



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

RECORD 2018/1

GEOLOGICAL SURVEY WORK PROGRAM FOR 2018–19 AND BEYOND

Perth 2018



Geological Survey of Western Australia



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Department of **Mines, Industry Regulation**
and **Safety**

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**Geological Survey of
Western Australia**

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Cover image: Elongate salt lake on the Yilgarn Craton – part of the Moore–Monger paleovalley – here viewed from the top of Wownaminnya Hill, 20 km southeast of Yalgoo, Murchison Goldfields. Photography by I Zibra, DMIRS

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Geological Survey work program for 2018–19 and beyond

Executive summary

Last year (2017–18) saw major changes to the newly formed Department of Mines, Industry Regulation and Safety (DMIRS) with the government-wide Machinery of Government agenda. This led to the Geological Survey Division being reformed into the Geological Survey and Resource Strategy Division (GSRSD), which saw our business scope grow to include amalgamating the former Department of Mines and Petroleum (DMP) spatial services into GSRSD, as well as the Resource Strategy group, Abandoned Mines and parts of the former Petroleum Division. Despite these changes the Geological Survey of Western Australia (GSWA) continued to publish reports, maps and digital products and maintain its databases in line with the Work Program 2017–18.

In 2017, the Fraser Institute's Annual Survey of Mining Companies (Stedman and Green, 2018) saw Western Australia drop its ranking from third to fifth most attractive mining investment destination worldwide. Of concern was the drop in ranking of our online geoscience databases (including online tenement and other specialist information systems) to the ranking of 17th in 2017. This drop in perception provides a challenge for GSWA in how we collect, manage and distribute our data into the future. Perceptions of our mineral policy environment remained in the top 10 worldwide.

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.

Petroleum exploration (onshore and offshore) in Western Australia remains in its serious four-year decline since 2012–13 — a decline of 80% and is now at levels last experienced in about 2005; however, at the end of 2017 there was a sustained lift in crude oil prices following coordinated supply constraints by the Organization of the Petroleum Exporting Countries, which may lead to increased petroleum exploration in 2018–19. The new government has introduced a permanent ban on the use of hydraulic fracturing for unconventional gas in the South West region and initiated a moratorium on the issue in the State, while an independent scientific inquiry is held into the implications of hydraulic fracturing for unconventional gas in Western Australia.

The previous four-year downwards trend in mineral exploration expenditure (2011–12 to 2015–16) has now switched to rising mineral exploration activity. Other positive signs are emerging, particularly with a new focus on lithium and other battery metals, and renewed interest in Western Australia's gold endowment and opportunities. Western Australia's spodumene sales increased by 167% to \$1.6 billion during 2017–18, and Western Australia's iron ore exports increased yet again in 2017–18 to a new record of 826 Mt. However, despite the increased export volume, sales values were down 3%.

Last year, the then Executive Director, Rick Rogerson, described the biggest challenge for GSWA during 2017–18 as securing long-term funding for the Exploration Incentive Scheme (EIS) beyond 30 June 2019. At the time of writing, the EIS has secured long-term funding through the apportionment of mining tenement annual fees.

For 2018–19, using its recurrent and EIS budget totalling \$29.78 million (excluding departmentally funded projects), GSWA employs about 126 full-time equivalent (FTE) staff and 10 permanent part-time staff. Eight FTE contract staff are funded from EIS and approximately 55 short-term fee-for-service contractors. There are about 32 active collaborative research projects partly funded by GSWA. GSWA plans to publish the following flagship products:

- Reports, Records, Bulletins and non-series books 35
- Series maps (1:100 000, 1:250 000) 1
- Other maps (including State maps and plates) 15
- Data packages 20

Other headline deliverables for 2018–19 are:

- Mines and mineral deposit database (MINEDEX) 2018 redevelopment
- Western Australian petroleum and geothermal information management system (WAPIMS) CO₂ enhancements
- redevelopment of Western Australian field observation database (WAROX9)
- delivery of geochronology data via a mapping application
- delivery of mineral systems data via a mapping application
- implementation of workflow and product allocation system, Pubstats, using K2.

A major challenge for GSWA, and one which will certainly impact on products delivered in future years, is aligning GSWA's 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



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 Energy Geoscience and Carbon Strategy branch oversees project GS10 Basins and Energy Geoscience. The primary goal of this 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 petroleum, coal and geothermal energy resources, and thus secure the State's energy future.

Historically, the team's focus has been on conventional oil and gas, although in recent years studies have broadened to include assessing the potential for petroleum resources from: tight sand, shale and coal seam reservoirs, geothermal resources from hot rocks and hot sedimentary aquifers, and potential for carbon capture and storage.

The team works in collaboration with other divisions of the Department of Mines, Industry Regulation and Safety (DMIRS) and other organizations including CSIRO, the Western Australian Energy Research Alliance, The University of Western Australia (UWA), Curtin University, Northern Territory Geological Survey (NTGS), Geological Survey of South Australia (GSSA), 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 geological mapping or new reviews 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. An investigation continued into the little-known Moora Basin, located adjacent to the northeastern margin of the Perth Basin.

During 2018–19, new areas of study will include an expansion on the previous palynological review of the Harvey Ridge. This will include all of the southern Perth Basin, leading to a future reassessment of the stratigraphy, which is currently closely tied to the stratigraphy of the northern Perth Basin despite large differences in depositional history. Seismic interpretation and mapping of the Southern Carnarvon Basin will commence, interpretation of the Canning Basin will continue, and both these projects will incorporate newly reprocessed vintage 2D seismic data. Other projects during 2018–19 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), the compilation of a Digital Core Atlas for Sally May 2 and Nicolay 1, and a review of the Cobb Embayment 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.

Moora Basin

The main issues and uncertainties in the Moora Basin include:

- the age range is very poorly constrained (Mesoproterozoic or Neoproterozoic with the possibility of an early Paleozoic component)
- very limited biostratigraphic control; stromatolites previously reported are poorly preserved; a previously reported problematic 'fossil' is reinterpreted as inorganic
- the origin of hydrocarbons (bitumen) reported in drillcore is uncertain, leading to the question of whether hydrocarbons are indigenous to the Moora Group or have migrated from the Perth Basin
- poor exposure and limited drilling.

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.

Outcomes of work program 2017–18

Canning Basin

Some of the main outcomes from studies in the Canning Basin 2017–18 are as follows:

- Ongoing interpretation of key horizons in the southern Canning Basin provides a series of maps to better understand its resources and structural framework. This work is to be published in three separate Reports. The first Report was published in 2017–18 as Geological Survey of Western Australia (GSWA) Report 178 A seismic interpretation of the southwestern Canning Basin, Western Australia.
- Mapping of the structural elements of the central western Canning Basin was completed, confirming the presence of a thick sedimentary section within the Willara Sub-basin and thin sedimentary cover over the Broome Platform. These results will be published in the 2018–19 financial year in the second Report of the series.
- Results of the dating of basement rocks from beneath the western Canning Basin suggest that the basin is underlain by metamorphosed Neoproterozoic Centralian Superbasin in the south, and Kimberley Basin in the north. South of the Fenton Fault, these metasedimentary rocks are intruded by late Neoproterozoic (c. 650 Ma) to Middle Cambrian (c. 505 Ma) granites and pegmatites, the youngest of which may be related to the extensional tectonic event that initiated rifting of the basin.
- Publication of GSWA Report 173 The Liveringa Group, Canning Basin: correlating outcrop to subsurface.

Perth Basin

Some of the main outcomes from studies in the Perth Basin 2017–18 include:

- publication of GSWA Report 174 A review of palynology from the Harvey region, southern Perth Basin, Western Australia
- assessment of the source-rock potential and thermal maturity of the Perth Basin, incorporating 1D and 2D basin models and a set of mapped source-rock quality trends; the Report is completed and will be published in the 2018–19 financial year
- completion of a regional seismic interpretation and mapping project, which has led to an improved definition of the structure and stratigraphy of the southern Perth Basin through integration of revised biostratigraphy from petroleum, mineral and water wells and seismic interpretation, resulting in new regional depth maps of key horizons; the Report and map grids are completed and will be published in the 2018–19 financial year.

Amadeus Basin

Some of the main outcomes from studies in the Amadeus Basin 2017–18 include:

- improved correlations as a result of ongoing work on stromatolite biostratigraphy; the Record of the biostratigraphy of the prospective Aralka Formation was completed and will be published in the 2018–19 financial year
- refined cross-border correlations as a result of collaboration with NTGS
- completion of the second edition MACDONALD 1:250 000 geological map revises the outcrop distribution, age and structure of a large portion of the western Amadeus Basin in Western Australia.

Moora Basin

Some of the main outcomes from studies in the Moora Basin 2017–18 are as follows:

- Analysis of bitumen from Goonderoo 1 and 1A cores and cuttings was undertaken. GC-MS data provided some information about original oil composition, but samples were quite degraded (data submitted to Western Australian petroleum and geothermal information management system [WAPIMS]).
- Field examination relocated ‘fossil’ sites near Moora that were reported in the 1950s; these are reinterpreted as pseudofossils (probably silicified aragonite needle clusters).
- Examination of stromatolites at field sites and in drillcore to improve age constraints; heavy silicification thus far downgrades the biostratigraphic value of this material and better material is desirable.
- Detrital zircon geochronology of a sandstone from the upper part of the Moora Basin succession is in progress and should provide a maximum depositional age for the top of this very poorly age-constrained succession.

Regional studies

The main outcome from regional studies during 2017–18 is a greater understanding of the petroleum prospectivity of proposed future State Acreage Release Areas.

Products released 2017–18

Report 173 The Liveringa Group, Canning Basin: correlating outcrop to subsurface

Report 174 A review of palynology from the Harvey region, southern Perth Basin, Western Australia

Report 178 A seismic interpretation of the southwestern Canning Basin, Western Australia

MACDONALD 1:250 000 Geological Series Map

External publications — see Appendix B

Planned work program and products 2018–19

Regional geological, geophysical and petroleum geochemical studies for the Amadeus, Canning, Carnarvon, Moora, Perth and Officer Basins will continue during 2018–19 and beyond.

Canning Basin

Studies will continue on: the Ordovician Goldwyer, Nambeet and Willara Formations and the age-equivalent Prices Creek Group; the Devonian–Carboniferous Fairfield Group; the mid-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 mid-Carboniferous – Permian
- publication of the Report on seismic interpretation and mapping of the western central Canning Basin (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 which were acquired over the Canning Basin in 2017 and 2018
- writing of the Record on the Cobb Embayment, southeast Canning Basin, to be released in 2019–20
- continuation of investigations into the age and composition of the basement underlying the Canning Basin
- commencement of a field and petrographic study of the Ordovician Prices Creek Group and investigation of correlation with the Nambeet Formation
- completion of a digital core atlas for Sally May 2, publication to be released in 2019–20.

Perth Basin

Studies on biostratigraphy and petroleum systems will continue, including:

- commencement of a palynological data review for the southern Perth Basin (excluding the Harvey region)
- publication of a Report on the seismic and structural interpretation of the southern Perth Basin
- publication of a Report on the petroleum geochemistry and petroleum systems modelling of the Perth Basin
- 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
- new age constraints on the Tumblagooda Sandstone.

Officer Basin

Studies on the petroleum potential of the Officer Basin will commence, including:

- review of new well data with an emphasis on the petroleum potential of the Officer Basin
- new analysis of well samples.

Moora Basin

The results of investigations into bitumen in cores and biostratigraphy of the Moora Basin will be recorded, including:

- analysis of results to determine the origin of bitumen from the fractures within the cores from Goonderoo 1 and 1A
- new insights into the age of the very poorly dated Moora Basin from detrital zircon geochronology, when results are received.

Amadeus Basin

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

- commencement of writing of Report on revised stratigraphy of the western Amadeus Basin
- production of a publication on the biostratigraphy of the Aralka Formation
- ongoing cross-border collaboration with NTGS (which includes 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
- commencement 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 GSWA's WA unearthed series)
- release of external publications related to many of the above topics.

Products planned for release 2018–19

Seismic interpretation of the Willara Sub-basin and Broome Platform, Canning Basin, Western Australia (Report)

Seismic and structural interpretation of the southern Perth Basin (Report)

Petroleum geochemistry and petroleum systems modelling of the Perth Basin, Western Australia (Report)

Complete expanded extent and improved correlation of the Aralka Formation, Amadeus Basin (joint NTGS/GSWA Record)

3D model of the southwestern Canning Basin (digital product)

3D model of the western central Canning Basin (digital product)

Paleontology Reports (ad hoc, as required)

GS12 Land Use Planning

Manager: Warren Ormsby

Land Use Administration: Samantha Carter, Rebecca Foster

Land Use Geoscience: 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.

In February 2018, the new Land Use Planning branch was created by combining former Legislation and Compliance – Land Use from the Mineral Titles Division with Land Use Geoscience. 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. The branch has also played key roles in:

- undertaking assessments associated with native title settlement projects including the South West Native Title Agreement
- undertaking strategic assessment for the Perth–Peel region
- clarifying and streamlining administrative arrangements with other government agencies in consultation with other divisions within DMIRS.

The number of proposals received as normal workflow from other government agencies decreased again in 2017–18, although there were a substantial number associated with native title settlement projects.

Pending an external review, the strategic assessment project was suspended in April 2018. This project used a whole-of-government approach to avoiding and minimizing the impact on significant Commonwealth and State environmental matters balanced against the need for planning for future urban, industrial, infrastructure development and basic raw materials extraction.

The proposed creation of new conservation reserves throughout Western Australia and the proposed upgrading of existing reserves continue to be significant land use issues affecting the resources industry. The branch works with government to minimize the impacts on access to strategic mineral and petroleum resources and associated (mining and petroleum) interests in the selection of proposed conservation initiatives.

Other roles for 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.

Outcomes of work program 2017–18

The branch produced the following outcomes:

- Additional funding continued to be provided for the South West Native Title Settlement project (Fig. 1). One additional fee-for-service staff member was contracted to facilitate the branch's role in this project. A combined total of 1443 'screening' assessments for potential land tenure changes were completed for native title settlement projects. These assessments are in addition to the 697 referrals listed below in the 'products released' table.
- Work commenced with the Department of Planning, Lands and Heritage on integrating all new native title settlement project tasks into the South West Native Title Settlement computer-based assessment system.
- Consultation continued with local government in the Goldfields region to discuss strategic land use planning around Goldfields town sites. In particular, the branch worked closely with the City of Kalgoorlie–Boulder and other agencies to identify and assist with the land approval for a potential lithium processing facility.
- The branch assisted Main Roads Western Australia with the identification of areas with potential for gravel resources for use in long-term road maintenance and construction throughout the State.

Products released and outcomes 2017–18

Provision of information, advice and assessments in response to requests from other government agencies — 697 referrals dealt with

Aboriginal land, conservation areas, mineral and petroleum titles and geology, Western Australia — 2018 (map)

Planned work program and products 2018–19

The branch will continue to provide information, advice, assessment and approval in response to routine requests from other government agencies. The estimated number of referrals is expected to continue at similar levels to those experienced in 2017–18, that is, about 700 referrals for the year (Fig. 2). In addition, the branch also works on a range

of special high-priority projects, where the priority is set by other government agencies or by shires.

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 be substantial land assessment ‘screening’ and approvals associated with both the South West Native Title Settlement and other similar projects. These tasks will be facilitated by the completion of the full integration of the assessment processes into the South West Native Title Settlement computer-based assessment system.

Products planned for release 2018–19

Aboriginal land, conservation areas, mineral and petroleum titles and geology, Western Australia — 2019 (map)

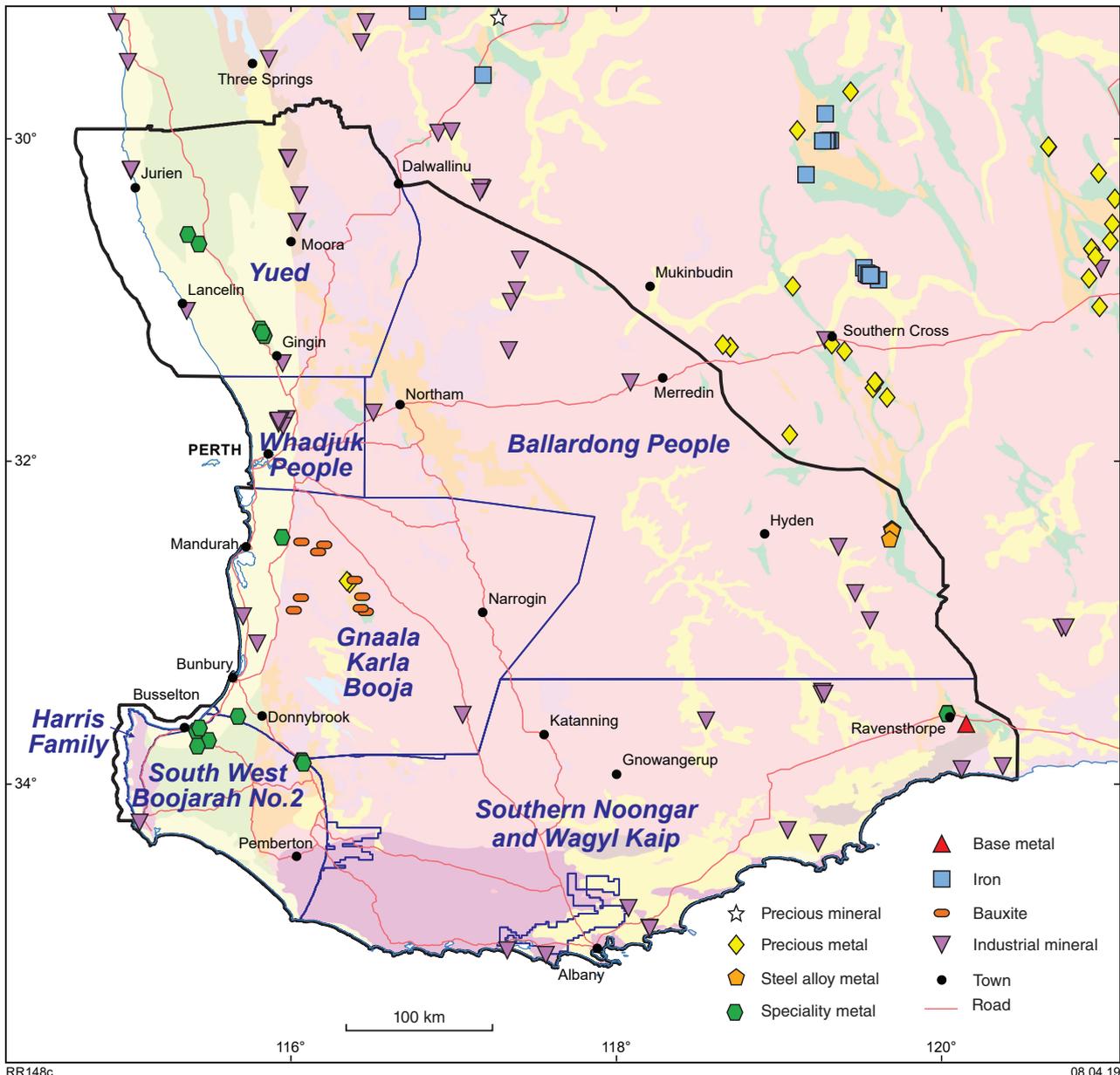
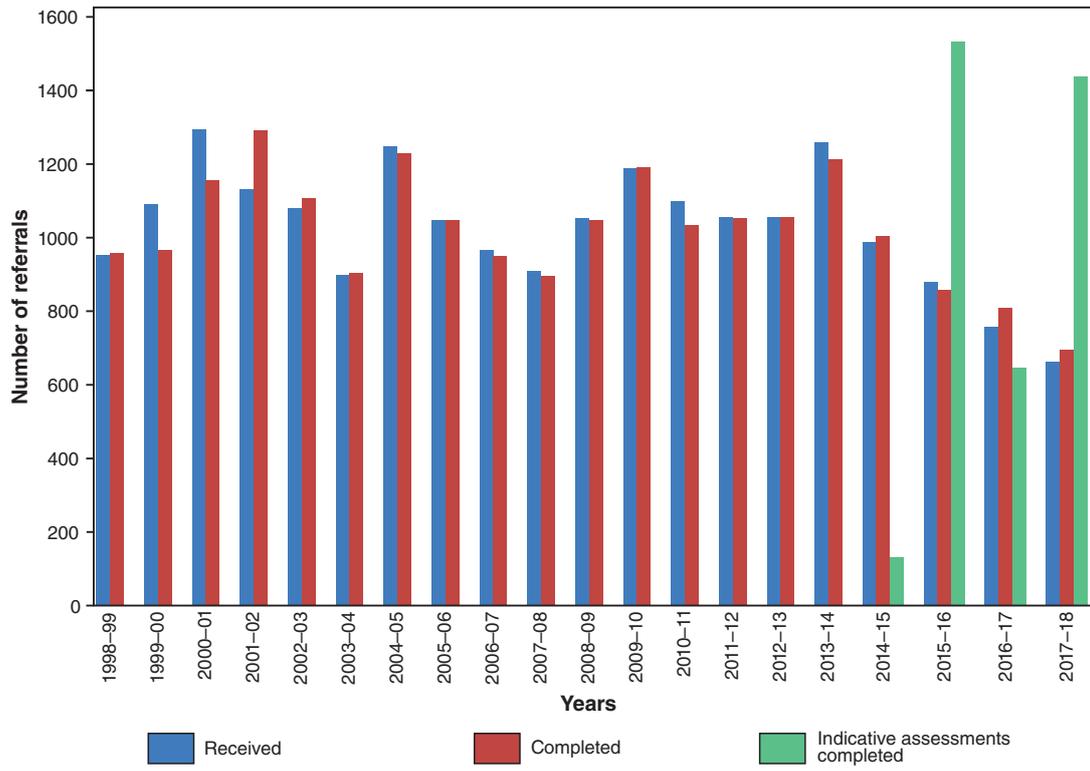


Figure 1. South West Native Title Settlement project location map. The thick blue line denotes the South West Native Title Settlement area; thin blue lines denote the boundaries between Noongar native title claim groups



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Figure 2. Land Use Planning annual referral statistics

GS14 Commodity and Industry Analysis

Manager: Nicole Wyche (acting)

Team members: Roger Cooper, Cecilia D'Ercole, Jodi Dunbar, Amanda Jones, Jutta Pagel, Caroline Strong

The Commodity and Industry Analysis branch tracks mineral exploration and mining activities in Western Australia, allowing DMIRS to provide data and specialist technical advice on most mineral commodities. The branch collects data on mineralized sites, exploration and mining projects, mineral resources and mineral production. Users of this data include other DMIRS groups, other government agencies, research organizations and a range of industries and individuals. The branch also performs compliance assessments relating to the *Mining Act 1978* and related legislation.

