounts and contribute to isotopic data.

Outputs

- Co-branded GSWA Reports and GIS layers
- hafnium isotopic maps and oxygen isotopic analyses

- Western Australian atlas of crustal evolution
- Magmatic petrogenesis of the Rudall Province
- Isotopic signature of crystalline basement of the Eucla Basin.

CSIRO Ultrafine soils phase 2 (CRC-P*)



Project Manager: Richard Chopping

Partner researchers/institutions: Ryan Noble (CSIRO)

GSWA contact: Nadir de Sousa Kovacs

Duration of project: 2019–21

Project description

Supporting the MinEx CRC NDI Western Australia focus area, undertaking UltraFine+ re-analysis of West Arunta regolith geochemistry samples and other samples collected during geophysical deployments.

Outputs — planned or actual

Geochemical analyses in WACHEM, Records or Reports.

Current state of knowledge on the Mesozoic of Western Australia

Project Manager: Deidre Brooks

Partner researchers/institutions: Curtin University

GSWA contact: Deidre Brooks

Duration of project: 2017–19

Project description

The aim is to contribute to the understanding of the geology of the Mesozoic era within Western Australia, by researching and documenting the current status of knowledge. This will be published in GSWA's Western Australia unearthed series.

Outputs — planned or actual

Publication as part of the Western Australia unearthed series.

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: 2019–21

Project description

This China Western Australia Seismic (CWAS) 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 for developing a better understanding of the basement of the Canning Basin and its potential for mineral systems.

Outputs — planned or actual

Seismic models of the western margin and central part of the Canning Basin, including: crustal thickness maps, a crustal shear wave velocity model and body-wave tomographic model down to 400 km depth, to be delivered after the end of phase 3 in 2021.

* CRC-P, Cooperative Research Centres Project

Do the mineral systems in the southern Kalgoorlie Terrane have a camp-scale geophysical signature**Project Manager:** Michael Dentith**Partner researchers/institutions:** UWA**GSWA contact:** Klaus Gessner**Duration of project:** 2018–19**Project description**

Geophysical data will be collected, processed and interpreted from the region between Kalgoorlie–Kambalda–Norseman. This experiment will investigate 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

Co-branded GSWA Reports and Records.

Earth composition and evolution — preservation of legacy collections project**Project Manager:** Michael Wingate**Partner researchers/institutions:** John de Laeter Centre and Curtin University Library**GSWA contact:** Michael Wingate**Duration of project:** 2018–20**Project description**

The project will protect, preserve and enable reuse of a collection of SHRIMP mounts from dozens of ore genesis studies, as well as supplementary materials (researcher notes, interpretation, images, etc.). These mounts are globally significant, as many of the deposits are now mined out, inaccessible and/or too expensive to revisit. The collection will be archived by GSWA, with materials discoverable via GeoVIEW.WA and/or AuScope.

Outputs — planned or actual

Physical sample collection, plus digitized information and metadata, suitable for publication as a spatial data layer by GSWA and AuScope.

Geological studies of gabbroic rocks intruding the Arid Basin in the Albany–Fraser Orogen**Project Manager:** Tim Johnson**Partner researchers/institutions:** Chris Clark, Chris Kirkland (Curtin University)**GSWA contact:** Catherine Spaggiari**Duration of project:** 2015–18**Project description**

The principal aims of the proposed research are to:

- determine the depth of magmatism and the pressure and temperature of metamorphism of the gabbroic rocks that intrude the sedimentary rocks of the Arid Basin
- compare these to the metamorphic P–T of the sedimentary rocks (i.e. Snowys Dam Formation) of the Fraser Zone
- determine emplacement mechanisms and timing of gabbroic intrusions and their relationship to metamorphism.

Outputs — planned or actual

Glasson, K 2018, A petrographic and geochronological assessment of the gabbroic and metagabbroic rocks of the Fraser Zone, Albany–Fraser Orogen, Western Australia: Geological Survey of Western Australia, Record 2018/5, 57p.

Journal paper: A window into an ancient back arc? The magmatic and metamorphic history of the Fraser Zone, Western Australia (Precambrian Research, in review).

Gold fingerprinting**Project Manager:** Lena Hancock**Partner researchers/institutions:** John Watling (TSW Analytical Pty Ltd); Paul Duuring, Olga Blay (GSWA)**GSWA contact:** Lena Hancock**Duration of project:** 2019–21**Project description**

LA-ICP-MS and various SEM analyses are required to investigate silver and trace element contents, microstructure and inclusions in gold grains/nuggets acquired for the GSWA Pilbara gold fingerprinting project. This project aims to investigate the source of gold nuggets in the Pilbara study area by determining the composition of collected gold nuggets and attempting to match them with known examples gold occurrences hosted in bedrock located in the study area.