A key component of this branch's service is the maintenance and enhancement of Western Australia's mines and mineral deposits information database (MINEDEX). MINEDEX provides a broad range of data on minerals industry activity (current and historic), and allows advanced searching on minerals activity data and for compliance documents such as environmental registration files. MINEDEX is a core DMIRS business system that generates unique site and project identification codes used throughout DMIRS to reference activities for compliance reporting. MINEDEX codes are used by the following DMIRS systems: Environmental Assessment and Regulatory System (EARS), Royalties Management System (RMS) and the Safety Regulation System (SRS). MINEDEX is available as an internal and registration-free external textual database, and provides nightly updates of spatial data for use in DMIRS spatial data applications including TENGRAPH and GeoVIEW.WA.

Commodity and Industry Analysis produces a range of commodity-related publications, often with an investment information theme, as well as providing data for other GSWA publications. The branch also has a regulatory role and is responsible for the assessment of mineralization and resource reports submitted in support of mining lease applications, and for providing Mining Act advice on applications for expenditure exemptions, extensions of term, retention licences, retention status, combined reporting and special prospecting licences. Commodity and Industry Analysis also assesses sterilization reports.

Outcomes of work program 2017–18

The branch managed to complete most planned items, and a number of unplanned products. The number of planned investment opportunity flyers was reduced due to workload constraints. Completed tasks are summarized in the following table.

Products released in 2017–18

Major resource projects, Western Australia — 2018 (map)
Mines — operating and under development, Western Australia — 2018 (map)
WA Hotspots July 2018 (Mines, deposits and prospects in Western Australia)
Investment Opportunity Flyers released for cobalt, lithium, graphite, rare earth elements (REE) and vanadium
MINEDEX points edited and scaled for use on four published map sheets (MACDONALD and LANDSDOWNE 1:250 000 Geological Series map sheets; NINGHAN and GABANINTHA 1:100 000 Geological Series map sheets)
Resource Projects, Goldfields Region — 2017 (map)
Diamond exploration and prospectivity of Western Australia (digital data package)
Staff contribution to GSWA external publications (see Appendix B)
Battery metals commodity series flyer

In addition to the above, the branch completed the following:

- creation of approximately 1185 new MINEDEX sites
- creation of many custom MINEDEX data extracts for a range of uses
- assessment of 883 compliance applications
- responded to 3355 queries from internal and external stakeholders.

MINEDEX developments 2017–18

Several upgrades were made to MINEDEX during 2017–18 to improve the efficiency of data entry, accessibility and extractability. ArcGIS use for MINEDEX spatial data capture was replaced by the in-house developed application GeoResources on 11 December 2017.

The major data collection improvement project for 2017–18 was the MINEDEX–RMS data integration project. This project allows collection of site-based production data in addition to the traditional tenement-based production data, and improves the quality of the data received. This project was delivered via a redesigned Royalties Online Production Report launched on 1 October 2017, in time for September 2017 quarter production reporting.

Two new development projects were initiated in 2017–18:

- online reporting of Section 40e ('prospecting permit') mineral recovery data
- MINEDEX user interface redevelopment project; launched to modernize the database and to provide a better user experience.

Planned work program and products 2018–19

In 2018–19, the branch will focus on technical developments of MINEDEX as well as the following core tasks:

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

Products planned for release 2018–19

Major resource projects, Western Australia 2019 (map)

Mines — operating and under development, Western Australia, 2019 (map)

Significant exploration activity in Western Australia ('hotspots' map poster)

Western Australia Atlas of mineral deposits and petroleum fields 2019 (book and map)

Investment opportunity flyers will be produced if resources are available

MINEDEX developments 2018–19

The major development project for 2018–20 is the MINEDEX user interface redevelopment project. This project will replicate the ageing MINEDEX in appropriate and compatible programming language, data structure and accessibility for modern usage (e.g. mobile phone and tablet use). The project will commence as soon as the business analysis phase is completed in July 2018.

The branch has also submitted a proposal to develop online reporting of Section 40e ('prospecting permit') mineral recovery data.

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 under the project area GS20, 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 both 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 Exploration Incentive Scheme (EIS; reported herein under ES43 Mineral Systems Atlas). 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 geographic information system (GIS) packages, and internal and external publications.

The branch maintains a strong scientific capacity. It retains three of the geologists recruited via the GSWA Geology Masters (GeM) program (which provides geology honours graduates early professional development via completion of a masters degree). Lee Hassan retired in the latter part of 2017, but prior to this completed and published some significant work on volcanogenic massive sulfide (VMS) systems. Lena Hancock continues to contribute her mineralogical expertise, and to manage and further develop the HyLogger facility (Project GS95). Paul Duuring has considerably expanded the capacity and scope of the branch for individual and team-based mineral systems studies, and is also a significant contributor to the continuing professional development of less-experienced team members. Franco Pirajno is retained by the branch on a casual, fee-for-service basis to provide technical expertise and coaching.

Outcomes of work program 2017–18

The Minerals Exploration Geoscience branch continued its studies of VMS, rare earth element (REE), gold, nickel and iron ore deposits. These studies focus on determining characteristics of the geological setting, mineralization and associated alteration that inform metallogenic interpretations and also provide useful tools for targeting mineral deposits at all scales, thereby reducing the technical risk of discovery for resource companies.

The branch also completed conceptual design and preliminary product development work for a digital, GIS-

based Mineral Systems Atlas, a substantial new initiative to deliver GSWA geoscience data specifically tailored for minerals-oriented exploration and research.

VMS systems

A study of the variably deformed and metamorphosed Kingsley VMS deposits near Wheatley, in the South West Terrane of the Yilgarn Craton, was completed and the GSWA Record describing this work was published. Studies of the geochemical and spectral footprints of metamorphosed and deformed VMS mineralization in the Quinns District of the Yilgarn Craton were published in the journal *Economic Geology*, and some of this work was also published early in 2017–18 as a GSWA Report.

Representative diamond drillcore acquired from one of the more significant deposits in the Manindi VMS camp has been logged, sampled and hyperspectrally scanned using GSWA's HyLogger-3 to test mineral vectors developed in studies of VMS mineralization at Golden Grove and Weld Range (described in GSWA Report 141).

REE systems

Geological and metallogenic studies continued on several Western Australian REE systems. Sidy Morin-Ka completed and published a GSWA Report based on his Master of Economic Geology dissertation, which describes development of a technique for directly detecting and distinguishing REE using hyperspectral technologies, using Mount Weld, Gifford Creek and Browns Range as case studies. The branch is investigating the poorly understood hydrothermal, vein- and breccia-hosted heavy REE mineralization in the East Kimberley and north Tanami regions. An industry collaborative study of the age and alteration of the hydrothermal, heavy REE-dominated Browns Range deposits has been completed, and a GSWA Report is being prepared describing the full details of the study. The age of the mineralization event at John Galt deposit has been determined, and some other physical and chemical constraints are being obtained from fluid inclusions and alteration studies.

Gold systems

GSWA initiated a government–industry collaborative project to determine the prospectivity of regions for primary hypogene gold mineralization using the morphological and geochemical features of ‘alluvial’ gold nuggets and their ‘regolith-stratigraphic’ settings. The initial pilot study of the Kurnalpi Goldfield includes collaboration with the gold forensic group at TSW Analytical to develop an analytical technique for obtaining

quantitative geochemical data using laser ablation inductively coupled mass spectrometers (LA-ICP-MS). This is the first systematic study of its type in Western Australia; results will eventually inform gold prospectivity assessments for other Western Australian metallogenic terranes.

Studies of gold deposits in the Ashburton Basin continued, focusing primarily on the Mt Clement deposit, reviewing historical exploration data, field reconnaissance mapping and sampling of the local geology, logging and sampling of drillcore archived by GSWA, and petrographic and geochemical analysis of samples. A Report is being prepared. This and subsequent work contributes to a much larger, ongoing collaborative investigation of the architecture and metallogeny of the Capricorn Orogen that is occurring under the banner of the National ‘UNCOVER’ initiative.

Nickel systems

Lauren Burley continued preparing her Master of Economic Geology dissertation on the Fisher East komatiite-hosted nickel mineralization for publication as a GSWA Report and as an article in *Ore Geology Reviews*. She is now pursuing a program of systematic, regional-scale sampling of lithostratigraphy and selected komatiite-hosted nickel sulfide systems adjacent to the boundaries between the Kurnalpi, Burtville and Yamarna Terranes, as part of a larger collaborative project between GSWA, CSIRO and UWA. The aim of this program is to understand the tectonostratigraphic and metallogenic evolution of the far eastern Yilgarn Craton. She also continues a study of the geochemical fertility of mafic volcano-plutonic rocks of the Warakurna Large Igneous Province for nickel–copper–platinum group element (PGE) mineralization, using targeted mapping and sampling of mafic intrusive rocks in the Edmund and Collier Basins, and petrological and lithochemical analyses.

Iron systems

The EIS-funded government–academia–industry collaborative study of banded iron-formation (BIF)-hosted iron ore metallogeny in the Yilgarn Craton (part of Project ES43) was completed prior to project leader Paul Duuring joining GSWA in early 2016. Some of the results of mapping iron ore and associated alteration using HyLogging were published in 2016–17 as a series of GSWA Records. An overall synthesis is to be published as a GSWA Report and series of external publications. The study of Yilgarn iron ore systems is being extended with a program to obtain ages for hydrothermal iron mineralization, beginning with selected iron deposits in the Weld Range, Koolyanobbing and Windarling regions. Initial work during early 2017 focused on sensitive high-resolution ion microprobe (SHRIMP) U–Pb dating of co-genetic phosphates, using the facility at the John de Laeter Centre, Curtin University. A study on the physical–chemical characteristics and source of mineralizing fluids responsible for the Weld Range iron deposits was published in *Ore Geology Reviews*.

Mineral Systems Atlas

In a significant new initiative, the branch notably advanced the creation of an interactive, GIS-based Mineral Systems Atlas, which will deliver ‘mappable geological proxies’ for critical metallogenic processes that are derived from systematic ‘mineral systems analyses’ of known or probable mineral systems in Western Australia. The mappable geological proxies are to be created from existing and enhanced or newly created public domain datasets, for use in GIS-based mineral prospectivity studies by mineral explorers. The Atlas will be engineered so that constituent ‘proxy layers’ are automatically updated whenever the underpinning databases are modified.

As part of a ‘proof of concept’ study, the Minerals Exploration Geoscience branch has defined mappable proxies for komatiite-hosted nickel systems, and commenced work on generating several high-priority geological proxies for this mineralization type. This early work has highlighted issues with access to, and content of, information in GSWA’s data holdings, prompting the branch to initiate a review of all GSWA databases, with the goal of identifying and effecting improvements. Such improvements will include expanding the information content of the MINEDEX database to include comprehensive published mineral deposit age data.

Other activities

Several members of the branch co-authored papers on the Fisher East nickel deposits (L Burley), Yilgarn and Pilbara iron deposits (P Duuring), and the metallogeny of the Paterson Orogen (T Beardsmore), which are included in the Australasian Institute of Mining and Metallurgy (AusIMM) Monograph 32 ‘Australian Ore Deposits’, published in the latter half of 2017 (see Appendix B).

The branch also continued to manage or monitor a number of other minerals-oriented research initiatives funded by GSWA’s EIS (refer to the work programs for projects ES43 and ES50). This included supervision of a study by UWA Master of Science student Henry Roll on the nature of gold mineralization at the Coyote gold deposit. This project included the logging and sampling of drillcore archived by GSWA and the interpretation of associated spectral data. The resulting thesis was published as a GSWA Record.

Products released 2017–18

Record 187 Detection and identification of rare earth elements using hyperspectral techniques (based on Master of Economic Geology dissertation)

Record 2017/9 Metamorphosed VMS mineralization at Wheatley, southwest Western Australia

Record 2017/10 Alteration associated with the Austin-Quinns VMS deposits

Record 2017/12 Controls on hydrothermal alterations and gold mineralisation at Coyote deposit, Western Australia

Record 2018/2 GSWA 2018 Extended abstracts: promoting the prospectivity of Western Australia, contributions:

Western Australia: a battery metal powerhouse, p. 34–39

Provenance fingerprinting of gold nuggets from the Kurnalpi Goldfield, p. 40–43

External publications — see Appendix B

Planned work program and products 2018–19

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 REE deposits
- the age and nature of mineralizing fluids for heavy REE mineralization at John Galt, East Kimberley
- nickel sulfide mineralization at Fisher East, northeastern Yilgarn
- syngenetic gold mineralization at Mt Clement, Capricorn Orogen
- metallogeny of Archean BIF-hosted iron ore in the Yilgarn Craton.

Work on VMS systems in 2018–19 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 field geological mapping and sampling, and laboratory studies of fluid inclusions and alteration at the John Galt deposit, to place constraints on the physical and chemical conditions of mineralization. The branch will also embrace any opportunities that arise for government–industry collaborative metallogenic studies of other REE deposit types in Western Australia.

Also continuing during 2018–19 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 Kurnalpi region with respect to regolith evolution, and publication of at least one GSWA Report describing the results of the pilot study. The Minerals Exploration Geoscience branch will also co-author a publication describing the newly developed methodology for quantitative trace element analysis of gold grains. Studies of gold provenance and prospectivity using ‘alluvial’ nuggets will be expanded to the Pilbara Craton, pending negotiation of projects and sourcing of suitable sample material.

The study of the Mt Clement gold deposit will be completed and the results published, following which there will be reconnaissance mapping, sampling and laboratory studies of less well-documented deposits in the region, to further the larger study of the metallogeny of the Ashburton Basin. The metallogenic analysis of the Paterson Orogen will continue, and include targeted, field-based logging and sampling of drillcore from significant domains, arranged where necessary via newly developed government–industry collaborative projects.

The branch will also initiate a mineral system study of gold (and other) mineralization in the southwestern Yilgarn Craton, beginning with a review of the currently known metallogeny of this region.

Field mapping and sampling, and petrological and lithochemical studies will be completed for the mafic Warakurna Large Igneous Province, its copper–nickel–PGE prospectivity assessed and the results published. The study of regional nickel prospectivity of the eastern Yilgarn Craton will also continue, within the context of the larger GSWA–CSIRO–UWA collaborative project to understand the tectonostratigraphic evolution of that region.

Development of the Mineral Systems Atlas will also continue (see Project ES43). The branch will finish constructing several significant geological proxy layers for komatiite-hosted nickel and BIF-hosted iron mineral systems, and will undertake a systematic analysis of other systems to define mappable geological proxies for critical metallogenic processes, assisted where possible by subject matter experts in other organizations. The branch will also work with departmental IT staff to construct a prototype interactive, digital Mineral Systems Atlas that will deliver the ‘proxy’ datasets.

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 2018–19

Geological setting and nature of nickel mineralization at Fisher East, NE Yilgarn Craton (Report; provisional title; based on Master of Economic Geology dissertation)

Hole P112DD002 — Mapping iron ore and alteration patterns, Yilgarn Craton (Record)

Mapping iron ore patterns in banded iron-formation, Mt Richardson (Record)

Metallogeny of Archean BIF-hosted iron ore deposits in the Yilgarn Craton, Western Australia (Report and series of external publications)

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 southwest Yilgarn Craton (Report; provisional title)

Geological setting and alteration characteristics of the Manindi VMS deposits, Murchison Terrane (Report; provisional title)

Alteration and age of the Browns Range heavy rare earth elements deposits (Report; provisional title)

Results of fluid inclusion analysis of samples from the John Galt REE prospect, East Kimberley (Record; provisional title)

Origin of rare earth element mineralization at the John Galt prospect, East Kimberley (Report; provisional title)

SHRIMP U–Pb dating of xenotime from the Wolverine and John Galt REE deposits (Geochronology Records)

Planned work program and products 2019–20 and beyond

The Minerals Exploration Geoscience 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.

GS45 Pilbara Craton

Manager: Arthur Hickman

Team members: GSWA staff as required

The Pilbara Craton provides Australia's best preserved geological record of Eoarchean to Mesoarchean crustal evolution and contains several of the world's oldest examples of various styles of mineralization. Most fossil evidence of the earliest life on Earth has come from Paleoproterozoic metasedimentary rocks in the east Pilbara, and this area continues to attract new research projects by leading international geoscientists. Along with the Kaapvaal Craton of South Africa, the Pilbara also provides our oldest evidence for major asteroid impacts, which some scientists interpret to have partly controlled Earth's early crustal evolution.

The Pilbara Craton underlies approximately 400 000 km² of northwest Australia, but its total exposure is less than 70 000 km², of which almost 90% is located in the northern Pilbara. Between 1995 and 2005, this 60 000 km² northern part of the craton was the subject of a collaborative mapping project between GSWA and GA. The project was established to clarify the tectonic evolution of the granite–greenstone terranes in the northern Pilbara, and how this evolution influenced mineralization. The 1995–2005 phase of the project enabled the release of 30 new 1:100 000-scale Geological Series maps and seven revised 1:250 000-scale Geological Series maps. From 2005 onwards, data from the project continued to be released through additional maps, reports and digital products.

The Pilbara mapping project resulted in a major revision of the stratigraphy, structure and crustal evolution of the northern Pilbara Craton, with important implications for its mineral potential. Extensive geochronological data collected revealed that exposures in the east Pilbara are the oldest granite–greenstone terrane of the craton, named the East Pilbara Terrane. Repeated volcanic cycles and contemporaneous intrusion of granites over 310 Ma (3530–3220 Ma) constructed this terrane in the form of an extensive volcanic plateau overlying older crust. Isotopic data reveal that the older crust included widespread felsic igneous rocks, mainly 3680–3550 Ma, that were derived from partial melting of substantially older mafic crust. The tectonic evolution of the East Pilbara Terrane was dominated by vertical tectonic processes, instead of the horizontal crustal growth and recycling that are typical of Phanerozoic-style plate tectonic processes. Episodic, vertical crustal growth and reworking in the East Pilbara Terrane explains its present dome-and-keel crustal architecture, which has no Phanerozoic analogues. This style of crustal evolution explains the rarity of large mineral deposits in the East Pilbara Terrane because fluid sources were more restricted than in plate tectonic settings such as magmatic arcs above subduction zones.

The crustal evolution of the Pilbara Craton experienced a fundamental change at c. 3200 Ma, when the 300 Ma continental volcanism and vertical deformation of the East Pilbara Terrane was replaced abruptly by rifting, continental breakup and the commencement of plate tectonic processes. Only post-3200 Ma successions of the craton contain mineralization formed by plate tectonic processes, and it is these processes that produced the largest mineral deposits.

Mineralization in the Pilbara Craton is extremely diverse and spans 650 Ma, from the 3480–3460 Ma VMS deposits of the Dresser and Duffer Formations (Warrawoona Group) to 2850–2830 Ma rare-metal pegmatites of the Split Rock Supersuite. The most economically important mineral commodity has been iron ore, with total historical production in excess of 300 megatonnes. Iron ore deposits are enriched Mesoarchean banded iron formations in the Gorge Creek and Soanesville Groups. Gold and copper mineralization is present throughout the East Pilbara Terrane but all the deposits are relatively small. Larger gold deposits are located along shear zones within late Mesoarchean sedimentary basins (Mosquito Creek and Mallina), but individual deposits are nevertheless small by Australian standards. Tin and tantalum have long been mined from pegmatites and secondary alluvial deposits, but the current exploration focus is mainly on lithium.

Project work is currently focused on release of a detailed geological Report on the east Pilbara Craton, followed by fully populating the Explanatory Notes System (ENS) database for the northern Pilbara.

Outcomes of work program 2017–18

Report 181, describing a study of new zircon Lu–Hf and whole-rock Sm–Nd isotope data from the Mount Edgar Dome (East Pilbara Terrane), was written and released in 2017–18. The study, undertaken jointly with Curtin University, concluded that the Paleoproterozoic magmatic events in the East Pilbara Terrane, from 3460 to 3220 Ma, involved reworking of existing crust as opposed to addition of new juvenile material. Such crustal recycling is consistent with the volcanic plateau tectonic model and inconsistent with Phanerozoic-style subduction.

A geological Report reviewing the Eoarchean to Mesoarchean crustal evolution of the east Pilbara Craton was written, and will be released in 2018–19. This Report includes a compilation of all available geochronological data on the east Pilbara, and uses these data to supplement previously published information on crustal evolution. Contributions were made to three external papers, and various additions were made to the ENS database.

Products released 2017–18

Report 181 Crustal evolution of the Mount Edgar Dome from Hf isotope evidence

Three external publications — see Appendix B

Planned work program and products 2018–19

Future compilation of mapping and explanatory notes will continue under GS63.

GS52 East Yilgarn (Kalgoorlie Office)

Manager: Jyotindra Sapkota

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

The Eastern Goldfields Superterrane occupies the eastern third of the Archean Yilgarn Craton. 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. An understanding of the tectonic evolution of the Eastern Goldfields, including the structure and stratigraphy, is essential to the understanding of the controls on formation and distribution of mineralization in the region.

The published 1:100 000-scale Geological Series map sheets that cover the entire Eastern Goldfields Superterrane are available in the GIS-based East Yilgarn Geological Information Series data package. This product is being upgraded to implement formal stratigraphic concepts, which include recent new data and concepts arising from various research projects, particularly the large body of new geophysical, geochronological, geochemical and isotope data.

Outcomes of work program 2017–18

New mapping, data and stratigraphic information have been integrated into the East Yilgarn Geological Information Series (GIS) data package south of Kalgoorlie–Boulder, in the Widgiemooltha and Norseman regions. The new 1:100 000-scale interpretation of this area has been released. Explanatory notes (hosted by the ENS database) have been completed and published for the Menzies and Leonora areas.

A large suite of whole-rock geochemistry analyses has been acquired on diamond drillcore from the western part of the Eastern Goldfields in conjunction with HyLogger scans of sampled cores. These data, much of which was obtained from core collected through the EIS Co-funded Exploration Drilling program, are being used to characterize stratigraphy in conjunction with the new mapping interpretations that are being undertaken by staff from the GSWA Kalgoorlie office.

The GSWA Kalgoorlie Open Day in November included a series of talks, workshops and core displays that attracted more than 100 members of the local geological community.

The GSWA Kalgoorlie office hosted visits from various industry and government delegations, and school and university groups, and continued to provide geological information to visitors to the Goldfields region.

Products released 2017–18

East Yilgarn GIS data package 2018 update to include:

- reinterpreted geology of the Widgiemooltha and Norseman areas
- explanatory notes for the Menzies–Leonora area

Planned work program and products 2018–19

The 2018–19 year will see the acquisition of high-resolution seismic data in the Ora Banda to Kambalda region, acquired along five to six east- and northeast-trending lines, totalling about 250 line-km. Surface geological investigation of the proposed traverses will be carried out; however, most interpretation of the data will occur in the 2019–20 season.

The ongoing revision of the East Yilgarn GIS data package to incorporate the new structural and stratigraphic framework will continue. In 2018–19, new geological interpretation will focus on the region northwest of Davyhurst. Explanatory notes coverage will include parts of the Kalgoorlie–Kambalda, Ora Banda – Menzies and Widgiemooltha–Norseman regions.

An ongoing program of systematic geochemical sampling, from both outcrop and drillcore, will fill gaps in the existing dataset and provide detailed coverage of greenstone successions in the region. Structural and metamorphic studies will be conducted along the major shear zones in the Eastern Goldfields Superterrane. Matt De Paoli will present preliminary results of the tectonometamorphic work along the Ballard Shear Zone at The Institute for Geoscience Research (TIGeR) conference (Perth) in September 2018, and the abstract for the talk has been submitted.

GSWA is collaborating with Ray Cas of the Centre for Ore Deposit and Earth Sciences (CODES; University of Tasmania) on an honours project to study the geological setting of the Golden Mile Dolerite at Kalgoorlie.

Products planned for release 2018–19

East Yilgarn GIS data package 2019 update to include:

- the area between Davyhurst and Agnew
- updated Eastern Goldfields Superterrane stratigraphy
- updated ENS entries
- geochemical data collected as part of the Eastern Goldfields Superterrane (EGST) Greenstone Geochemical Barcoding program

Record 2018/15 A new look at lamprophyres and sanukitoids, and their relationship to the Black Flag Group and gold prospectivity

External publications — see Appendix B

Planned work program and products 2019–20

Much of the 2019–20 period will be devoted to interpretation of the high-resolution seismic data collected in the Ora Banda – Kambalda region during 2018–19, working towards public release of the interpretations.

In addition, the incorporation of regional stratigraphy into the East Yilgarn GIS data package will continue, with releases as appropriate. Explanatory notes will be prepared to cover the whole of the area encompassed by the data package, and will be delivered in the ENS database. Future stratigraphic interpretation will focus on completing the western part of the Eastern Goldfields Superterrane (Kalgoorlie Terrane) and then extend to the east.

Ongoing collection of granite–greenstone geochemical and geochronological data will be used to assist in describing stratigraphy and geodynamic setting for the Eastern Goldfields Superterrane. Comprehensive GIS databases including metamorphic and non-GSWA geochronological data covering the Yilgarn Craton are also in preparation.

Products planned for release 2019–20

Geological interpretation of high-resolution seismic data

East Yilgarn GIS data package updates to include:

- Eastern Goldfields Superterrane 1:500 000 State geology layer
 - Eastern Goldfields Superterrane stratigraphy
 - ENS database update
-

Publications detailing the new regional stratigraphy for the Eastern Goldfields Superterrane

Yilgarn metamorphism GIS layer

GS53 Chief Geoscientist and Terrane Custodians

Manager: Simon Johnson

Team members: Huntly Cutten, Terry Farrell, Imogen Fielding, Sarah Goss, Roger Hocking, Fawna Korhonen, David Martin (part-time), 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 State Geoscience branch's part in achieving this are 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. 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.

Outcomes of work program 2017–18

The continued update and release of State geoscience data layers were a high priority during 2017–18. Work concentrated on updating the 1:500 000 orogenic events layer as well as releasing the 1:100 000 interpreted bedrock geology layers (lithologies, structures and linear geological units) for project areas across the State. The latter includes new GeoVIEW.WA functionality that allows attribution of lithostratigraphic units to be updated automatically on a weekly basis. The 1:100 000 project area regolith–landform layer will be released in 2018–19, alongside a seamless 1:500 000 regolith–landform geology layer for the northern half of the State. The section continued populating the data entry module of ENS, with the publication of about 300 new lithostratigraphic units and updates to 50 units, bringing the total number of published lithostratigraphic units to about 925. The ENS data entry system was updated to include a module to allow the entry of regolith–landform units. Population of this module will continue throughout the coming months.

The GSWA field and rock observation database (WAROX) was updated with additional field sites from the 2016–17 field season, as well as newly captured legacy data. This brings the statewide dataset to a total of about 240 000 field observations, 65 000 structural measurements, 50 000 field photographs and sketches, as well as regolith and landform information, sample location data and petrographic descriptions. Functionality for the ArcMap version of the dataset was increased.

A short geotourism book on the sedimentary geology and geomorphology of the Kennedy Range area was also released.

The branch is responsible for GSWA content of department web pages; it routinely supervised content updates and the creation of new pages, coordinated the half-yearly revision of all GSWA pages, and assisted the transition from the Department of Mines and Petroleum to the new DMIRS website.

Products released 2017–18

Release of 1:100 000 interpreted bedrock geology data, 2018 on GeoVIEW.WA for project areas across the State

Compilation of WAROX data, 2018 (statewide data release)

Update to the 1:500 000 orogenic events digital map layer

Extended ENS content over existing and new geological provinces

Geotourism book on the geology of the Kennedy Range area

Planned work program and products 2018–19

Work during 2018–19 will focus on the update of our online data delivery systems and on progress towards the update and delivery of new, key data layers to GeoVIEW.WA, including a seamless 1:500 000 regolith–landform layer for the northern half of the State. The southern half will be released either towards the end of the 2018–19 financial year or early in the 2019–20 financial year. Updates are also planned to the 1:500 000 interpreted bedrock geology layer to ensure the data are current. Work will begin on the implementation and progressive attribution (dip, age, reactivation events) of the current State 1:500 000 linear structure layer. Work will continue on preparing a seamless 1:100 000 interpreted bedrock geology layer for the eastern Capricorn Basins, with work

concentrating initially on the Earraheedy Basin on the NABBERU 1:250 000 Geological Series map sheet.

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 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 (WA unearthed) as well as several geotourism products including a popular geology book marking the 50th anniversary of the Meckering earthquake in October 2018, as well as a book on the geology of the Kalbarri area.

Products planned for release 2018–19

Compilation of WAROX data, 2019 update, with potential delivery through GeoVIEW.WA

Update attribution table (dip, age, reactivation events) of State 1:500 000 linear structures digital map layer and begin data population

Update of State 1:500 000 interpreted bedrock geology digital map layer

Release of 1:100 000 project geology regolith–landform digital map layer in GeoVIEW.WA

Release of seamless 1:500 000 regolith–landform digital map layer in GeoVIEW.WA for the northern half of the State

Updates to the 1:100 000 interpreted bedrock geology layer including the addition of the Hamersley–Fortescue and eastern Capricorn Basins data

Extended ENS content (including regolith)

Explanatory notes for State impact structures and associated lithostratigraphic units

Popular geology book marking the 50th Anniversary of the Meckering earthquake

Popular geology book on the geology of the Kalbarri area

Planned work program and products 2019–20 and beyond

Work will continue to focus on the maintenance, upgrade and population of spatial and textual datasets, extension of the WA unearthed products to layperson’s guides and region-by-region guides, and quality assessment of GSWA products and data. Legacy capture of geoscience for ENS remains a long-term goal.

GS54 Geochronology and Geochemistry

Manager: Michael Wingate

Team members: 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 contributes to enhancing the prospectivity of the State. Geochronological techniques are used 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 SHRIMP instruments in the John de Laeter Centre at Curtin University are used extensively by GSWA for U–Pb geochronology. GSWA also uses LA-ICP-MS instruments in the John de Laeter Centre to date detrital zircons, to analyse metamorphic phosphate minerals such as monazite and xenotime in thin sections (see GS53 State Geology), and to measure the trace element compositions of zircons.

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

GSWA geoscience projects submit samples for whole-rock geochemistry for a range of purposes. These include understanding the source and petrogenesis of igneous suites, relationships within and between igneous suites, source (provenance) and compositional characterization of sedimentary rocks, and to constrain metamorphic modelling. 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, PGE etc.) depending upon project requirements. Analytical services are outsourced to several Perth-based laboratories with the main techniques applied being x-ray fluorescence spectrometry for major elements and some trace elements, and inductively coupled plasma mass spectrometry (ICP-MS) for trace elements. All data are made available online through DMIRS geochemistry database, WACHEM.

The Laboratory section, managed by John Williams, supports the varied aspects of GSWA's geochronology, isotope geology and geochemistry programs with world-class sample preparation services provided in-house by the GSWA laboratory 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.

Outcomes of work program 2017–18

In 2017–18, the GSWA laboratory processed about 95 rock samples for U–Pb geochronology and almost 1900 samples for whole-rock geochemistry. During calendar years 2017 and 2018, 63 and 61 samples, respectively, were analysed by GSWA geochronologists using the SHRIMP facilities at Curtin University, and an additional 25 samples were analysed using LA-ICP-MS instruments. Figure 3 shows the distribution of analysed samples both geographically and by tectonic unit. These samples were dated in support of GSWA geoscience programs in the west Musgrave Province, the Yilgarn Craton (Youanmi and South West Terranes, and Eastern Goldfields region), the Albany–Fraser, Capricorn and Pinjarra Orogens, the Kimberley region, the Edmund Basin and in basement rocks beneath the Canning Basin. Results are released individually as Geochronology Records, 92 of which were published during 2017–18, and are included in several GSWA and external publications.

During 2017–18, the Geochronology and Geochemistry branch participated in and contributed to several collaborative research projects:

- Minerals Research Institute of Western Australia (MRIWA) M446 Rutile — Re–Os sulfide geochronology (MRIWA; John de Laeter Centre, Curtin University); completed 2018
- MRIWA M448 Rutile — Pathfinder to ores (MRIWA; John de Laeter Centre, Curtin University)
- MRIWA M470 — Mineral systems on the margin of cratons: Albany–Fraser Orogen / Eucla Basement case study (MRIWA; Ponton Minerals Pty Ltd; Curtin University)
- Earth composition and evolution — preservation of legacy collections project (John de Laeter Centre and Curtin Library, Curtin University; Australian Research Data Commons; AuScope; UWA)
- Narryer Terrane geochronology and isotope geology (PhD project, School of Earth Sciences, UWA)
- K–Ar dating of fault rocks (Kyoto University and CSIRO)
- Pyroxene Ar/Ar dating of Western Australian mafic dyke swarms (John de Laeter Centre, Curtin University)
- Using Pb isotopes in detrital feldspars to fingerprint sediment provenance (Centre for Exploration Targeting, Curtin Node, Curtin University) — completed 2018, new Australian Research Council (ARC) Linkage, Infrastructure, Equipment and Facilities (LIEF) application in review

- Crustal evolution of Western Australia (Centre for Exploration Targeting [CET], Curtin Node, Curtin University) — completed 2018
- (U–Th)/He geochronology of iron oxides in duricrust at Boddington gold mine (John de Laeter Centre, Curtin University) — completed 2018

Products released 2017–18

Report 176 Tectono-magmatic evolution of the Neoproterozoic Yalgoo dome (Yilgarn Craton): Diapirism in a pre-orogenic setting

Report 181 New Hf isotope insights into the Paleoproterozoic magmatic evolution of the Mount Edgar Dome, Pilbara Craton: implications for early Earth and crust formation processes

Report 183 Metamorphosed Mesoproterozoic Cu–Mo–Ag mineralization: evidence from the Calingiri deposits, southwest Yilgarn Craton

Report 186 Building the Archean continental crust: 300 Ma of felsic magmatism in the Yalgoo dome (Yilgarn Craton)

Record 2017/7 Towards a geochemical barcode for Eastern Goldfields Superterrane greenstone stratigraphy – preliminary data from the Kambalda–Kalgoorlie area

Record 2017/8 The deep seismic reflection profile 11GA-Y01 in the west Musgrave Province: an updated view

Record 2018/4 A new Mesoproterozoic mafic intrusive event in the Capricorn Orogen

Record 2018/10 Geochemistry of Archean granitic rocks in the South West Terrane of the Yilgarn Craton

Record 2018/2 GSWA 2018 Extended abstracts: promoting the prospectivity of Western Australia, contributions:

- New approaches in understanding the Yilgarn Craton, p. 1–3
- Zircon composition as a fertility indicator of Archean granites, p. 18–21
- Looking beneath the Canning Basin: new insights from geochronology, seismic and potential-field data, p. 30–33

92 Geochronology Records and U–Pb datasets released to online applications (GeoVIEW.WA) and to published maps and digital products

Compilation of geochronology information 2018 (includes 92 new Geochronology Records on USB)

812 whole-rock geochemistry analyses released to online applications (GeoChemExtract and GeoVIEW.WA)

14 external journal articles and 13 conference abstracts (see Appendix B), and GSWA Open Day posters

Planned work program and products 2018–19

GSWA's geochronology program will continue to generate U–Pb zircon, baddeleyite and monazite ages in support of regional mapping and other geoscience programs in the Yilgarn Craton (Eastern Goldfields Superterrane and the Youanmi and South West Terranes), the Capricorn Orogen (Gascoyne Province and Proterozoic Basins), the Albany–Fraser Orogen and the Kimberley, Amadeus, Murrumbidgee and Canning Basins. The results of Sm–Nd, Lu–Hf, Re–Os and oxygen isotope studies (see ES46 Enhanced Geochronology and Acquisition of Isotope Data), together with new results from in situ phosphate dating, will be integrated with SHRIMP U–Pb and geological information by geochronologists and mapping program staff. Several collaborative research projects listed above will continue in 2018–19. 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.

Currently under construction is a new geochronology and mineral chemistry database, 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 new database will also enable publication of 'external' geochronology data, via a dedicated layer in GeoVIEW.WA.

The laboratory will continue to process samples for whole-rock geochemistry and isotope geochemistry as required by GSWA geoscience programs. The Greenstone Geochemical Barcoding project (see GS52 East Yilgarn) is the largest single user of whole-rock geochemistry, with more than 1000 samples analysed each year.

Products planned for release 2018–19

Compilation of geochronology information, 2019

Geochronology Records, U–Pb datasets and whole-rock geochemistry analyses released to online applications (GeoChem Extract and/or GeoVIEW.WA)

GSWA publications, external journal articles and conference abstracts

Planned work program and products 2019–20

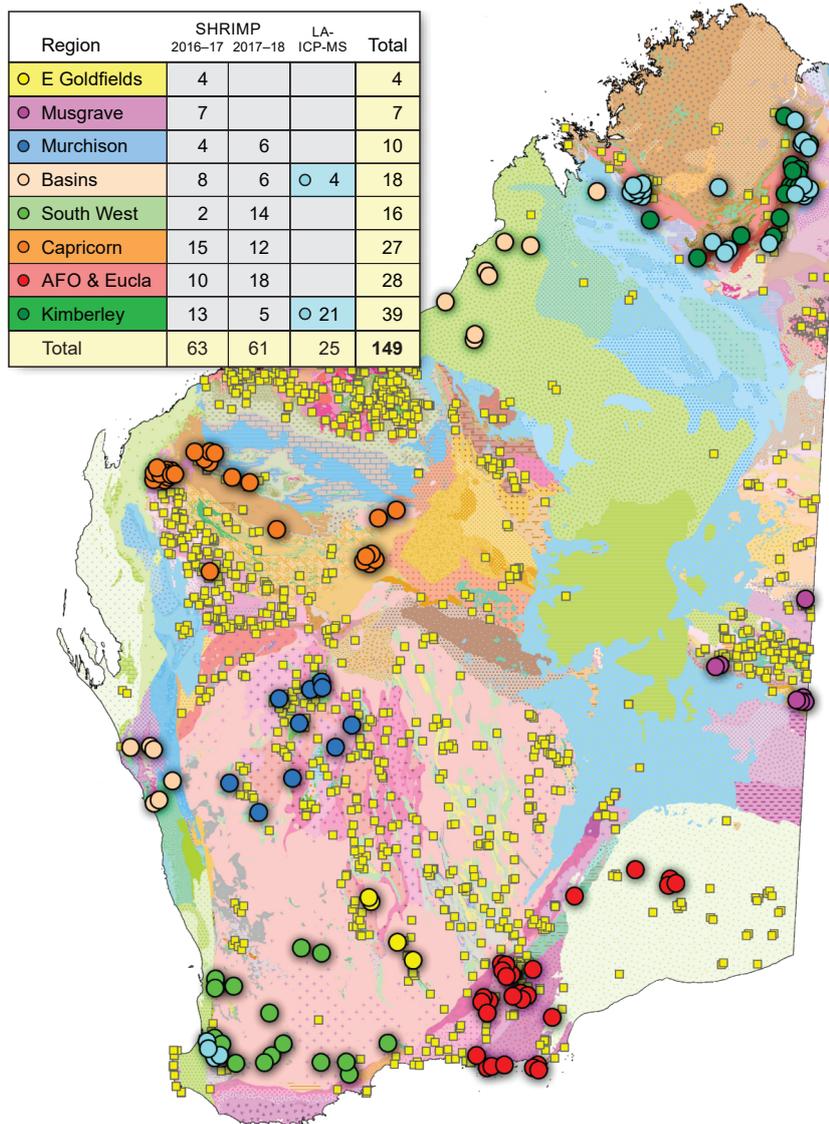
Future geochronology work will continue to support GSWA's mapping and geoscience programs. Geochronology results and publications will be informed by a range of additional data, including the results of Sm–Nd, Lu–Hf and oxygen isotope studies (see ES46 Enhanced Geochronology and Acquisition of Isotope Data). The Geochronology and Geochemistry branch will continue to expand its range of geochronological and isotopic techniques through in-house research and external scientific collaborations. Development and implementation of the geochronology and mineral chemistry database will continue.

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)

GSWA publications, external journal articles and conference abstracts



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Figure 3. Geographic and tectonic distribution of GSWA samples analysed by SHRIMP ion microprobe and LA-ICP-MS. Yellow squares represent data between 1995 and 2016. Abbreviation: AFO, Albany-Fraser Orogen

GS55 Geophysical Acquisition and Processing

Manager: David Howard

Team member: John Brett

The acquisition, processing, synthesis and interpretation of geophysical and remotely sensed spectral information are integral parts of GSWA's regional regolith and bedrock geology mapping process. The role of the Geophysical Acquisition and Processing section is to plan and manage the various regional geophysical data acquisition projects, to deliver the datasets to the public and internal users, and to provide processing, interpretation services and advice as required.

Outcomes of work program 2017–18

Regional survey data acquisition activities are reported under the EIS programs — ES30 Airborne and Ground Geophysical Surveys. Updates of the now standard statewide compilations of magnetic, radiometric and gravity grids and images were published.

The Airborne Geophysics Index data repository (MAGIX) of company airborne survey data continued to grow. During 2017–18, 85 new company airborne survey

datasets containing about 277 000 line-km of data were received for inclusion in the repository. At 30 June 2018, the MAGIX repository contained some 10.1 million line-km of company data from 2368 surveys. Open-file datasets are available for download via the department's GeoVIEW.WA online system.

Planned work program and products 2018–19

The planned work program for 2018–19 and beyond — dependent on the then prevailing GSWA budget — is described separately under programs ES30 (Airborne and Ground Geophysical Surveys). The work will be managed by the Geophysical Acquisition and Processing section.

All new data acquired will be included in updates to the statewide compilation magnetic, radiometric and gravity grids and images. The section will continue to manage the MAGIX data repository and the submission, archive and release of airborne and some ground survey datasets supplied by the exploration industry.