Outputs — planned or actual

GSWA publications documenting the results and interpretation of LA-ICP-MS data from gold nuggets.

K–Ar dating of fault rocks**Project Manager:** Huntly Cutten**Partner researchers/institutions:** Horst Zwingmann (Kyoto University); Tonguc Uysal, Andrew Todd (Australian Resources Research Centre [ARRC], CSIRO)**GSWA contact:** Huntly Cutten, Michael Wingate**Duration of project:** 2015–20**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 previously could only be dated indirectly. The project will hopefully be expanded to include the eastern Capricorn Orogen basins.

Outputs — planned or actual

Peer-reviewed journal papers; GSWA Report.

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.

Mapping sulfur sources in selected Precambrian terranes of Western Australia to enhance predictive targeting for gold and base metal mineralization**Project Manager:** Marco Fiorentini**Partner researchers/institutions:** CET, UWA**GSWA contact:** Trevor Beardsmore**Duration of project:** 2014–19**Project description**

The aim of this project is to spatially constrain sulfur sources of gold and base metal mineralization in key terranes of Western Australia.

Outputs — planned or actual

Peer-reviewed journal papers; conference proceedings; GSWA Report.

MinEx CRC Program 3: National Drilling Initiative**Project Manager:** Richard Chopping**Partner researchers/institutions:** Multicollaborative project**GSWA contact:** Richard Chopping**Duration of project:** 10 years (2018–28)**Project description**

MinEx CRC will create new opportunities for mineral discovery by delivering more productive, safer and environmentally friendly drilling methods and 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 comprises 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

GSWA involvement in MinEx CRC includes additional involvement in Project 6 (discussed below). GSWA 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 Modelling**Project Manager:** Richard Chopping**Partner researchers/institutions:** Multicollaborative project**GSWA contact:** Richard Chopping, Klaus Gessner**Duration of project:** 3 years (2019–22)**Project description**

In addition to the NDI research discussed above, GSWA will also be involved in MinEx CRC Project 6, which will develop automated 3D modelling methodologies. This project is related to the ARC Linkage project for 3D stochastic modelling.

Outputs — planned or actual

Regional-scale 3D map constructed from GSWA data using MinEx CRC developed tools.

MRIWA project M446 — 4D evolution of Western Australian ore systems: Re–Os sulfide geochronology**Project Manager:** Neal McNaughton (John de Laeter Centre, Curtin University)**Partner researchers/institutions:** Svetlana Tessalina, Fred Jourdan, Vitor Barrote (PhD candidate) (John de Laeter Centre, Curtin University); Thermo Fisher Scientific**GSWA contact:** Michael Wingate**Duration of project:** 2016–20**Project description**

The aims are to provide benchmark geochronology for metals exploration in Western Australia to complement the extensive 2D and 3D geological mapping and data of GSWA and industry. This sulfide geochronology project provides a new opportunity to introduce direct dating of ore sulfides along with fingerprinting metal sources, and will fill a major gap in 4D analysis of mineralized terrains, a topic recognized as a national deficiency. The specific aims are for two deposit types, VHMS and orogenic gold.

Outputs — planned or actual

Peer-reviewed journal papers; conference proceedings; MRIWA Report.

MRIWA project M448 — 4D evolution of Western Australian ore systems (WA4D): rutile — pathfinder to ores**Project Manager:** Neal McNaughton (John de Laeter Centre, Curtin University)**Partner researchers/institutions:** Noreen Evans, Fred Jourdan, Jennifer Porter (PhD candidate) (John de Laeter Centre, Curtin University); Independence Group NL**GSWA contact:** Michael Wingate**Duration of project:** 2015–20**Project description**

This project will utilize publicly available geochemical data on rutiles formed in different ore and unmineralized environments to build a geochemical database, and to add new geochemical data for rutiles from Western Australian ore systems and barren rocks. From this database, existing geochemical discriminants of mineralization will be tested, and by virtue of the enhanced capabilities of modern analytical techniques to be employed, new discriminants will be developed for each ore commodity that will shed light on the origin of formation of rutile. The project will target Western Australian ore systems for new data, to compare and contrast against published data, and will include:

- rapid/automated rutile identification and in situ analysis
- verification of rutile mineralization ages by other geochronology methods (U–Pb, Ar–Ar)
- sponsor-initiated case studies of rutile geochemistry / age discriminants for gold and base metal exploration in Western Australia
- feedback to 4D metallogenic mapping.

Outputs — planned or actual

Peer-reviewed journal papers; conference proceedings; MRIWA Report.