GS56 North Australian Craton

Manager: Catherine Spaggiari

Team member: Christopher Phillips

The North Australian Craton comprises most of the northern part of the Australian continent and incorporates a complex assemblage of terranes, basins and igneous provinces that range in age from Neoproterozoic to Phanerozoic. The craton is host to numerous mineral deposits and major mines, including lead–zinc–silver±copper (Mount Isa, McArthur River), uranium (Ranger, Rum Jungle), iron oxide–copper–gold (Tennant Creek), gold (The Granites, Callie), diamonds (Argyle), nickel–copper (Sally Malay) and iron (Koolan Island). In Western Australia, the craton comprises Paleoproterozoic to Mesoproterozoic rocks exposed in the Kimberley, west Tanami and west Arunta regions, overlain by sedimentary rocks of the Neoproterozoic Centralian Superbasin and the Phanerozoic Canning, Ord and southern Bonaparte Basins.

In the Kimberley region — which has been a focus area for the North Australian Craton project — metasedimentary and meta-igneous rocks of the 1912–1788 Ma Lamboo Province are exposed along the upthrust margins of the overlying Kimberley Basin. The Lamboo Province has been subdivided into the King Leopold Orogen, which forms a northwest-trending belt to the south of the Kimberley Basin, and the Halls Creek Orogen, which forms a northeast-trending belt to the east. The Lamboo Province records a complex history of sedimentation, magmatism and deformation that has been interpreted to reflect the collision of the Kimberley Craton with the proto-North Australian Craton. The 1814–1740 Ma Kimberley Basin comprises an extensive fluvial to shallow-marine sedimentary basin that extends across the Lamboo Province, and possibly has correlatives in isolated sedimentary outliers around the margins of the basin. Extensive mafic intrusive and volcanic rocks within the basin comprise the 1799–1791 Ma Hart–Carson Large Igneous Province. These rocks are overlain by sedimentary successions of Mesoproterozoic to Neoproterozoic age that include the Carr Boyd, Birrindudu and Louisa Basins.

Second edition 1:250 000 Geological Series mapping programs in 1986–89 and 1990–95 were focused on the King Leopold and Halls Creek Orogens, and were accompanied by SHRIMP U–Pb zircon geochronology and extensive whole-rock geochemistry, in collaboration with the Australian Geological Survey Organisation (AGSO; now GA). The current work program is expanding the coverage of second edition 1:250 000 Geological Series mapping, with the aim of delivering seamless coverage across the Kimberley region. Production of 1:100 000 Geological Series maps previously focused on the Halls Creek Orogen during the 1990–95 mapping program, and has been extended into the King Leopold Orogen during the current work program. Targeted studies examining aspects of the geology of the Kimberley region have accompanied the geological mapping. These include dating of sedimentary units, igneous suites and

tectonothermal events, geochemical and isotope studies of magmatism, and the studies of the sedimentology and volcanology of basin successions.

Current work includes progressive extension of the 1:250 000 Geological Series mapping, a project examining the age, character and correlations of Paleoproterozoic to Neoproterozoic sedimentary basin outliers, and a study evaluating geodynamic models of the Paleoproterozoic development of the Lamboo Province.

Outcomes of work program 2017–18

Kimberley region

A significant component of the work program for 2017–18 focused on the production of the LANSLOWNE second edition 1:250 000 Geological Series map sheet, incorporating the results of GSWA mapping over the past several years. Complementing this mapping was the finalization of a Report on the stratigraphy and sedimentology of the Kimberley Basin (redefined to include both the Speewah and Kimberley Groups).

The ENS database was updated with detailed descriptions of all the stratigraphic units comprising the Eastern Zone of the Lamboo Province. These entries included the results of new mapping and age data from the Eastern Zone, as well as incorporating the new stratigraphy established in Report 164. These units can be accessed online and through the Kimberley GIS data package 2018.

Further fieldwork was conducted in the Kimberley region with a view towards production of additional second edition 1:250 000 Geological Series map sheets, as well as updates to the 1:250 000 and State 1:500 000-scale interpreted bedrock geology digital map layers. As part of this fieldwork, samples were collected for geochronology. As a result of this sampling, LA-ICP-MS dating and Lu–Hf isotope analysis was carried out on detrital zircons from sedimentary basin outliers in order to build the geochronology dataset for regional correlations. SHRIMP zircon dating was carried out on representative samples of the component granitic suites of the Sally Downs Supersuite to better define the spatial and temporal variations in magmatism.

A 2018 version of the Kimberley GIS data package is planned, which will incorporate the LANSLOWNE 1:250 000 Geological Series map sheet and updates to the geochronology, geochemistry, ENS and WAROX databases.

Tanami and west Arunta regions

Following the recent 1:100 000 and 1:250 000 second edition Geological Mapping Series in the Tanami and west Arunta regions, the MACDONALD second edition 1:250 000 Geological Series map sheet was released in 2018.

Products released 2017–18

LANSDOWNE second edition 1:250 000 Geological Series map

MACDONALD second edition 1:250 000 Geological Series map

Population and publication of the ENS database for units of the Eastern Zone of the Lamboo Province

Planned work program and products 2018–19

The work program for 2018–19 will include the production of second edition 1:250 000 Geological Series maps to ensure coverage across the Kimberley region, with fieldwork for the CAMBRIDGE GULF 1:250 000 map sheet planned for the 2018–19 field season. A component of this fieldwork will involve collecting further samples for detrital zircon geochronology of assumed Paleoproterozoic to Mesoproterozoic basin outliers with further access to previously unsampled units.

The North Australian Craton branch is working towards a seamless 1:250 000 interpreted bedrock geology digital map layer of the whole Kimberley region, with accompanying updates to the State 1:500 000 geology digital map layer. In 2018–19, the MONTAGUE SOUND 1:250 000 map sheet area will be digitally updated and included in the progression of the Kimberley seamless coverage. The report on the revised stratigraphy and sedimentology of the Kimberley Basin will also be released in 2018–19. This Report will document the results of recent GSWA mapping and geochronology, and the implications for the development and geodynamic setting of the basin. These products will be released individually and as part of the Kimberley GIS data package update for 2019.

Updated 2019 versions of the Kimberley and Tanami GIS data packages are planned, which will incorporate new maps and updates to the geology, geochronology, geochemistry, ENS and WAROX databases.

A report on the P–T–t evolution of the King Leopold Orogen is scheduled for release in 2018–19, which will present the results of thermobarometry and in situ monazite geochronology of amphibolite facies metamorphic rocks.

Products planned for release 2018–19

Kimberley GIS data package 2019 update, including:

- LANSDOWNE second edition 1:250 000 Geological Series map sheet
- population and publication of the ENS database for units of the Eastern Zone of the Lamboo Province

Tanami GIS data package 2019 update, including:

- MACDONALD second edition 1:250 000 Geological Series map sheet
- interpreted regolith–landform Geology of the Ngururrpa Area, northeastern Western Australia – digital map layer

Update to Kimberley 1:100 000 solid geology layer and 1:500 000 State geology layer

ENS entries for the whole Kimberley Basin

Stratigraphy and sedimentology of the Kimberley Basin (GSWA Report)

Planned work program and products for 2019–20

The following Reports are works in progress, in either the data collection stage or currently being written:

- A Report revising the stratigraphy, age and provenance of assumed Paleoproterozoic to Mesoproterozoic basins in the Kimberley and northern Tanami regions. These basins have no previous geochronology. Correlations with sedimentary basins across the North Australian Craton will be explored.
- A Report on the geodynamic setting of the Lamboo Province is being finalized, incorporating age data from metasedimentary and meta-igneous rocks across all three zones in the Lamboo Province.
- A Report presenting age data and geodynamic setting of the Granites–Tanami Orogen.
- A Report on the volcanology, geochemistry and tectonic setting of the Hart–Carson Large Igneous Province.
- The seamless coverage of the Kimberley region with updates to the 1:250 000 and State 1:500 000 geology layers will be an ongoing project.
- Interpretation of the basement geology imaged in Kwirrikura to Gregory Range section of the Kidson Seismic line.

This project will continue under the banner of Proterozoic Margins for 2019–20.

GS57 West Musgrave Province

Manager: Heather Howard

Team members: Raphael Quentin de Gromard, Hugh Smithies

The West Musgrave Province is the Western Australian portion of the Mesoproterozoic to Neoproterozoic Musgrave Province that straddles the borders between Western Australia, South Australia and the Northern Territory. The extremely varied geology encompasses structurally complex low- to high-grade metamorphic terrains that record a history involving up to six magmatic and deformational events including the Mesoproterozoic Musgrave Orogeny and the Neoproterozoic–Cambrian Petermann Orogeny. Forming the junction of Proterozoic orogenic trends in central and southern Western Australia, the Musgrave Province is critical to an understanding of the Proterozoic crustal evolution of Australia. The province includes the voluminous layered mafic–ultramafic Giles intrusions and associated smaller mafic intrusions. These intrusions have been the site of significant nickel, copper and PGE discoveries. The economic potential of extensive felsic volcanic sequences has not been fully explored; however, recent exploration in these rocks has also uncovered significant gold mineralization.

Despite its importance in understanding the Proterozoic evolution of Australia and its economic potential, the Musgrave Province remains one of the most understudied parts of Proterozoic Australia. Some of the main impediments in this regard have been land access issues and the geographical isolation of the region. Very few detailed geoscientific research projects have been carried out in the west Musgrave Province, with focused PhD studies completed in 1971 by CM Gray and in 1997 by RW White being perhaps the most notable. Regional 1:250 000-scale geological mapping of the west Musgrave Province in the late 1960s culminated in the publication of Bulletin 123 (Daniels, 1974), which documented the regional geology of the area between Warburton and Wingelinna. A subsequent survey was undertaken in the 1990s by GA (then AGSO), which focused primarily on the mafic–ultramafic Giles intrusions, but also considered additional regional geological issues. This survey culminated in the publication of AGSO Bulletin 239 in 1996 (Glikson et al., 1996). In 2004, GSWA released the west Musgrave Geological Exploration Package (Record 2004/9). This package combined pre-existing and newly acquired digital datasets, including Landsat TM and ASTER satellite image data, 1:25 000-scale colour orthophotography, and aeromagnetic and radiometric data (at 400 m line-spacing) for six 1:100 000 Geological Series map sheets covering the central eastern part of the west Musgrave Province project area (BATES, BELL ROCK, BLACKSTONE, HOLT, COOPER and FINLAYSON). Since then, GSWA has acquired similar datasets covering the entire project area (including DEERING, GUNBARREL, DICKENSON, DIORITE, TABLE POINT, BENTLEY, GOLDEN POINT, MOUNT EVELINE, WARBURTON RANGE and AGNES).

It has become clear that there are major geological differences between the northeastern and southwestern parts of the project area, but it is unclear how significant the boundary between these two regions truly is, and whether that boundary is the Mann Fault, a major east-trending regional structure, or the Tjuni Purlka Zone, a recently defined zone of extensive northwest faulting. The later structural zone was clearly the site of extensive felsic magmatism and deformation during the Mesoproterozoic Musgrave Orogeny. It seems most likely that this zone was the main control on the structural architecture of the region, perhaps modified to a large degree by east-trending faults like the Mann Fault, during the Neoproterozoic Petermann Orogeny. One of the main geological differences across this zone is the absence, in the northeast, of the 1330–1300 Ma calc-alkaline crust that forms a significant component of the area to the southwest.

The economically important mafic intrusions emplaced during the 1090–1040 Ma Giles Event primarily occupy the tectonic contacts bounding either side of the Tjuni Purlka Tectonic Zone. The Giles Event has now been shown to be much more magmatically and structurally complicated and long-lived than previously thought. This hampers exploration models for orthomagmatic deposits. Our dating of copper-mineralized gabbros shows that at least some of the orthomagmatic mineralization relates to intrusions that are late (c. 1067 Ma) in the geological history of the larger mafic intrusions, small with respect to the main mafic intrusions, and most likely peripheral to those larger intrusions.

Products released 2017–18

Record 2017/8 The deep seismic reflection profile 11GA-Y01 in the west Musgrave Province: an updated view

Planned work program and products 2018–19

The fieldwork and map compilation components of the project have been completed. There will be a final release of the completed digital maps and explanatory notes (via the ENS database) in the West Musgrave GIS data package update to conclude this project.

Products planned for release 2018–19

West Musgrave GIS data package 2019 update, including completed explanatory notes for the region

Post-Mesoproterozoic evolution of the west Musgrave Province (GSWA Report)

GS58 West Yilgarn

Manager: Tim Ivanic

Team member: Jack Lowrey

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

Outcomes of work program 2017–18

New mapping in the Yalgoo–Singleton greenstone belt has established stratigraphic relationships, based on recent geochronology and geochemistry results (NINGHAN 1:100 000 Geological Series map sheet). Field mapping is nearing completion over most of the Yalgoo–Singleton greenstone belt, focused around the Yalgoo dome. Structural studies in the Yalgoo dome have determined the relationship between granite emplacement and the greenstone stratigraphy.

Field mapping has been completed in the Meekatharra region (GABANINTHA 1:100 000 Geological Series map sheet), resulting in modifications to the published stratigraphy and upgrading of previously published GIS products.

Field mapping and geochemistry and geochronology sampling has commenced in the Dalgaranga area. The results of this work aim to test and expand the framework of the Murchison Supergroup and intrusive suites in this region.

Drillcore sampling for petrography, geochemistry and geochronology has commenced on greenstone belts within the Southern Cross Domain, which will augment surface mapping and sampling in the Sandstone area initially.

A program of sampling granites and associated rocks in the South West Terrane to collect geochemical and isotopic data was completed.

Cooperative projects include:

- a geochemistry and isotopes project with associated structural studies in the Narryer Terrane with Dr Tony Kemp from UWA and Prof Cees Passchier from the Gutenberg University in Mainz
- structural studies in the Murchison Domain with various collaborators (Monash University, Gutenberg University)
- an ARC Linkage project with Sydney University to study the geochemistry and tectonic setting of the Murchison Domain
- a mineral chemistry project on the Windimurra and Narndee Igneous Complexes with the Guangzhou Institute of Geochemistry
- a metamorphic study of contrasting greenstone successions in the Yalgoo–Singleton greenstone belt with the University of Waterloo (Canada)
- a whole-rock isotopes study of granites in the Youanmi Terrane with Monash University.

Products released 2017–18

Report 186 Magmatism in the Yalgoo dome

Report 176 Tectono-magmatic evolution of the Neoproterozoic Yalgoo dome (Yilgarn Craton): Diapirism in a pre-orogenic setting

Record 2018/10 Geochemistry of Archean granitic rocks in the South West Terrane of the Yilgarn Craton

Five external publications (see Appendix B)

Planned work program and products 2018–19

The release of the Murchison GIS data package 2018 update will include the NINGHAN and GABANINTHA 1:100 000 Geological Series map sheets and new explanatory notes cover units within these regions.

Field mapping and compilation will be completed on the area broadly covering the DALGARANGA 1:100 000 Geological Series map sheet, and the results will be published on the Murchison GIS data package 2019 update.

Mapping, sampling and collection of new analytical data, including geochemistry, geochronology and isotopic data and geochemistry sampling will continue in the Southern Cross Domain and the western Murchison Domain, with initial focus on the Sandstone greenstone belt.

Cooperative projects will continue, including structural and isotope studies in the Narryer Terrane, and geochemistry, metamorphic and structural studies in the northern Youanmi Terrane.

Products planned for release 2018–19

Murchison GIS data package 2018 will be updated to include: the NINGHAN and GABANINTHA 1:100 000 Geological Series map sheets

Murchison stratigraphy and explanatory notes update

Murchison GIS data package 2019 will be updated to include: the DALGARANGA 1:100 000 Geological Series map sheet the 1:500 000 State geology digital map layer Murchison stratigraphy and explanatory notes update

Layered Intrusions of the Youanmi Terrane (GSWA Report)

Volcanic geochemistry of the northern Murchison Domain (GSWA Report)

GSWA Records and Reports derived from collaborative projects: Mount Mulgine metamorphism

External publications relating to work program where appropriate

Products planned for release 2019–20

Youanmi GIS 2020 (new package, to include updated Murchison GIS datasets)

Explanatory notes update

Sandstone 1:100 000 interpreted bedrock geology digital map layer

Report on stratigraphic updates and correlations in the western Yilgarn

GSWA Records and Reports derived from collaborative studies

External publications relating to work program where appropriate

Planned work program and products 2019–20

Field mapping in the Youanmi Terrane will continue in 2019–20. Data will be compiled for release in the GIS package, which will be renamed Youanmi GIS in this and future versions. A Report covering the series of stratigraphic updates over the last five years will be prepared and published. Reports and Records of various aspects of the geology of the western Yilgarn Craton will be prepared. Comprehensive GIS databases including metamorphic and non-GSWA geochronological data covering the Yilgarn Craton are also in preparation.

GS61 Albany–Fraser Orogen and Eucla Basement Project

Manager: Catherine Spaggiari

Team member: Raphael Quentin de Gromard

The Albany–Fraser Orogen flanks the southern and southeastern margin of the Archean Yilgarn Craton over a distance of at least 1200 km, and is part of the West Australian Craton (WAC). The orogen is dominated by Paleoproterozoic and Mesoproterozoic rocks formed during reworking of the southern Yilgarn Craton from at least 1815 Ma through to 1140 Ma. Fragments of Archean crust, interpreted to be remnants of the Yilgarn Craton, are also preserved within the orogen. The eastern part of the orogen and adjoining Proterozoic Madura and Coompana Provinces collectively comprise the Eucla basement, being entirely covered by younger basin rocks. The Coompana Province extends across the border into South Australia, and links to the Gawler Craton. New data from these hidden basement provinces has enabled a better understanding of the development of the southern WAC margin over time, on the prospectivity of the region, and has informed models of Proterozoic Australia assembly.

Several mineral systems are now recognized in the Albany–Fraser Orogen. They are:

- Neoproterozoic (c. 2500 Ma) thrust-related shear zone gold hosted in retrogressed amphibolite to granulite facies ortho and paragneisses (Tropicana, Tropicana east)
- Paleoproterozoic (c. 1760 Ma) intrusion-related gold–silver (Voodoo Child)
- Paleoproterozoic stratabound sedimentary clastic-hosted lead–zinc–silver–copper–gold (Trilogy)
- Paleoproterozoic (1800–1600 Ma) magnetite iron ore (Southdown)
- Mesoproterozoic (c. 1300 Ma) orthomagmatic mafic and ultramafic intrusion-related nickel–copper–cobalt (Nova–Bollinger).

The Tropicana–Havana deposit in the Tropicana Zone in the northeastern part of the orogen is currently being mined, and an underground mine for the Nova–Bollinger nickel–copper sulfide deposit in the Fraser Zone is operational. These recent discoveries are significant because they demonstrate that regions previously thought as unprospective, often because they were perceived to be ‘the wrong age’, were simply poorly understood. The provinces of the Eucla basement have potential for copper–gold (including non subduction-related porphyry, subduction or arc related, and exhalative or VMS style), iron oxide–copper–gold (IOCG), nickel–copper–PGE and nickel sulfide deposits, although it is conceivable that other types of deposits could occur. Both the Albany–Fraser Orogen and the adjoining Eucla basement are major greenfields exploration regions, and are challenging to explore largely because of the extensive cover.

Although a handful of diamond drillholes exist in the Madura Province, no basement mineral exploration holes have been drilled in the Western Coompana Province. The EIS Eucla basement stratigraphic drilling program has partly addressed this deficiency, with five stratigraphic holes now drilled in the Western Coompana Province, and three in the Madura Province.

One of the aims of this project is to open up new frontiers in mineral exploration in these greenfields regions by understanding the magmatic, sedimentary and tectonic environments. As a result, exploration teams are better able to evaluate prospectivity and potential targets. This is exemplified by the discovery of the nickel–copper sulfide deposit at Nova in the Fraser Zone, and the ongoing exploration to find similar deposits in this region. Previously, the Fraser Zone was interpreted to be a remnant of one or more oceanic arcs, but analysis of whole-rock geochemical and isotope data has shown that this is not the case, and that the Fraser Zone gabbros were intruded into a deep basin through Yilgarn–Biranup continental basement, in the presence of a high geothermal gradient.

The Madura and Western Coompana Provinces are virtually unexplored, although there is some indication of nickel and PGE mineralization in the c. 1410 Ma Loongana intrusion, now interpreted as an oceanic arc. There is also the potential for copper in much of the region, as indicated by its presence in most of the stratigraphic cores. The presence of Macquarie Arc-like shoshonites in the Western Coompana Province is encouraging for copper–gold. The Coompana Province presents an entirely new region that is tectonically linked to the Gawler Craton in South Australia. The new drillcores from the EIS Eucla basement stratigraphic drilling program, and the 13GA-EG1 Eucla–Gawler seismic line, have been of enormous value in constraining these relationships.

Outcomes of work program 2017–18

Significant advances have been made in our understanding of the evolution of the Albany–Fraser Orogen and Eucla basement, which include the following:

- Geochemical and isotopic studies have indicated that the Madura and Coompana Provinces are dominated by Proterozoic oceanic basement, although they preserve diverse geological histories.
- Deep crustal geophysical data analysis and modelling have allowed full integration of geophysical datasets

including passive seismic (the Albany–Fraser experiment [ALFREX] array), several seismic reflection lines and magnetotelluric (MT) lines, which, in conjunction with geological information, have provided insight into the crustal architecture in 3D and the role of major structures.

- New detailed structural mapping and sampling in the east Albany–Fraser Orogen, with emphasis on the Fraser Zone, is unravelling the complex structural architecture and timing of events.
- Ongoing collaborative work with Curtin University and industry including crustal evolution, petrochronology, sulfur isotope and P–T studies have helped determine the processes and tectonic environment of mineralization, and prospectivity of the region. Main outcomes include the production of orogen-scale isotopic maps, new zircon and rutile dates combined with thermometry data, new in situ sulfur isotope data from the Fraser Zone and new P–T data from gabbroic and metagabbroic rocks of the Fraser Zone.
- Members of the GS61 team led a pre-conference field trip to the Albany–Fraser Orogen, as part of the Specialist Group in Tectonics and Structural Geology (SGTSG) of the Geological Society of Australia in November 2017. Highly experienced attendees in the field of structural geology provided a new understanding of key outcrops of the east Albany–Fraser Orogen. The conference abstract volume and the field guides for this trip and for the mid-conference fieldtrip in the Denmark–Albany region and post-conference field trip to the Leeuwin Province have been published by GSWA.

Products released 2017–18

Report 177 Crustal and uppermost mantle structure of the east Albany–Fraser Orogen from passive seismic data

Record 2017/14 SGTSG 2017 Albany–Fraser Orogen pre-conference field trip: transect across an Archean craton margin to a Proterozoic ophiolite

Record 2017/15 SGTSG mid-conference field trip guide: the western Nornalup Zone, Albany–Fraser Orogen, Western Australia

Record 2017/17 SGTSG Denmark 2017 abstract volume: Biennial meeting of the Specialist Group in Tectonics and Structural Geology, Geological Society of Australia, 8–12 November 2017, Denmark, Western Australia

Record 2018/5 A petrographic and geochronological assessment of the gabbroic and metagabbroic rocks of the Fraser Zone, Albany–Fraser Orogen, Western Australia

Record 2018/6 SGTSG post-conference field trip guide: the Leeuwin Complex, Western Australia

Record 2018/9 The tectonothermal evolution of a portion of the southern Fraser Mobile Belt, Western Australia

Posters for GSWA 2018 Open Day

Three external publications — see Appendix B

Planned work program and products 2018–19

- Focusing on detailed structural and metamorphic analysis of the eastern Albany–Fraser Orogen, with particular emphasis on the S-bend region surrounding the Fraser Zone. This involves publishing significant datasets and their interpretations; a GSWA Report on the structural evolution of the S-bend area is with co-authors at present and will be under review shortly. Ongoing and future work includes 1:100 000-scale digital mapping, detailed structural mapping and analysis, sampling, microstructural work, Tescan Integrated Mineral Analyser (TIMA) analyses, routine and non-routine geochronology and P–T work.
- Finalizing the detailed work on the stratigraphic and exploration drillcores from the Eucla basement and interpretations of geophysical data.
- Updating and expanding the contributions in the ENS database.

Because of extensive cover, these studies all utilize available drillcores, including donated core and EIS co-funded cores, and interpretation of high-resolution magnetic data flown by exploration companies. The GS61 program is integrated with the MRIWA M470 project, which is a collaboration between exploration industry sponsors and Curtin University (led by Chris Kirkland) titled ‘Mineral systems on the margin of cratons: Albany–Fraser Orogen — Eucla basement case study’. Work is ongoing and results will be published as GSWA Records and Reports when available.

Work has commenced on understanding connections between the west and east Albany–Fraser Orogen, and a geochemical and isotopic sampling traverse will be undertaken when time permits. This work will link to geochemical analysis in the Southwest and Youanmi Terranes of the Yilgarn Craton.

Products planned for release 2018–19

Stratigraphic and co-funded drilling of the Eucla basement — the Proterozoic geology beneath the Nullarbor Plain (Report)

A hyperspectral characterization of the Eucla Basement drill cores (CSIRO Report; Record)

Hydrogeochemistry of the Eucla Basin (CSIRO report; Record)

A magnetotelluric survey across the east Albany–Fraser Orogen, Western Australia (Report)

Structural evolution of the S-bend region of the east Albany–Fraser Orogen (Report)

The cooling and exhumation of the Albany–Fraser Orogen, Western Australia, by $^{40}\text{Ar}/^{39}\text{Ar}$, Rb/Sr and U/Pb thermochronology (Report)

Explanatory notes of selected units of the Albany–Fraser Orogen (ENS database)

External publications

Planned work program and products 2019–20

Compilation of Albany–Fraser Orogen 1:100 000-scale digital mapping and reporting of structural and metamorphic synthesis, which will provide an understanding of the kinematic and magmatic history of crustal-scale features and potential links to mineralization.

Results from the MRIWA M470 project will be published as GSWA Records and Reports when available.

The first release of a pre-Mesozoic, 1:100 000-scale interpreted bedrock geology digital map layer of the Eucla basement is in planning.

Products planned for release 2019–20

GIS digital data package of the southeast Albany–Fraser Orogen

Explanatory Notes for selected units of the Albany–Fraser Orogen, Madura and Coompana Provinces

Structural and metamorphic evolution of the southeast Albany–Fraser Orogen (Report)

Pre-Mesozoic 1:100 000-scale interpreted bedrock geology digital map layer within a Eucla basement Geological Exploration Package

GS62 3D Geoscience

Manager: Klaus Gessner

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

The aim of the 3D Geoscience section is to increase the knowledge of Western Australia's subsurface through the integration of geophysical, geological and geochemical data in 3D structural models. EIS-funded collaborative projects with leading research institutions that complement GSWA's capabilities in data acquisition, analysis and modelling are a large part of the section's activities.

The emergence of 3D structural modelling and numerical simulation techniques allow the extension of knowledge from exposed and well-understood areas to inaccessible or data-poor parts of the solid Earth. These techniques also test the validity of conceptual models and interpretations.

The objectives of the 3D Geoscience section are to:

- develop the capability to build, manage, analyse and store 3D models according to GSWA quality standards and stakeholder needs
- engage with leading research institutions that complement GSWA's capabilities in data acquisition, analysis and modelling.

The 3D Geoscience section focuses on solid Earth models of the composition and structure of the Earth's crust and mantle at the micro to hundreds of kilometres scale. Input data include geological observations, active and passive source seismic data, and measurements of mineral spectra, radiation, magnetization, density and electrical properties. The workflow to generate 3D models involves data acquisition, processing, visualization, interpretation, publication and archiving.

Mapping of large-scale crustal structure is fundamental to building a 3D architecture of the crust. This starts with detailed structural mapping combined with geochemical and geochronological analysis to build the basic framework of information for geological development of an area.

3D Geoscience is committed to producing models and developing modelling workflows that satisfy the requirements of GSWA and its stakeholders, and that integrates with existing databases and products.

Integrated geophysical and geological transects across the West Australian, North Australian and South Australian Cratons and their margins in Western Australia, and the intervening Neoproterozoic and Phanerozoic basins, provide a key to the geological evolution of the Australian lithosphere over some four billion years of Earth history. These transects also provide an understanding of the localization of mineral systems within the upper crust. In addition to the active source seismic acquisition, 3D Geoscience is collaborating on passive source surveys.

Active source

Deep seismic reflection surveys were acquired in consultation with GA. Exploration companies are able to contribute to lines in their areas of interest. The lines use existing roads wherever possible to minimize costs, cultural and environmental impact and rehabilitation.

Each seismic reflection survey line is sampled for gravity, and usually for MT. Ongoing MT survey work, together with processing and interpretation will be consolidated under this project and will include cooperative work with the CET at UWA in the Capricorn Orogen, and in the Eastern Goldfields of the Yilgarn Craton.

Passive source

The use of passive source seismic techniques is a low-cost, non-invasive method for determining crustal seismic velocities and structure including the Moho and below, using earthquakes and background vibrational noise as the energy source. Receiver function studies of the reflected phases on incoming earthquakes give the depth to the Moho, and correlation studies of the ambient noise give the shear wave velocity and structural layering within the crust and upper mantle. Data acquired from these studies is complementary to data acquired by active techniques and easily collected over a 3D volume.

Outcomes of work program 2017–18

Mapping of major shear zones in the Yilgarn Craton has continued, with mapping of the Moyagee Fault and Waroonga Shear Zones. The study of emplacement of syn- to post-tectonic granites within the Yilgarn Craton, such as the Yalgoo dome, combined with geochemistry and geochronology is working towards a tectonic model for the development of the Yilgarn orogeny. Mapping continued in the Murchison area for the DALGARANGA and KIRKALOCKA 1:100 000 Geological Series map sheets.

Contributions have been made to regional mapping teams, with the forward modelling of cross-sections of 1:100 000 Geological Series map sheets in production (Fig. 4).

A 3D model of the Albany–Fraser Orogen (Fig. 4) was constructed from all available data from the region, including inverted potential field data to expand the interpretation away from the 12GA-AF1, 2 and 3 seismic lines and ALFREX Moho passive seismic surface. The final model shows Albany–Fraser Orogen geological units that have been tested by forward modelling of gravity data supported by petrophysical data.

In collaboration with Intrepid Geosciences, two 3D models of Western Australian geology (Merlinleigh and Brockman Syncline, Fig. 4) originally built by Intrepid have been converted from Geomodeller software into GOCAD and Geoscience Analyst for distribution through the GSWA Data and Software Centre.

Planning and preparation was conducted for the next deep crustal seismic line across the remote Kidson Sub-basin in the Canning Basin, and shooting of the line will commence in 2018 (Fig. 4).

The Capricorn Orogen passive array (COPA) is being run in collaboration with CET and the Centre of Excellence for Core to Crust Fluid Systems as part of the Science and Industry Endowment Fund (SIEF) Capricorn Distal Footprints project, with the objective to target mineral systems in the Capricorn Orogen. It started in early 2014 and continued through 2018, with the seismometers moving across the study area (Fig. 4). Several conference talks and papers have been published, with more to come. The processing of MT data in the Capricorn Orogen also continued.

The fieldwork for a short-term feasibility study using passive seismic techniques was completed with UWA to investigate the feasibility of using the ambient noise and receiver function techniques in the Perth Basin (Fig. 4) to study crustal velocity and structure. This also included a novel project that explores how the Metropolitan Fibre Optic Network can be utilized to achieve this. Prof Mike Dentith, the UWA project leader, is presently writing up the results.

A new passive seismic deployment started in the Canning Basin, in conjunction with the Institute of Geology and Geophysics at the Chinese Academy of Sciences (IGG-CAS). The China Western Australia Seismic Experiment (CWAS) will study the northwest margin of Australia for remnants of the opening of the Tethys Ocean, as part of a transglobal project coordinated by the Chinese Academy of Sciences. An offshore sister project between IGG-CAS and Macquarie University is investigating the deep structure of the northwest shelf with the aim of determining the onshore and offshore crustal structure below the Palaeozoic basins. To this end, seismometers were located in a transect along the trace of the active source line 14GA-CC1 and ocean bottom seismometers, provided from the Australian National Seismic Imaging Resource pool, along a perpendicular line offshore. CWAS will run for two to three years.

In collaborative project LP140100267 ‘Reducing 3D geological uncertainty via improved data interpretation methods’, an uncertainty framework was developed and applied to geophysical inversion, as well as the continued investigation of the topological analysis of drillholes, maps and 3D volumes. From LP140100267, four journal papers and two conference papers were produced, and the project provided critical leverage to two new research projects of strategic importance to the Geoscience Directorate (Mineral Exploration Cooperative Research Centre [MinEx CRC] and ARC LP170100985 ‘Enabling 3D stochastic geological modelling’).

In 2017–18, the book ‘Characterization of ore-forming systems — advances and challenges’ was published. The book is an edited volume produced by invitation from the Geological Society of London, following a series of

European Geophysical Union meeting sessions convened with Dr Peter Sorjonen-Ward (Geological Survey of Finland) and Prof Tom Blenkinsop (Cardiff University).

Products released 2017–18

Report 177 Crustal and uppermost mantle structure of the east Albany–Fraser Orogen from passive seismic data

Record 2017/13 Compilation of geophysical modelling records, 2017

Record 2017/17 SGTSG Denmark 2017 Abstract Volume, contribution:

Deep density structure of the Albany–Fraser Orogen and Yilgarn Craton margin from constrained 3D gravity modelling, p. 21

Mount Brockman Syncline, 2006 — overview and list of components, *in* Mount Brockman Syncline, 2006 — 3D Geomodel Series

Merlinleigh Sub-basin, 2013 — overview and list of components, *in* Merlinleigh Sub-basin, 2013 — 3D Geomodel Series

Record 2018/7 3rd Lithosphere workshop, 5–6 November 2017, The University of Western Australia

Mount Brockman Syncline, 2006 — 3D Geomodel Series

Merlinleigh Sub-basin, 2013 — 3D Geomodel Series

External publications — see Appendix B

Planned work program and products 2018–19

The 3D Geoscience section will continue to contribute to regional mapping projects with a targeted effort in the Eastern Goldfields of the Yilgarn Craton. Sections across mapped areas and a new passive seismic and MT deployment (in conjunction with UWA) will form a complementary study to the new active seismic lines planned in the area. Detailed structural mapping along the seismic lines will form the framework of the geophysical interpretations.

The final mapping within the Murchison for the DALGARANGA and KIRKALOCKA 1:100 000 Geological Series maps aims to have these areas for publication in 2019.

3D models and accompanying GSWA Records are planned for the Albany–Fraser and 3D fault network model for the northwest and central Yilgarn Craton. Continued input into the Capricorn 3D model will come from the results of the COPA project. 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 present a study of shallow-level seismic techniques using the Tromino systems along with other geophysical data to quantify depth to bedrock and support regolith studies.

Emphasis will be in publishing the results from collaborative field projects that have recently been finished in peer-reviewed journals, including the passive seismic projects in the Capricorn Orogen and the Perth Basin, and the Perth Metropolitan distributed acoustic sensing project.

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 IGG-CAS.

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

The group is part of ARC project LP170100985 ‘Enabling 3D stochastic geological modelling’, a large Monash University-led international project for reducing risk for the resources industry by developing 3D stochastic modelling — the next generation of 3D modelling software. This project will run for three years. As a major contributor, GSWA will be playing an active role in advising and following the progress of the project.

Products planned for release 2018–19
East Albany–Fraser Orogen, 2018 — 3D Geomodel Series
Yangibana — 3D Geomodel Series
Yalgoo–Singleton — 3D Geomodel Series
Lawlers Anticline, 2019 — 3D Geomodel Series
3D fault model of the northern Murchison
3D modelling of the Albany–Fraser Orogen (Record)
X-ray Microtomography (Record)
The Precious Earth book
Compilation of geophysical modelling records, 2019 (Record)
Geochemistry of Archean granitic rocks in the South West Terrane of the Yilgarn Craton (Record 2018/10)
Yalgoo and isotopes (Report or Record)
Perth Basin passive seismic (Report)
Passive seismic studies of the Capricorn Orogen (Record)
Crustal structure beneath the southern Pilbara sub-basins (Report)

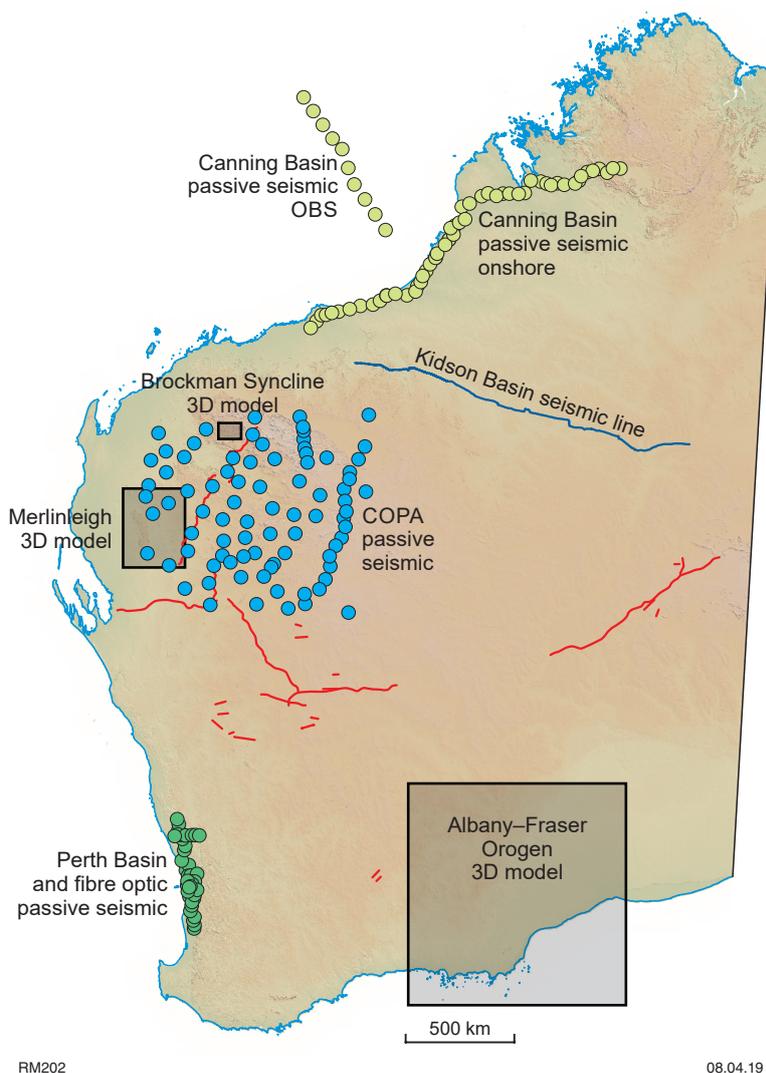


Figure 4. Products and activities of GS62 3D Geoscience. Red lines represent forward modelled geophysical sections, the blue line is the planned Kidson Basin seismic line. Coloured spots are locations of seismometers in various passive seismic arrays. Abbreviations: COPA, Capricorn Orogen passive array; OBS, ocean bottom seismometers

GS63 Tectonic Evolution of the Fortescue and Hamersley Groups

Manager: Heather Howard

Team members: Arthur Hickman, David Martin

The 2775–2630 Ma volcano-sedimentary Fortescue Group and the conformably overlying 2630–2445 Ma Hamersley Group belong to the Mount Bruce Supergroup, which unconformably overlies the granite–greenstones of the Pilbara Craton in Western Australia. Not only does this supergroup incorporate the world’s best preserved sequence of Archean ultramafic to felsic volcanic deposits and arguably the world’s most continuous transect across the Archean–Proterozoic boundary, it remains the most economically important stratigraphic unit on the Australian continent.

The stratigraphy of the Fortescue Group has previously been described in detail by GSWA. It has an estimated thickness of 6.5 km. In most areas, it is subdivided into seven formations, which are grouped into four major tectonostratigraphic units, including several basaltic units with volumes and aerial extents similar to Phanerozoic flood basalt provinces. At the base is the Mount Roe Basalt, which consists of subaerial basaltic lavas, subaqueous basaltic (pillow) lavas and water-lain volcanoclastic rocks. This is overlain by sedimentary, mafic and felsic volcanic rocks of the Hardey Formation, subaerial basaltic flows (Kylena and Maddina Formations), sedimentary and volcanoclastic rocks (Tumbiana Formation) in the north Pilbara, and subaqueous basaltic to komatiitic lavas and volcanoclastic rocks in the south (Boongal, Pyradie and Bunjinah Formations). The uppermost unit (Jeerinah Formation) is mostly argillaceous in the north, but contains abundant basaltic lava and volcanoclastic rocks in the south.

The Hamersley Group is a dominantly low-grade metasedimentary succession that includes chert, BIF, jaspilite, dolomite, mudstone, siltstone, felsic volcanic rocks and numerous dolerite sills. It is subdivided (in ascending order) into the Marra Mamba Iron Formation, Wittenoom Formation, Mount Sylvia Formation, Mount McRae Shale, Brockman Iron Formation, Weeli Wolli Formation, Woongarra Rhyolite and Boolgeeda Iron Formation.

Mantle plumes have been proposed to explain the evolution of many Phanerozoic flood basalt provinces in general; however, the three main basaltic units of the Fortescue Group were interrupted by sedimentary deposition (Hardey and Tumbiana Formations) and therefore, a single plume model is inadequate. The lower part of the Fortescue Group has been interpreted in terms of a two-phase continental breakup model, but an alternative explanation argued that discrete periods of lithospheric extension alone, related to continental breakup, could account for this flood basalt volcanism.

GSWA suggested the Fortescue Group is part of a rift sequence where west-northwesterly trending faults controlled the margins of the rift and were buried beneath

a breakup unconformity. This was overlain by a passive margin sequence, comprising the uppermost unit of the Fortescue Group and overlying Hamersley Group. A collisional setting for the BIF and mafic and felsic rocks in the upper part of the Hamersley Group has been proposed. The debate on stratigraphic definition, tectonic setting and evolution of the Mount Bruce Supergroup remains largely unresolved.

Second edition 1:250 000-scale mapping of the Fortescue and Hamersley Basins region was completed between 1980 and 1992, and several areas, mainly overlying the northern part of the Pilbara Craton, were also covered by 1:100 000-scale mapping during the 1990s and 2000s. In 2011, 581 km of deep seismic reflection data were acquired along several traverses from the Pilbara Craton, across the Capricorn Orogen, to the Yilgarn Craton. One of these lines (10GA-CP1) imaged the Fortescue and Hamersley Basins. Aerial magnetic and radiometric data at 400 m line-spacing are available from government or commercial sources over the area. Recent Landsat TM satellite imagery and orthophotography are also available.

Since GSWA mapping began in the region, there have been significant advances in the understanding of the tectonic history of the Capricorn Orogen, the northern margin of which includes Fortescue and Hamersley Group rocks within the Ophthalmia Fold Belt. No regional synthesis of the structural history and tectonic setting of the Ophthalmia Orogeny has ever been undertaken.