MRIWA project M470 — Mineral systems on the margin of cratons: Albany–Fraser Orogen / Eucla basement case study**Project Manager:** Chris Kirkland**Partner researchers/institutions:** Chris Clark, Katy Evans, Steve Reddy (Curtin University); Oliver Kiddie (Ponton Minerals)**GSWA contact:** Catherine Spaggiari**Duration of project:** 2016–19**Project description**

Research will focus on the partially covered terrain of the Albany–Fraser Orogen and the covered Eucla Basement of Western Australia. The project will utilize a lithosphere-scale mineral systems approach to establish the fundamentals (timing, scale and material) of mass transfer processes within the crust. The project will utilize a broad range of geochronology techniques to enhance GSWA's regional U–Pb zircon coverage and will apply crustal evolution studies via novel analytical equipment to rapidly delimit domains of enhanced mantle input.

This research project includes three modules:

- isotopic monitors of crustal evolution; through cutting edge split stream LA-ICP-MS instrumentation (hafnium in zircon, neodymium in rutile)
- petrochronology; by coupling U–Pb geochronology (on a wide range of different mineral phases) to the grain-scale mineral chemistry as a proxy for the conditions of the crust during specific periods in time
- sulfide sources and budgets; through the use of multiple sulfur isotopes combined with trace element ratios, a robust fingerprint of sulfur mobility and metal reservoirs in the region will be developed.

Outputs — planned or actual

Peer-reviewed journal papers; conference proceedings; PhD theses and MRIWA report as GSWA Reports.

MRIWA project M521 — Lithospheric and crustal-scale controls on multistage basin evolution: impacts on mineralizing systems**Project Manager:** Weronika Gorczyk, Mark Jessell**Partner researchers/institutions:** MRIWA (UWA; First Quantum Minerals; Fortescue Metals Group)**GSWA contact:** Catherine Spaggiari**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 and 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 e-material resources in Western Australia (CRC-P)**Project Manager:** Michael Wingate**Partner researchers/institutions:** John de Laeter Centre, Curtin University; AXT Pty Ltd**GSWA contact:** Michael Wingate**Duration of project:** 2019–22**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

External publications 2020–21; Report 2021–22.

Narryer Terrane isotopes project**Project Manager:** Hugh Smithies**Partner researchers/institutions:** Tony Kemp, Matthew Rowe (UWA)**GSWA contact:** 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

GSWA Report and external papers.

Kemp, IS, Wilde, SA and Spaggiari, C 2019, Chapter 18 — The Narryer Terrane, Yilgarn Craton, Western Australia: Review and Recent Developments *in* Earth’s Oldest Rocks (second edition), *edited by* MJ Van Kranendonk, VC Bennett and JE Hoffmann: Elsevier, p. 401–433.

Rowe, ML 2016, Petrology and geochemistry of the Eoarchaean Manfred Complex: origin and components: Geological Survey of Western Australia, Record 2016/22, 150p.

National Virtual Core Library — Western Australian node**Project Manager:** Lena Hancock**Partner researchers/institutions:** AuScope with NCRIS funding, CSIRO**GSWA Contact:** Lena Hancock**Project Duration:** Ongoing

Project description

GSWA houses, manages and operates a HyLogger-II semi-automated core logging facility as part of the National Virtual Core Library (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 and other third parties.

Outputs — planned or actual

Periodic geoscience publications utilizing HyLogger data, as well as procedural publications (www.dmp.wa.gov.au/hylogger).

Oxygen isotope analyses of zircons

Project Manager: Michael Wingate

Partner researchers/institutions: UWA / Centre for Microscopy and Microanalysis

GSWA contact: Michael Wingate

Duration of project: Ongoing

Project description

This is a collaborative project which 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 (planned).

Paleoproterozoic mafic magmatism of the Kimberley Basin, Western Australia

Project Manager: Catherine Spaggiari

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

GSWA contact: Christopher Phillips

Duration of project: 2012–20 (incomplete – awaiting deliverables)

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

GSWA Report

Hollis, JA, Orth, K, Sheppard, S, Tyler, IM, Kirkland, CL and Wingate, MTD 2013, Setting and prospectivity of a large igneous province: the 1800 Ma Hart Dolerite, Kimberley region, in GSWA 2013 extended abstracts: promoting the prospectivity of Western Australia: Geological Survey of Western Australia, Record 2013/2, p. 9–13.

Orth, K 2015, The Carson-Hart Large Igneous Province intrusive complex: implications for Speewah-style vanadium–titanium–iron mineralization in the Kimberley region, in GSWA 2015 extended abstracts: promoting the prospectivity of Western Australia: Geological Survey of Western Australia, Record 2015/2, p. 19–22.