SHRIMP U–Pb zircon geochronology carried out on the succession by GSWA was limited, and whole-rock geochemical data was mainly acquired before the widespread use of modern LA-ICP-MS techniques. In terms of both high-quality geochemical and isotopic data, the Fortescue and Hamersley Basins remain distinctly underpopulated compared with the geological regions to the north and south.

Importantly, the well-preserved felsic, mafic and ultramafic units within the Fortescue Group are also partial age equivalents of volcano-sedimentary sequences accumulating in the Yilgarn Craton. As such, they not only provide an ideal opportunity to understand the petrogenesis of Archean greenstone-related sequences, but also to understand the tectonic setting that led to economically important Proterozoic deposits of the Hamersley Group. Despite this, a detailed, systematic, regional synthesis of the geochemical variation of magmatic units throughout the entire Mount Bruce Supergroup has not been undertaken.

The main objective of the project is to increase the geological knowledge of the Fortescue and Hamersley Groups in terms of their context within the wider Mount Bruce Supergroup and Capricorn Orogen. This will mainly

involve using spatially and stratigraphically controlled, high-precision geochemical, isotopic and geochronological data, obtained from outcrop and diamond drillhole sampling to construct a ‘magmatic stratigraphy’ of the Mount Bruce Supergroup in key areas and extend this to a regional scale. Limited remapping of significant stratigraphic and structural relationships will be carried out in order to understand the relationships between the volcanic and sedimentary units. This will be integrated with petrogenetic constraints on magmatism to better understand the tectonic evolution of the Mount Bruce Supergroup.

Outcomes of work program 2017–18

The main outcomes from the Fortescue–Hamersley project to arise from the 2017–18 period are listed below:

- The work program has initially focused on data collection, including the collation of available legacy data from the Fortescue and Hamersley Groups and HyLogger scanning of drillcore from the Hamersley Basin.
- Up-to-date mapping at formation level is now available for the Fortescue–Hamersley Basin in the southern Pilbara region.
- A number of stratigraphic revisions have been recognized, including a regional disconformity, to local low-angle unconformity, at the base of the Turee Creek Group and also at the base of the Boolgeeda Iron Formation.
- New occurrences of known glaciogenic horizons and a potentially new horizon have been identified. These horizons have been formally named in order to assist the description and correlation of this globally important succession.
- Preliminary, high-precision geochemical and isotopic data, obtained from a detailed sampling traverse in the Paraburdoo area, reveal much geochemical variation in the stratigraphy of the Fortescue Group. The geochemical variation evident in the lower part of the Fortescue Group can be explained by a komatiitic magma source that was modified by assimilation and fractional crystallization processes. In contrast to this, the primitive basalts of the Jeerinah Formation may support a change in tectonic setting up stratigraphy, from rift to passive margin as described by Thorne et al. (2011).

Products released 2017–18

Fortescue–Hamersley 2018 GIS data package (new product) including:

- reinterpretation of the bedrock geology of the southwestern Hamersley province at 1:100 000 scale
- compilation of legacy data (aerial photographs, field notebooks and samples)
- imagery for the project area

Report 185 The mapped stratigraphy and structure of the mining area C region, Hamersley province

Lithostratigraphic units from the Hamersley Group (21 units added to the ENS database)

Planned work program and products 2018–19

The initial fieldwork for the Fortescue–Hamersley project has been aimed primarily at validating existing mapping and identifying areas for detailed future work. Systematic outcrop and drillcore sampling of the mafic and felsic igneous units that belong to the Mount Bruce Supergroup will continue. Targeted mapping will continue and detail will be added to the digital map layers as it is available. Records on the geochemistry of the Fortescue Group and the Hardey Syncline will also be produced.

From 2018–19 financial year, the Pilbara Craton (GS45) will be included in the new Pilbara/Hamersley (GS63) project plan. A detailed geological Report on the geology, crustal evolution and mineralization of the east Pilbara Craton will be released. Following completion of this Report, work will commence on writing up lithostratigraphic units (ENS database) from the Pilbara Craton that are on the digital 1:500 000 interpreted bedrock geology digital data layer.

Products planned for release 2018–19

The 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)

Explanatory notes to accompany the 1:500 000 interpreted bedrock geology layer for the Pilbara Craton

Two external publications (conference proceedings)

Planned work program and products 2019–20

The following work and products are planned for 2019–20 onwards:

- Work will continue to contribute towards new releases of GIS data packages, along with new geochemistry data.
- New Records will be published, all working towards a reassessment of the tectonic setting and geological evolution of the Fortescue and Hamersley Groups.
- Interpretation of that part of the Kidson seismic line covering the region between Gregory Range and Marble Bar.
- A geological Report on the Hickman Impact Crater will interpret all existing information from GSWA drilling (2012), a GSWA low-level airborne geophysical survey, and geochemistry of meteorite fragments and melt glass.

GS64 Geoscience Mapping Through Cover

Acting manager: Catherine Spaggiari

Team members: Nadir de Souza Kovacs, Sara Jakica

GS64 is a new project in 2018–19 and incorporates the regolith and cover component of GS43 Geochemistry and Regolith, which finished in 2017–18. GS64 is linked to ES36, which is the EIS project area for the MinEx CRC.

The mapping of the distribution of different regolith types 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 drillcores. 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 the ENS database. 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.

Since 2011, GSWA has demonstrated the application of single-station passive seismic to provide estimates of the depths to various horizons or basement in shallow cover and up to a depth of 1000 m. The passive seismic instruments used are Tromino seismometers produced by MoHo s.r.l. in Italy. With the purchase of four more instruments and integration with the multichannel seismic acquisition system SoilSpy, the capability of this technology has been extended so that passive and active seismic array acquisition surveys are possible. The aim is to test the integration of the passive seismic approach with regional AEM data captured over the Capricorn Orogen so that this methodology can be applied to other regions, for example, areas of interest for the MinEx CRC drilling projects. The techniques are being trialled on various paleochannels to estimate their size, depth and shape. This will inform landscape evolution studies and ground water analysis.

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 pisolitic 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 the regolith mapping, these data and their interpretations will help detect the distribution of economic mineral signatures in the cover.

Outcomes of work program 2017–18

- Evaluation of new geochemical analytical techniques, including both laboratory-based and portable techniques
- Continued population of the WACHEM database
- (U–Th)/He dating of duricrust of 10 samples (per annum) for geochronological analysis of secondary iron oxides in weathering systems
- Compilation of the northern half of the 1:500 000-scale State digital regolith map near completion
- New methodology devised for compilation of the State regolith digital map, combining new and legacy data and map layers
- Regolith classification scheme completed and ENS regolith module in place
- Tromino single-station passive seismic data acquisition, processing and interpretation of breakaways near Leonora
- Passive seismic data acquisition using a Tromino array combined with existing AEM data to produce a 3D model of the cover sequence and the Yangibana paleochannel in the Gascoyne region (in progress).

Regolith geochemistry programs have focused on greenfields terrains, creating a need to investigate types of sample media that can provide ‘vision’ through cover to bedrock, and potential bedrock-hosted mineralization. In desert terrains dominated by eolian deposits, the fine (silt and clay) fraction of regolith has proven useful as a multi-element sample medium, especially when combined with a partial extraction approach during analysis. GSWA has investigated the potential of biogeochemistry, specifically the chemistry of spinifex, to detect abnormal fluid fluxes over regional faults and whether this chemistry is indicative of fluids migrating from bedrock mineralization.

Products released 2017–18

Record 2018/3 Regolith geochemistry of the Ngururrpa area, northeastern Western Australia

Interpreted regolith–landform digital layer of the Ngururrpa lands and other data (digital files with Record 2018/3)

Interpreted regolith–landform map of the Ngururrpa lands (1:250 000 non-series map; Plate 1 in Record 2018/3)

Regolith component of LANSLOWNE second edition 1:250 000 Geological Series map sheet

Regolith component of MACDONALD second edition 1:250 000 Geological Series map sheet

Posters for GSWA 2018 open day

Three external publications — see Appendix B

Products planned for release 2018–19

Release of the northern half of the State 1:500 000-scale regolith–landform digital map layer

Release of the southern half of the State 1:500 000-scale regolith–landform digital map layer

State 1:500 000-scale regolith–landform digital map layer – new compilation methodologies (Record)

Regolith–landform mapping classification scheme (Record)

Data entry for units in the new regolith module in the ENS database

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 2018–19

- Work is focused on release of the northern half of the 1:500 000-scale State regolith–landform digital map layer, to be followed by the southern half in the latter part of 2018–19; includes documentation of the methods developed and used
- Development of methodologies using small-array passive seismic data acquisition to map regolith layers and paleochannels in conjunction with AEM geophysical data and to provide estimates of depths 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 the ENS database
- Dating of regolith materials using the (U–Th)/He method, in collaboration with the John de Laeter Centre
- A targeted geochemical sampling approach, in conjunction with geochronology and biochemistry sampling, will be utilized during regolith mapping and regolith profile studies; this will provide information about paleoweathering patterns and local geochemical dispersion patterns from bedrock.

Planned work program and products 2019–20

Work will focus on regolith mapping and landscape evolution analysis within the MinEx CRC drilling project areas, with an emphasis on linking this work to an improved understanding of the distribution of mineral footprints in the cover. 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.

Products planned for release 2019–20

Step back in time to the Yangibana paleochannel: a 3D model using passive seismic data (Record)

The application of passive seismic methods to estimate cover thickness in the Capricorn Orogen (Record)

GS80 Editing and Publishing

GS81 Mapping and Events

GS82 Graphics

GS83 GIS

GS84 Spatial Systems

GS85 Geoscience Promotions

General Manager: Stephen Bandy

Team members: Ryan Aston, Paul Backhouse, Robin Bower (Manager GS80), Derek Canham, Jason Challis, Kriti Chhabra, Shaun Coldicutt (Manager GS81 and GS85), Joel D'Antoine, Bhumita Fadadu, Annick Francois, Marie Ferland, Kiran Gavni, Isabel Granado, Kay Greenberg, Gary Hartley, Bec Hitchings, Joe Hogen-Esch, Dave Horrocks, Stewart Jefferys, Daniel Jolly, John Kirk, Irena Lesiak, Leo Liu, Jonathan Marchant, Frank Matera, Sue Mulligan, Joyce Peng, Michael Prause (Manager GS82), Martin Stephen, Bernd Striewski, Adam Symonds, Daniel Then (Manager GS83), Brad Tapping, Darren Wallace (Manager GS84), Stephen White

Experienced well-qualified staff are critical to the quality and delivery of geoscience 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 Spatial and Geoscience Information branch, which is responsible for the production of all GSWA products, including geoscientific maps, Reports, Records and data packages for delivery as physical or 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 branch also manages 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.

Outcomes of work program 2017–18

There was continued focus on the management and delivery of geoscience data. Major outcomes of the work program included:

- promotion of Western Australia's prospectivity at international and national conferences, open days and trade shows

- release of GeoResources, an internal web viewer that allows the spatial editing of MINEDEX points which obviates the dependency on ArcGIS licences
- release of digital data layers downloadable from the Data and Software Centre and through GeoVIEW.WA
- release of the State 1:100 000-scale interpreted bedrock geology and linear structures on GeoVIEW.WA and the Data and Software Centre (linked to the ENS database)
- ongoing updates to web-based applications
- collaboration with the Department of Treasury to produce web mapping services (WMS) online for their energy infrastructure (joint project with Mapping and Spatial Systems)
- provision of database and online systems training in Kalgoorlie and Perth for mining geologists and prospectors
- completion of the Native Title South West Settlement final assessment system tool across the Department of Lands and DMIRS
- update to the ENS database to include regolith.

Products released 2017–18

Products released in 2017–18 were (see Appendix A for a detailed list):

- 39 manuscripts
- 3 Geological Series maps (1:100 000 and 1:250 000 scale)

- 9 geological maps at other scales (including State maps and plates)
- 15 digital products.

Planned work program and products 2018–19

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

- 35 manuscripts
- 1 Geological Series map (1:100 000 and 1:250 000 scale)
- 15 geological maps at other scales
- 20 digital products
- MINEDEX 2018 redevelopment
- WAPIMS CO₂ enhancements
- redevelopment of WAROX9
- delivery of geochronology data via a mapping application
- delivery of mineral systems data via a mapping application
- implementation of workflow and product allocation system Pubstats using K2.

GS91 Mineral Exploration Information Management

Acting manager: Julia Thom

*Team members: Monique Brouxhon, Subashni De Biran, Ann Fitton (retired March 2018)
Fiona MacCorquodale, Robert Pizzi, Christine Suchodolski*

The department 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 Statutory Mineral Exploration Information section also manages the processes that allow internal and external stakeholders to view and sample the valuable mineral core collection housed in the two core libraries.

Outcomes of work program 2017–18

The online report-writing application for mineral exploration reports was launched in February 2015. It has been available for just over three years, during which time companies have had an opportunity to use it for the compilation of their annual reports. Its use is still optional and at the end of June 2018, more than 6050 reports had been submitted.

The eleventh annual release of exploration reports, after an advertising and objection period on the website in early 2018, was completed in May 2018 — and 1189 reports were released. This release consisted of reports submitted to the department in 2012 and released under the provisions of Regulation 96(4) of the Mining Act, commonly known as the ‘sunset clause’. In addition, 1933 reports were released to open file as part of the normal cancellation process of dead tenements. At the end of June 2018, more than 89 000 reports were accessible to the public on the department’s website.

The mineral drillhole and surface geochemistry database was maintained. It now contains around 2.9 million drillholes and 9.7 million surface samples, the data from which are available to the public. Updates of the whole database, including the database schema, are released bi-annually and were released in September 2017 and March 2018.

Outcomes 2017–18

The online report-writing application for mineral exploration reports has been available for three years; at the end of June 2018 more than 6050 reports had been submitted via the system

Biannual updates of mineral drillhole and surface geochemistry database; updates released September 2017 and March 2018

Annual release of 1189 reports under the ‘sunset clause’ legislation

Release of 1933 reports on dead tenements

Review of mineral exploration reports for compliance with the Guidelines for Mineral Exploration Reports on Mining Tenements; reports are reviewed in the three months after receipt to ensure that companies comply with the most recent guidelines

Training in the use of the mineral exploration reports (WAMEX) and mineral drillhole databases in both Perth and Kalgoorlie; three training sessions per year, held in November 2017, March 2018 and June 2018

Identification of mineral exploration core suitable for inclusion in the Perth and Kalgoorlie core libraries; donations of mineral core continued in 2017–18 with the extended downturn in the industry

Planned work program and products 2018–19

Planned activities and outcomes are to:

- review and release surrender reports and their associated annual reports as they are received, together with the twelfth annual release of reports under the ‘sunset clause’ legislation to 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 and whether a drillhole has been rehabilitated in the collar table of drillholes, adoption of a unique sample ID for mineralogical samples and encourage digital submission of reports
- 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 of the 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 Statutory 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, the department 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. The department is also assisting NOPTA and GA to develop and maintain the National Offshore Petroleum Information Management System (NOPIMS), with very close links to WAPIMS and the Core Library database, 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.

Outcomes of work program 2017–18

Outcomes 2017–18

New functionalities and enhancement added to WAPIMS (e.g. historical permits layer on the GIS with a time bar, facilities grids, correspondence grids, HyLogger links, 'What's New' functionality)

Relocation of the State and Commonwealth residues to the Carlisle facilities and expansion of the slides collection in the Statutory Exploration Information group area on the first floor Mineral House

New Commonwealth data management system (NOPIMS) released, based on WAPIMS

Catalogued and archived petroleum data collections donated to DMIRS from industry and academia — more than 950 legacy tapes transcribed and archived, observers' logs, and well log data, core photo images and slides

Release of CIMS and linkage to WAPIMS

85 sampling requests processed

Data received:

- 322 Reports
- 17 well logs
- 198 survey data
- 6559 slides and residues
- monthly production, production test data, underground gas storage daily data

Data published on WAPIMS:

- 671 documents (reports, survey data and well logs)
- 6050 slides and residues

Planned work program and products 2018–19

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 to create enhancements to WAPIMS/ NOPIMS in collaboration with NOPTA and GA
- link CIMS to NOPIMS
- collaborate with NOPTA/GA in regards to better integration of our systems (WAPIMS, NOPIMS, National Electronic Approvals Tracking System Petroleum Geothermal Register [PGR])
- design forms and grids in the CIMS in order to combine all sampling approval in one interface
- implement '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 Group in capturing data submitted for the Gorgon CO₂ injection project and Tubridgi gas storage project
- assist the Energy Geoscience and Carbon Strategy section in creating the Digital Core Atlas and other projects as required (geochemical data capture, reprocessing)
- 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 section
- continue creating comprehensive data packages for petroleum acreage release
- 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 retrieving the analysis reports and the slides generated.

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 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 promotes 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 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 (Perth) 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 greenfields areas and allowing testing of new ideas and concepts.

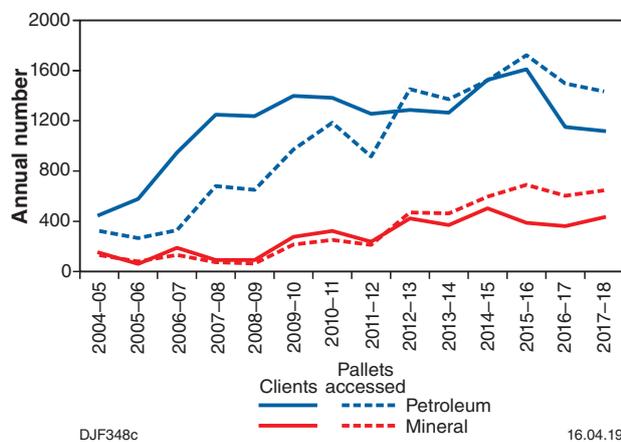


Figure 5. Perth Core Library usage statistics since 2004–05 for petroleum vs mineral clients

Outcomes of work program 2017–18

Despite the industry downturn in both the mineral and petroleum sectors, usage of the Perth Core Library at Carlisle remains at very high levels, with all of the main indicators steady during 2017–18 relative to 2016–17—this continues the decade-long trend (Fig. 5). Stakeholders from the petroleum exploration sector consistently outnumber those in the mineral exploration sector by a ratio of almost 4:1. The work at the core libraries is labour intensive — a total of 96 km of core was laid out and 2130 pallets accessed at Carlisle during 2017–18 (Fig. 6).

Carlisle site security was upgraded between May and July 2018, at a cost of around \$300 000. This included new access gates and monitored cameras.

In addition, a nodding donkey donated by AWE was installed onto a plinth and will be repainted in August 2018.

A crash barrier was installed at the corner of Harris and Briggs Streets in May 2018.

Planned work program and products 2018–19

In addition to maintaining the same level of service to stakeholders, the department’s plans for Carlisle are to add new line markings to indicate loading zones inside the main site. In addition, Exxon Mobil are in discussions with GSWA at present about donating Exxon Mobil core and cuttings from Victoria and Tasmania (~250–300 pallets).

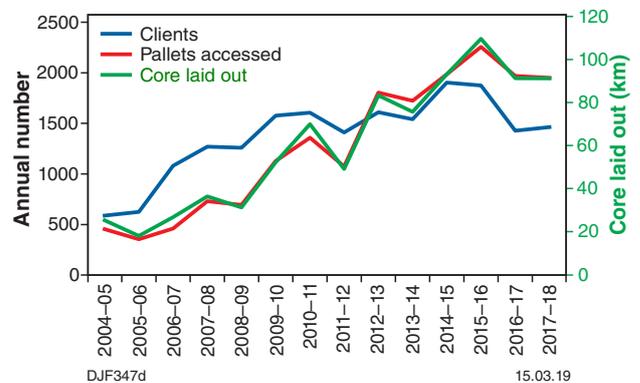


Figure 6. Perth Core Library usage statistics since 2004–05 for number of clients, pallets accessed and core laid out

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 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 an objective, semi-automated interpretation of mineralogy by comparing these data to a reference library of mineral spectra using 'The Spectral Geologist' software. High-definition digital images of the core are simultaneously obtained. The data are posted to a dedicated national website (NVCL) and to GeoVIEW.WA, where they can be viewed using open-access software. Full datasets are also available upon request.

Outcomes of work program 2017–18

For the year ending 30 June 2018, the GSWA HyLogger facility collected and processed VNIR–SWIR–TIR spectral data for 52 536 m of core from 146 drillholes. These comprised 93 EIS co-funded holes, 49 historical and donated mineral holes and four petroleum wells. The amount of core scanned is the largest in the facility's nine years of operation (Fig. 7).

For 2017–18, about 64% of the scanned core was derived from EIS Co-funded Drilling, whereas 'other' scanned core was mostly legacy mineral exploration core from the GSWA archive in the Perth Core Library and new mineral and petroleum exploration projects. During the year, more of the historical core was re-scanned using upgraded technology and data interpretation methodology. About 50% of the mineral core was freighted to Perth for scanning supported by the AuScope (NCRIS) grant scheme.

HyLogger staff also provided spectral data and advice or active involvement, for several research projects including:

- regional stratigraphy and hydrothermal alteration assemblages of the Fortescue Group (Hamersley Basin), in collaboration with other GSWA staff using hyperspectral, geochemical and isotopic data, validated with petrography and X-ray diffractometry (XRD)

- hyperspectral characterization of the stratigraphy of the Vasse Shelf coal deposits in the southern Perth Basin (Curtin University project)
- serpentinite alteration in the Yilgarn Craton (PhD, UWA)
- mineralogy of regolith at Hope Downs, Hamersley Basin (PhD, UWA)
- lithium mineralization in Londonderry pegmatite deposit (Master of Science, Curtin University).

In total for the year, data provided upon request from various agencies of scanned datasets covered 59 900 m of core.

Other activities that involved HyLogger staff included:

- publication of a batch of six new GSWA HyLogger records that summarize drillhole metadata and basic mineralogical interpretations
- provision of a two-day GSWA–CSIRO workshop showcasing the utility of the HyLogger for understanding mineral systems to industry clients and users of the data; this followed successful workshops delivered in May 2014, April 2015, May 2016 and June 2017
- provision of a one day HyLogger workshop and training for Chinese geologists as part of collaboration research
- upgrading of the 'HyLogger' layer within GeoVIEW.WA showing colour codes for different levels of data interpretation with the option to download more datasets and the links to the HyLogging summary reports
- utilizing GSWA benchtop XRD for hyperspectral data validation with six records uploaded to WAMEX and WAPIMS
- collaboration with CSIRO staff at the Australian Resources Research Centre in Perth for the interpretation and presentation of hyperspectral data.

Products released 2017–18

Five new HyLogger records of summary drillhole metadata and basic mineralogical interpretation. Links to the summary records are available through the HyLogger layer in GeoVIEW.WA: drillholes 15EIS001 (Gruyere gold deposit) and NLD046, NLD069, NLD070, NLD071 and NLD080 (Atlantis gold prospect, Tropicana deposit)

Planned work program and products 2018–19

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. 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 2018–19 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 department’s 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 to lead several special projects in 2018–19 to:

- develop procedures for using the portable/desktop XRD and scanning electron microscope to systematically and rapidly validate mineral identifications made by visual and hyperspectral logging of core and hand specimens, and provide technical support to GSWA geological staff using this facility

- deliver another workshop promoting the use of the hyperspectral technology to GSWA, academic and industry personnel.

Products planned for release 2018–19

HyLogging data processing and interpretation for assorted drillcores (numerous) (HyLogger records)

Portable XRD: applications to mineral identification in core (Record)

Planned work program and products 2019–20

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.

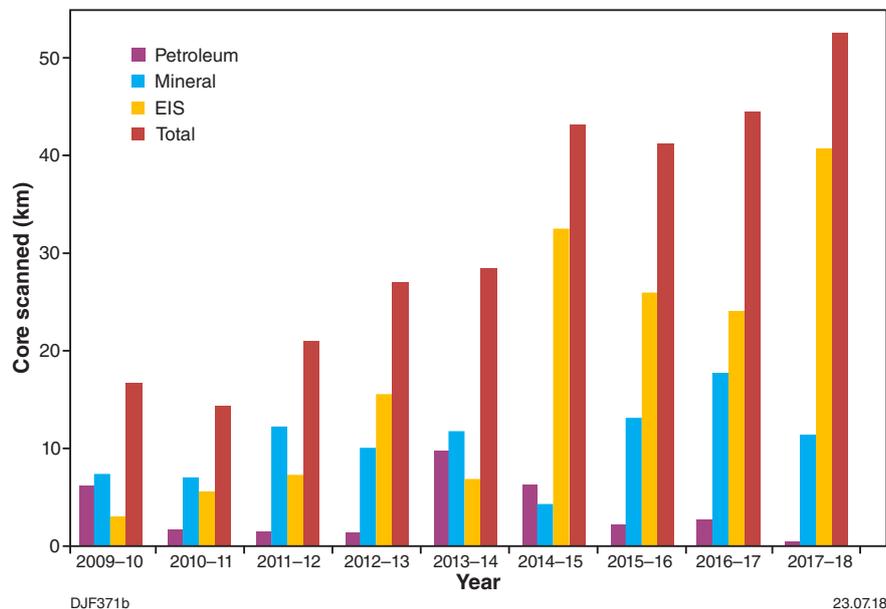


Figure 7. Spectral scanning of core through GSWA’s HyLogger at Carlisle, highlighting the importance of new EIS-funded drilling

PART 2

EXPLORATION INCENTIVE SCHEME — DETAILED WORK PROGRAMS



ES20 Government Co-funded Exploration Drilling

Manager: Charlotte Hall

Team member: Monique Brouxhon (fee-for-service contractor)

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 Director General or Deputy Director General of the department and consisting of representatives from the main industry representative groups and research sector, provides advice to the department on program guidelines. The committee, which meets twice yearly, also ensures that the program is relevant to the exploration industry.

The Co-funded Drilling program also undergoes a probity audit twice yearly by an external auditor. The assessment ensures the selection process for any round is transparent, impartial and defensible. The auditor also checks the process and control in the administration of the refund payments for previous rounds made in the previous six months before the audit.

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 previous rounds of applicants, beginning in 2011 there are now two rounds of co-funding per year running either over a financial or calendar year. This has resulted in an increase in the number of offers made in a financial year and in the number of projects completed (Fig. 8). Successful applicants are required to complete the proposed drilling project within the relevant financial or calendar year. Interim and final drilling reports plus core where cored drilling is undertaken, are submitted to the department before payment of the refunds, and the final report and core are released to open-file after a six-month confidentiality period.

Planned work program 2018–19

During 2018–19 drilling from three rounds will be undertaken by exploration companies. As can be seen in Figure 9, highlighted by the red rectangle, three rounds overlap the reporting year. Successful applicants of Rounds 16 and 17 are currently in the process of drilling. Round 16 applicants have until December 2018 to complete drilling, while Round 17 applicants will be required to drill by 30 June 2019. Figure 8 shows the number of successful applicants per round and the number of offers actually used up to the 2017–18 financial year.

- Round 18 of the Co-funded Drilling program will be open for applications from 24 August 2018 to 5 October 2018. This round is offering about \$5 million to support drilling projects undertaken during the 2019 calendar year.
- Round 19 will be open for applications in late February 2019 for applications for drilling projects to be drilled during the 2019–20 financial year.
- Two audits will be undertaken by an external auditor on the probity of the selection process for Rounds 18 and 19.
- A summary of co-funded drilling achievements and grant allocation during the 2017–18 financial year will be completed for reporting to the Department of Primary Industries and Regional Development, which manages the Royalties for Regions program and is the current source of funding of the EIS until the end of June 2019.
- A review of the single deep-stratigraphic drillhole data from completed Rounds 1 to 15 will be undertaken to determine if the capped value of \$200 000 is appropriate.

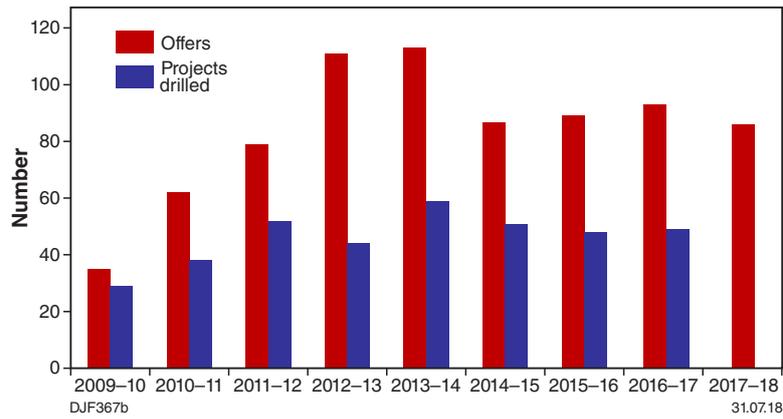
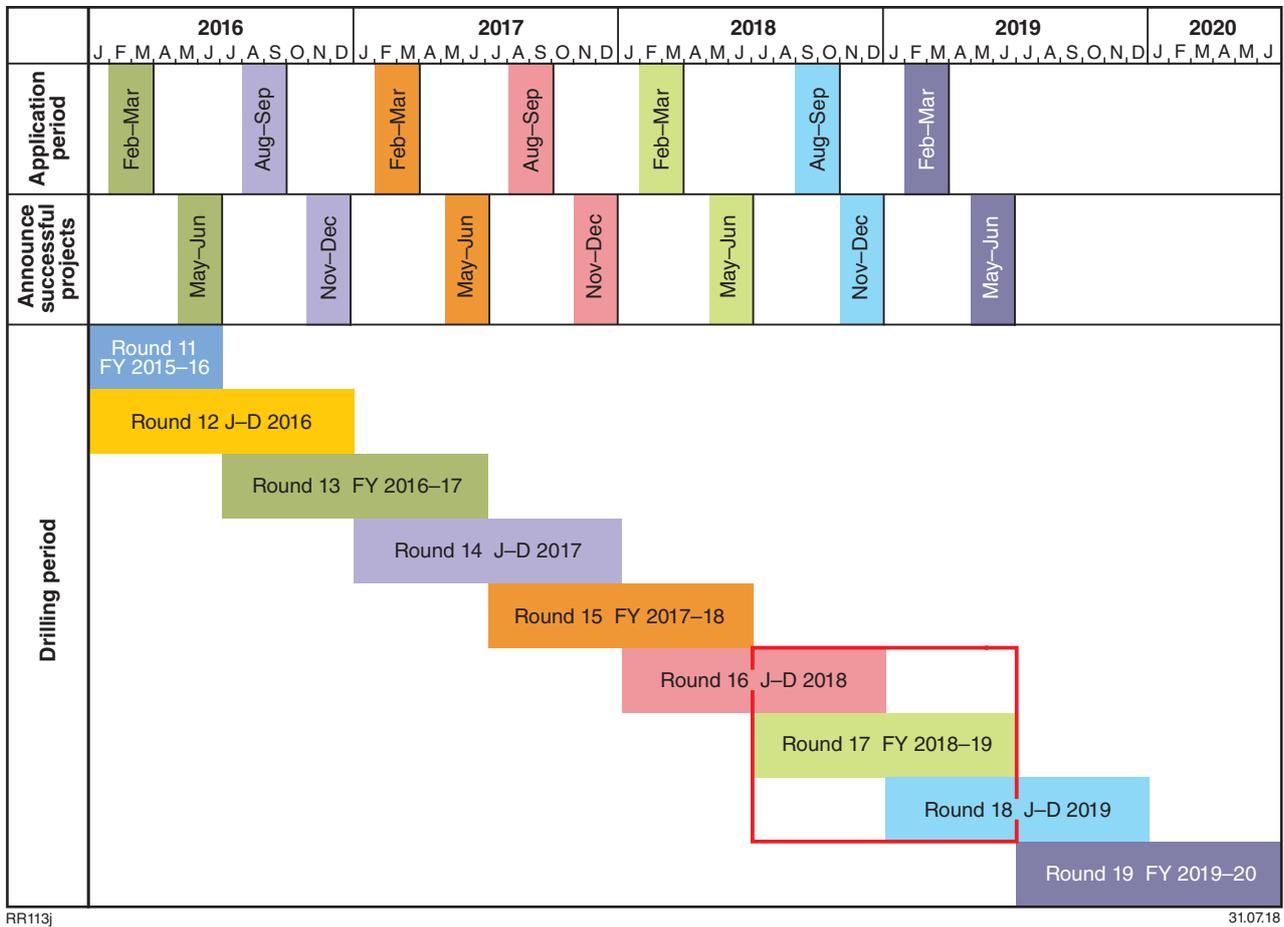


Figure 8. Projects offered funding as part of the EIS Co-funded Drilling program vs projects actually drilled, by year



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Figure 9. EIS Co-funded Drilling program schedule of Rounds 11-19. Abbreviations: J-D, January-December; FY, financial year

ES21 Resource Investment Information

Manager: Gaomai Trench

Team member: Richard Bruce

The objective of the project is to facilitate the provision of resource-related information to investors for mineral and petroleum investment into Western Australia to accelerate mineral exploration and discovery. This involves providing geoscientific, policy and regulations information to assist with attracting new resource investment, while also 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 project 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 and advice relating to policies and regulations
 - supporting the Minister for Mines and Petroleum on official travel overseas
 - liaising with Chinese State-owned enterprises (SOE) with offices in Western Australia
 - coordinating the China Geological Survey – GSWA Technical Cooperation program.
- visiting Chinese SOE and potential major investors — meeting with the Liaoning Geological Exploration and Mining Group, the China Mining Association, the Shandong Geology and Exploration Bureau and the Beijing Research Institute of Uranium Geology.

In 2017–18, the project also funded Western Australia's presence at a number of key international events including:

- NAPE Summit
- Prospectors and Developers Association of Canada Annual Convention, Trade Show and Investors Exchange (PDAC)
- annual China Mining Conference
- India–Australia Mineral Resources Investment Forums in Mumbai, Hyderabad and Kolkata
- exploration and mining investment seminars in Asia (some in cooperation with Austrade and Australia Minerals)
- annual Mining Investment Asia Congress, and Mines and Money in Hong Kong.

Planned work program 2018–19

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.

Outcomes of work program 2017–18

In July 2018, the group conducted a visit to Beijing, Shandong and Liaoning, China. Key activities during this trip included:

- attending the China International Gold Conference, with a display booth reaffirming relationships with major and potential investors, highlighting Western Australia's track record in resource development and investment attractiveness, and meeting major resource investors and key industry leaders

ES30 Airborne and Ground Geophysical Surveys

Manager: David Howard

Team member: John Brett

The Airborne and Ground Geophysical Surveys component of the EIS that began in 2009 encompasses the acquisition and processing of aeromagnetic, radiometric, gravity and AEM data on a regional scale for statewide coverage at increasing levels of resolution. All these regional surveys are run 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, at which time the focus shifted to the acquisition of detailed (100 m line-spacing) surveys in project-specific areas (Fig. 10).

Regional reconnaissance (5 km line-spacing) electromagnetic surveys funded by the EIS commenced in 2013–14 with the Capricorn Orogen survey complementing the earlier reconnaissance AEM surveys undertaken by GA. The current AEM focus is based on supporting GA’s AusAEM project that is part of the Commonwealth Government’s Exploring for the Future program in northern Australia (see Fig. 10).

The regional gravity survey component of the EIS has the objective of completing regional medium-resolution (<4 km station spacing) gravity coverage of Western Australia by 2020. As ground data acquisition programs were affected by land access difficulties in the north and east of the State, the acquisition program shifted to airborne gravity surveys beginning in 2016 with further large survey contracts awarded in 2017–18.

Notification of regional survey plans and status updates are published in GSWA’s Fieldnotes and on the website at <www.dmp.wa.gov.au/geophysics>.

Outcomes of work program

Funds and efforts in 2017–18 were concentrated on continuation of the airborne gravity program (Table 1; Fig. 11).

Data from the northeast Canning–Tanami airborne gravity surveys area were processed and released (51 000 line-km). Acquisition on the Kidson area survey (76 000 line-km) was delayed because of equipment issues; however, preliminary data were released and final data will be released in the third quarter of 2018.

Two Requests for Tender were issued and contracts awarded for new airborne gravity surveys in the Little Sandy and Great Victoria Deserts and the Kimberley Basin. Acquisition on these surveys commenced in April 2018 for completion by the end of 2018, and publication of data anticipated for the first quarter of 2019.

Airborne gravity surveys of Kidson, the Little Sandy Desert, the Kimberley Basin and the Great Victoria Desert were completed. A tender for a new airborne gravity survey in the Pilbara has been released, pending the availability of funds (Fig. 11).

Planned work program and products 2018–19

The airborne survey program for 2018–19 and beyond depends on the prevailing GSWA budget and program priorities.

Area prioritization for new surveys will be determined over the course of 2018–19.

Products planned for release 2018–19
Completion of the northeast Canning–Tanami airborne gravity surveys
Completion of the Kidson area airborne gravity survey

Table 1. GSWA airborne gravity surveys

ID	Survey name	Size (km)	Status	Release
1	East Kimberley 2016	38 000	Released	Feb 2017
2	Tanami – NE Canning 2017	50 000	Released	Apr 2018
3	Kidson 2017	75 000	Processing	(Sep 2018)
4	Little Sandy Desert 2018	52 000	Survey 71%	(Dec 2018)
5	Kimberley Basin 2018	61 000	Processing	(Oct 2018)
6	Warburton – Great Victoria Desert 2018	62 000	Survey 33%	(Dec 2018)
7	Pilbara — under consideration	69 000	Tender request	N/A

Notes:

- All surveys at 2.5 km line spacing
- Dates in parentheses are estimates
- Status as at 6 Aug 2018

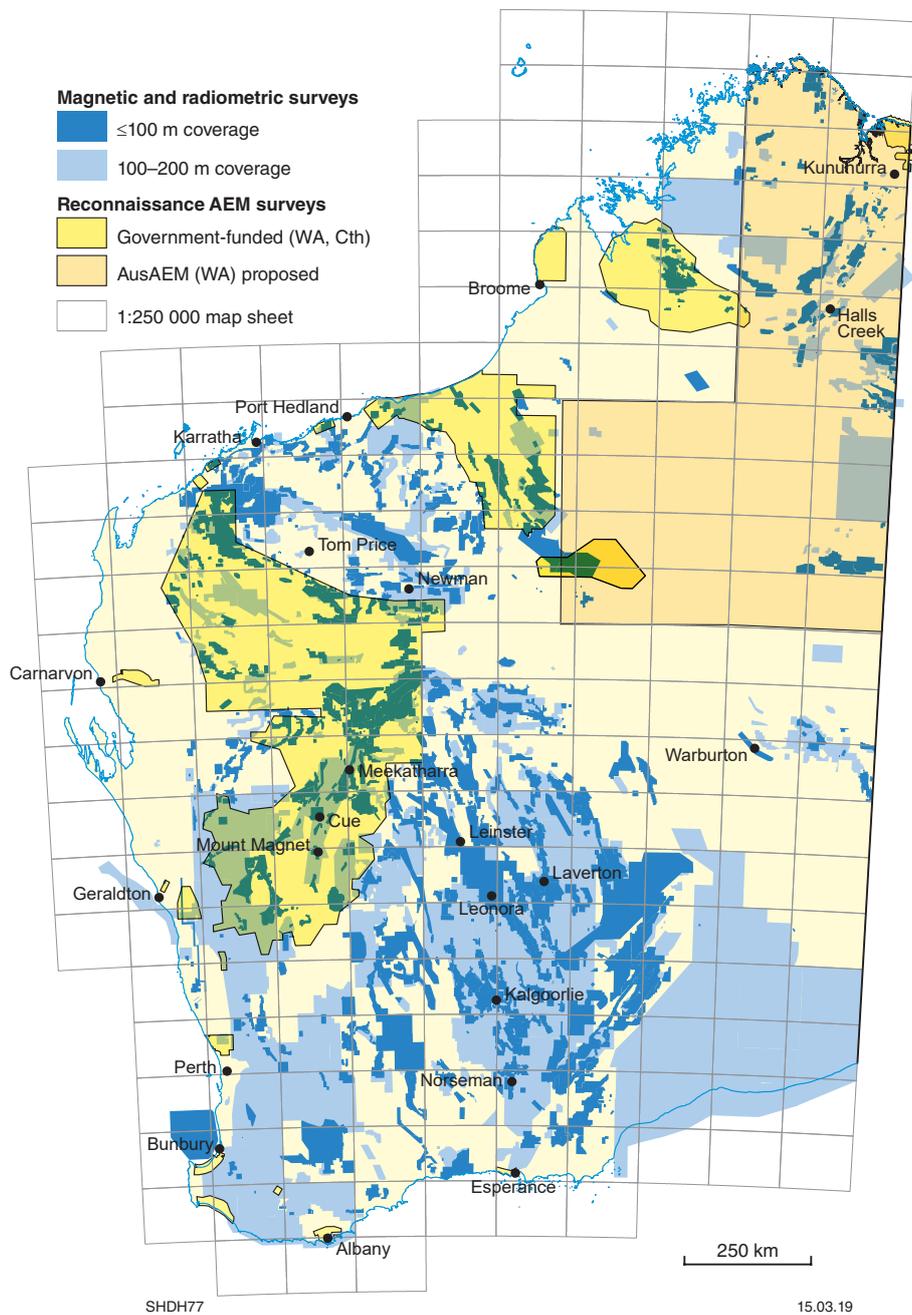


Figure 10. GSWA regional airborne magnetic, radiometric and electromagnetic coverage. Abbreviations: AEM, aeromagnetic; Cth, Commonwealth

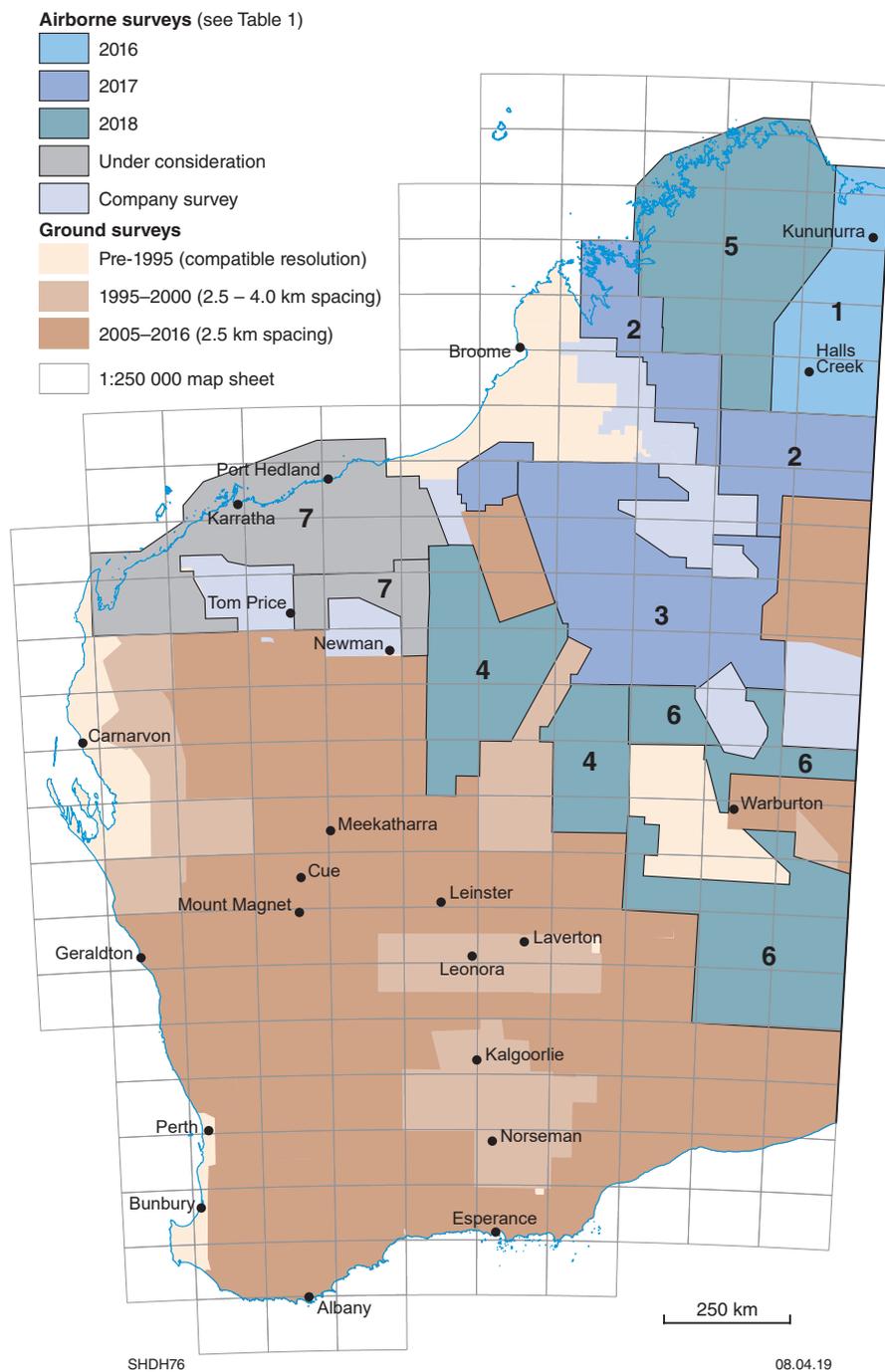


Figure 11. GSWA regional gravity survey coverage

ES31 Deep Seismic Survey Program

Manager: Ian Tyler

*Team members: Lucy Brisbout, Klaus Gessner, Ruth Murdie,
Huaiyu Yuan (Macquarie University)*

Integrated geophysical and geological transects across the West Australian, North Australian and South Australian Cratons and their margins in Western Australia, and the intervening Neoproterozoic and Phanerozoic basins, provide a key to the geological evolution of the Australian lithosphere over some four billion years of Earth's history. These transects also provide an understanding of the localization of mineral systems within the upper crust. In addition to collaborating with GA on the active source seismic acquisition, GSWA is collaborating with Macquarie University and UWA on passive source and MT surveys. These activities are described in detail in the GS62 3D Geoscience section of this document.