Phillips, C, Orth, K, Hollis, JA, Kirkland, CL, Bodorkos, S, Kemp, AIS, Wingate, MTD, Lu, Y, Iaccheri, L and Page, RW 2016, Geology of the Eastern Zone of the Lamboo Province, Halls Creek Orogen, Western Australia: Geological Survey of Western Australia, Report 164, 57p.

Seismic acquisition using distributed acoustic sensing in an urban environment**Project Manager:** Mike Dentith**Partner researchers/institutions:** UWA**GSWA contact:** Klaus Gessner**Duration of project:** 2017–19**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 in 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.

Outputs — planned or actual

GSWA Report.

Structural and metamorphic evolution of the east Albany–Fraser Orogen**Project Manager:** Catherine Spaggiari

Partner researchers/institutions: Chris Clark, Tim Johnson, Nick Timms, Chris Kirkland (Curtin University); Tom Blenkinsop, Jan-Marten Huizenga (Economic Geology Research Centre [EGRU], James Cook University); Eric Tohver (UWA)

GSWA contact: Catherine Spaggiari**Duration of project:** Ongoing**Project description**

Research into the structural and metamorphic history of the Fraser and Biranup Zones, focusing on P–T–t evolution. Methodology includes structural mapping, sedimentological analysis, microprobe analysis, pseudosections and phosphate, titanite and Ar–Ar dating.

Outputs

Adams, M 2012, Structural and geochronological evolution of the Malcolm Gneiss, Nornalup Zone, Albany–Fraser Orogen, Western Australia: Geological Survey of Western Australia, Record 2012/4, 132p.

Clark, C, Kirkland, CL, Spaggiari, CV, Oorschot, C, Wingate, MTD and Taylor, RJ 2014, Proterozoic granulite formation driven by mafic magmatism: An example from the Fraser Range Metamorphics, Western Australia: Precambrian Research, v. 240, p. 1–21.

Kirkland, CL, Spaggiari, CV, Johnson, TE, Smithies, RH, Danisik, M, Evans, N, Wingate, MTD, Clark, C, Spencer, C, Mikucki, E and McDonald, BJ 2016, Grain size matters: Implications for element and isotopic mobility in titanite: Precambrian Research, v. 278, Supplement C, p. 283–302.

Oorschot, CW 2011, P–T–t evolution of the Fraser Zone, Albany–Fraser Orogen, Western Australia: Geological Survey of Western Australia, Record 2011/18, 101p.

Scibiorski, E, Tohver, E, Jourdan, F, Kirkland, CL and Spaggiari, C 2016, Cooling and exhumation along the curved Albany–Fraser Orogen, Western Australia: Lithosphere, vol. 8, no. 5, p. 551–563.

Stokes, MA 2014, Structural evolution of the Pleiades Lakes region; Northeastern Albany–Fraser Orogen, Western Australia: Geological Survey of Western Australia, Record 2014/15, 145p.

Waddell, PJ 2014, Sedimentological and structural evolution of the Mount Ragged Formation, Nornalup Zone, Albany–Fraser Orogen, Western Australia: Geological Survey of Western Australia, Report 129, 116p.

(U–Th)/He dating of secondary iron oxides in lateritic duricrust in Western Australia

Project Manager: Richard Chopping

Partner researchers/institutions: John de Laeter Centre, Curtin University

GSWA contact: Richard Chopping, Michael Wingate

Duration of project: 2019–21

Project description

To develop a geochronological framework for interpreting the weathering, landscape evolution and paleoclimate history of Western Australia by (U–Th)/He dating of secondary iron oxides in lateritic duricrust throughout Western Australia.

Outputs — planned or actual

Digital dataset along with GSWA and external publications.

Completed Projects with Geoscience Australia: NCF activities

Project Manager: Ian Tyler

Partner researchers/institutions: GA

GSWA contact: Ian Tyler; Deidre Brooks

Duration of project: ongoing

Australian National Virtual Geophysical Laboratory (CMCG4003A-001388)

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Canning Basin CO₂ storage project (CMCG4003A-PA6)

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Exploring for the future – Kidson Sub-basin seismic (002850)

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Management of the National Offshore Petroleum and Greenhouse Gas Data Repository (CMCG4003A-P3)

NOPTA offshore petroleum and greenhouse gas data management project — National Offshore Petroleum Data and Core Repository (CMCG4030-P1)

Reprocessing of 2D seismic data in Western Australia (CMCG4003A-002605)

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South West Hub 3D seismic survey project (CMCG4003A-PA2)

Western Australian reconnaissance airborne electromagnetic surveys 2013–20 (CMCG4003A-PA4)

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Western Australian reconnaissance gravity surveys 2013–20 (WARGRAV2) (CMCG4003A-PA5)

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