Deep seismic reflection data are usually acquired as line surveys along existing roads, wherever possible, to minimize costs, cultural and environmental impact and rehabilitation. Each seismic reflection survey line is sampled for gravity, and in some cases for MT, to provide additional information about large-scale structures to mantle depths.

Outcomes of work program 2017–18

The main activity in 2017–18 was the planning, and early stages of data acquisition of a deep crustal seismic survey across the remote Kidson Sub-basin of the Canning Basin. Acquisition commenced in June 2018. Planning also commenced for a high-resolution 2D seismic survey in the Eastern Goldfields.

Products released 2017–18

Report 177 Crustal and uppermost mantle structure of the east Albany–Fraser Orogen from passive seismic data

Planned work program and products 2018–19

Acquisition of deep crustal seismic data across the remote Kidson Sub-basin is scheduled to be complete by August 2018. The data acquisition and processing phases of a high-resolution 2D seismic survey in the Eastern Goldfields are planned. A supporting three-year research project using passive source seismic and MT imaging will commence in July 2018. This project is to be led by Michael Dentith (UWA) and will be supported by GSWA.

Products planned for release 2018–19

3D fault model of the northern Murchison

Capricorn Orogen passive array (Record)

Kidson deep seismic survey data (May 2019)

ES36 Participation in MinEx CRC

Acting manager: Catherine Spaggiari

Team members: Nadir de Souza Kovacs, Sara Jakica

ES36 is a new project 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. The CRC comprises three programs (Fig. 12) that are scheduled to commence in January 2019. GSWA is a participant in Program 3, the National Drilling Initiative (NDI).

Research in the three programs in MinEx CRC will include:

- 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, bringing forward mine production
- implementation of an NDI – a world-first collaboration of geological surveys, researchers and industry that will undertake drilling in underexplored areas of potential mineral wealth in Australia.

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

MinEx CRC Program 3

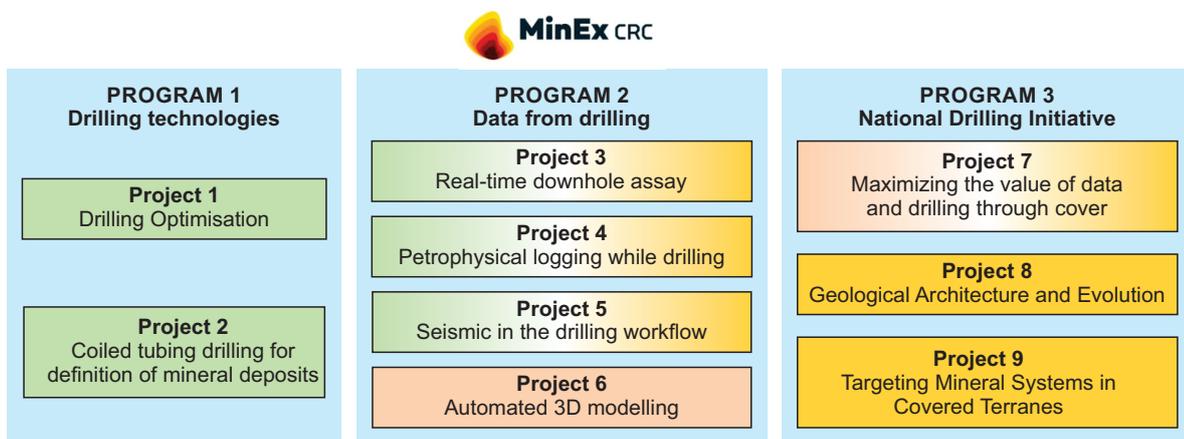
Program 3 comprises Projects 7, 8 and 9 (Fig. 12) that are designed to maximize the benefits of collaborative work across the geoscience research community, CSIRO, GA and geological survey organizations across Australia. The NDI vision is to drill multiple holes using new technologies developed by the 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 huge amount of new data and add value to existing data.

The aims of Project 7 maximizing the value of data and drilling through cover 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. to maximize 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 would result in significant efficiency gains and the ability to modify drilling programs in real time.

The main aim of Project 8 ‘Geological architecture and evolution’ is to provide new pre-competitive geoscience data in the NDI case study areas to increase data confidence and improve geological understanding. An improved understanding of 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.



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Figure 12. MinEx CRC Program outline

The aim of Project 9 ‘Targeting mineral systems in covered terranes’ 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 the 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. Focus will be on the region that underlies the Canning Basin, including the Officer and Amadeus Basins, and basement rocks of the Paterson and West Arunta Orogens, the far eastern edge of the Yilgarn Craton (Yamarna Terrane), and the Warri–Anketell Gravity Ridge, which appears to form a link between the Paterson Orogen and Musgrave Province. This work will align with other project work including GS64, GS56, GS10 and external collaborative projects through MRIWA.

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 and derivative maps on demand.

Outcomes of work program 2017–18

Outcomes 2017–18

Implement an online search tool that integrates with the WAROX database

Develop a new user interface for WAMEX

Enhance ENS to include regolith and mineral systems

Enhance geochemistry database (WACHEM) Stage 2

Redevelopment of Pubstats (publication management tool)

Upgrade WAPIMS to manage CO₂ reporting

Planned outcomes 2018–19

Planned outcomes 2018–19

Enhancements to Pubstats

Implement Mineral Systems Atlas

Implement CIMS

Upgrade GeoVIEW.WA Silverlight to HTML5 version

Section 40E reporting

ES43 Mineral Systems Atlas

Manager: Trevor Beardsmore

Team members: Lauren Burley, Paul Duuring, Josh Guilliamse, Sidy Morin-Ka, CET UWA, CODES, CSIRO, China Geological Survey

Under this program, GSWA has entered into research agreements with external groups or individuals to provide GIS-based exploration targeting products that effectively extol the potential of underexplored regions of Western Australia in easy-to-understand formats for geoscientists in the exploration industry. Many of these projects are managed or monitored by GSWA's Minerals Exploration Geoscience branch, and in some instances have received in-kind funding from the GS20 recurrent budget, but the majority of these minerals-oriented research projects have been partly to fully funded by the EIS.

Significant projects recently coming to a conclusion include:

- mineral prospectivity studies of the southwest Capricorn Orogen
- diamond prospectivity of Western Australia.

Outcomes of work program 2017–18

The mineral prospectivity analysis of the southeastern Capricorn Orogen, by UWA's CET, was near completion at the end of 2017–18, and the final report documenting the study is being prepared for release in 2018–19. Three GIS datasets with prospectivity models and toolboxes will also be released, as well as a new time–space correlation chart for the Capricorn Orogen.

Mark Hutchison completed a database and reports documenting diamond and diamond indicator mineral occurrences, geochemistry and prospectivity for Western Australia. This is the first major work on diamonds in Western Australia since the publication of GSWA Bulletin 132 (Jaques et al., 1986), and is of a similar style to the diamond prospectivity report for the Northern Territory (Hutchison 2012, NTGS Record 2012-001). Release of the Western Australian 'diamond' database and associated reports occurred in August 2017, at the 10th International Kimberlite Conference.

In a significant new initiative, the branch commenced work to create an interactive, GIS-based Mineral Systems Atlas, which will deliver 'mappable geological proxies' for critical metallogenic processes, that are derived from systematic 'mineral systems analyses' of known or probable mineral systems in Western Australia (see Project GS20 for more details).

Products released 2017–18

Report 179 Diamond exploration and prospectivity of Western Australia

Diamond exploration and prospectivity of Western Australia (2018) data package

Record 2017/16 Data methodologies applied in the Western Australian diamond exploration package

Record 2018/2 GSWA 2018 Extended Abstracts: promoting the prospectivity of Western Australia, contribution:
Diamond prospectivity of Western Australia: a major synthesis and review, p. 44–49,

Planned work program and products 2018–19

Most of the current portfolio of research projects are now, or soon will be, complete. Work programs related to these will largely focus on completing and releasing their respective Reports and datasets, including the final Report and three GIS datasets for the mineral prospectivity targeting work in the Capricorn Orogen.

The Minerals Exploration Geoscience branch will develop and release a prototype Mineral Systems Atlas that can inform GIS-based mineral prospectivity studies. This will include ongoing analysis of significant mineral systems in Western Australia to define 'mappable proxies' for critical metallogenic processes, and creation of additional statewide, digital 'proxy layers' derived from existing and enhanced or newly created datasets.

Products planned for release 2018–19

Prospectivity analysis of the Capricorn Orogen, Western Australia — using a mineral systems approach (provisional title) (Report)

Three GIS datasets with prospectivity models and toolboxes (Capricorn southern basins, Edmund–Collier Basins and Ashburton Basin)

Explanatory Report for Mineral Systems Atlas; plus other documentation

Testing LA-ICP-MS geochemistry of pyrite as a fertility and vectoring tool in exploration for orogenic gold and VMS deposits in Western Australia — CODES progress report, final Report and database (provisional title) (Reports and database)

Planned work program and products 2019–20

GSWA will negotiate new, relevant collaborative research projects, to be funded by the EIS.

The Minerals Exploration Geoscience branch will continue mineral systems analyses, to define geological 'proxies' for future development and addition to the Mineral Systems Atlas. The branch will also work in collaboration with the rest of the division to improve the geological databases that inform the content of the Mineral Systems Atlas.

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 program 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 (Fig. 13). 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.

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 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.

We are also studying the 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 the magma, all of which control its fertility for ore formation, and can be used as exploration indicators in remote or covered terrains.

Outcomes of work program 2017–18

Zircons from 76 dated samples were analysed for Lu–Hf isotopes during 2017–18, representing igneous, metamorphic and sedimentary rocks selected from the Youanmi Terrane of the Yilgarn Craton, the Albany–Fraser Orogen and the Kimberley region. Whole-rock powders for 93 samples were submitted in 2017–18 for Sm–Nd analysis, mainly from the Eastern Goldfields Superterrane, the Youanmi Terrane and the Kimberley region. Previously dated zircons from 56 samples were analysed for oxygen isotopes during 2017–18, mostly from granites of the Pilbara and Yilgarn Cratons and the Albany–Fraser Orogen. New isotope data are normalized to accepted GSWA standard values, checked for consistency, disseminated to GSWA projects and made publicly available online via GeoVIEW.WA, the GSWA Geochemistry (GeoChem Extract) web page, and within the annual compilation of geochronology information

released on USB. Isotope results so far have proven highly significant for understanding the crustal evolution of Western Australia, and feature prominently in GSWA publications and external journal articles.

New data have enabled further updates to isotope maps of the Yilgarn and Pilbara Cratons. The results highlight significant differences in crustal architecture between the western and eastern Pilbara Craton, and between the western and eastern Yilgarn Craton, indicating distinct geodynamics for the different regions in each case. In the eastern Pilbara Craton, limited addition of juvenile material and increased reworking of existing crust with time does not support a model of modern-style subduction prior to 3.2 Ga, but is consistent with vertical tectonic processes in a volcanic plateau-type setting. Data for the Yilgarn Craton continue to reinforce the idea of an older proto-craton in the west, and a younger, more primitive Eastern Goldfields Superterrane in the east.

Our comparison of 230 granites and 30 granite zircon samples from across the Yilgarn Craton with well-characterized copper-mineralized granites in southern Tibet indicates that many Yilgarn granites are less hydrous and more reduced than Phanerozoic mineralized granites. This research suggests that Archean high Sr/Y granites were formed mainly through partial melting of mafic lower crust in the garnet stability field, whereas Phanerozoic fertile, high Sr/Y granites were formed by amphibole-dominated fractionation of hydrous mafic magmas. Zircon trace element compositions for two causative granite samples from the c. 3.0 Ga Calingiri porphyry copper–molybdenum prospect in the South West Terrane imply that the mineralized Calingiri granites are more hydrous than non-mineralized Yilgarn granites. Zircon chemistry may hold the key to identifying Archean granite suites that are prospective for porphyry copper±molybdenum±gold mineralization, and this new technique may rejuvenate the prospectivity of typically weathered or covered Precambrian terranes.

A 2015–18 collaborative research project between GSWA and the Curtin University node of the CET was recently completed. This research aimed to integrate geochronology and isotope geology over a range of scales, to understand and predict the locations of metallogenesis. The project was highly successful, and generated two GSWA Reports and six refereed journal articles on topics as diverse as early Earth crust formation processes, isotope geology of hidden basement rocks beneath the Eucla Basin, isotopic characteristics of the Rudall Province, the Lu–Hf evolution of Archean crust, grain-size controls on isotopic resetting in titanite, and the use of lead isotopes in detrital feldspars to fingerprint sediment provenance.

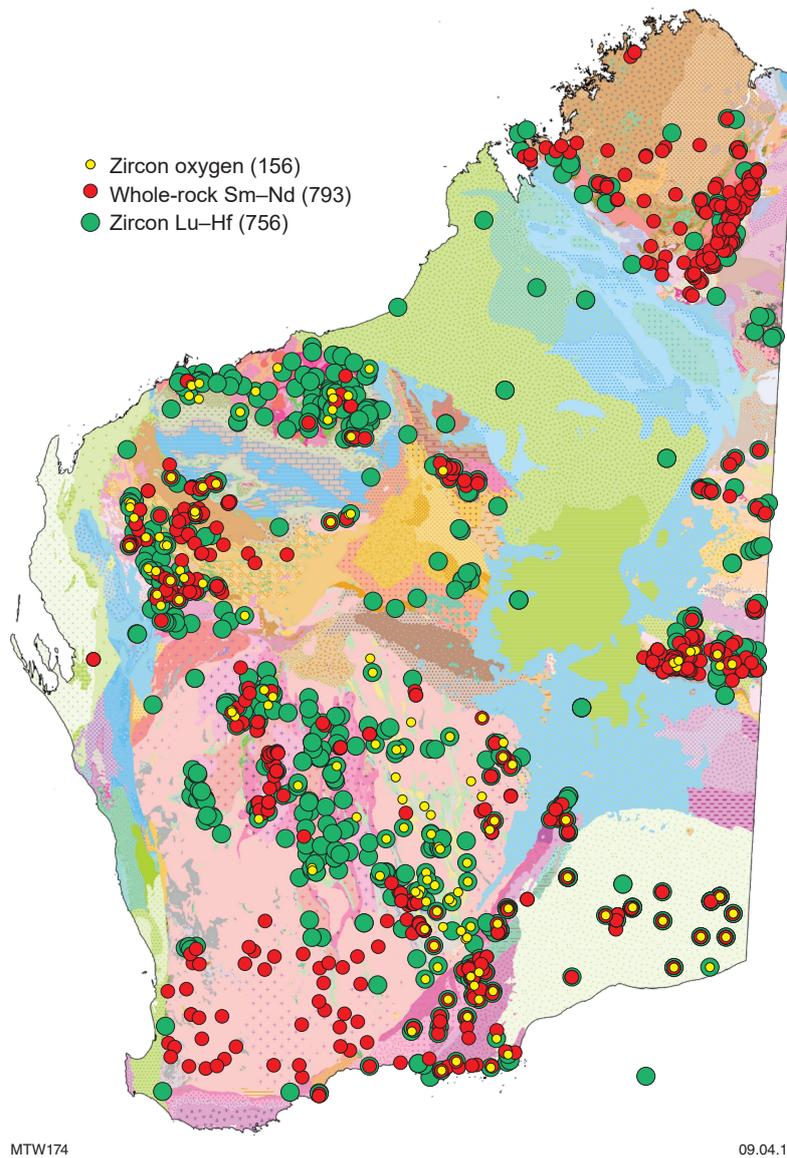


Figure 13. Locations of Lu–Hf, Sm–Nd and oxygen isotope samples up to June 2018

MRIWA project M448 Rutile – Pathfinder to Ores was completed in June 2018, and involved development of rutile protocols for metals exploration in Western Australia, and the construction of a database of rutile age and chemistry; the associated PhD project is not yet complete, although an interim report is anticipated. MRIWA project M446 Re–Os sulfide geochronology is continuing, and involves Re–Os isochron dating of sulfide minerals to determine precise ages for VMS zinc–lead–deposits and orogenic gold deposits. A 2016–19 MRIWA project, M470 Mineral systems on the margin of cratons: Albany–Fraser Orogen/Eucla basement case study, integrates Lu–Hf, Sm–Nd, oxygen and sulfur isotopes, U–Pb geochronology and whole-rock and mineral chemistry, to establish the timing, scale, and materials of lithosphere-scale mass transfer processes, and to highlight areas of enhanced mantle input within the eastern Albany–Fraser Orogen and adjacent Eucla basement rocks. Three PhD projects at Curtin University are focusing on crustal evolution, petrochronology, and sulfide sources and budgets, respectively.

Several smaller collaborative research projects have also been undertaken. A one-year pilot project on (U–Th)/He dating of duricrust samples from Boddington gold mine is complete, and the results have been published in a journal article and a GSWA Record is in prep. A project is underway to use Ar/Ar geochronology of pyroxene to date mafic and ultramafic igneous rocks that cannot be dated by other techniques. Although results so far hold promise, the work has experienced significant delays, owing to a temporary shutdown of the nuclear reactor in the US that is used for neutron irradiation of the samples. An exciting journal article is now in press, describing combined U–Pb, Ar/Ar and (U–Th)/He thermochronology that reveals several tectonothermal events between 715 and 200 Ma in the western Musgrave Province.

Products released 2017–18

Report 181 New Hf isotope insights into the Paleoproterozoic magmatic evolution of the Mount Edgar Dome, Pilbara Craton: implications for early Earth and crust formation processes

Record 2018/4 A new Mesoproterozoic mafic intrusive event in the Capricorn Orogen

Record 2018/10 Geochemistry of Archean granitic rocks in the South West Terrane of the Yilgarn Craton

Record 2018/2 GSWA 2018 extended abstracts: promoting the prospectivity of Western Australia, contributions:
Zircon composition as a fertility indicator of Archean granites, p. 18–23
Looking beneath the Canning Basin: new insights from geochronology, seismic and potential-field data, p. 30–33

Lu–Hf data released as part of the Compilation of geochronology information 2018

Lu–Hf, Sm–Nd, and trace element datasets released to online applications (GeoVIEW.WA and/or GeoChem Extract)

Seven external journal articles and 11 conference abstracts (see Appendix B)

Planned work program and products 2018–19

Analyses of Lu–Hf, Sm–Nd and oxygen isotopes will continue in 2018–19. Isotope data generated by this program will be checked for accuracy and consistency, provided to GSWA projects and published on the website as they become available. Existing and new zircon oxygen isotope data will be released for the first time in tabular 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 MT datasets, to advance our understanding of crustal architecture, geological evolution and mineralization. Syntheses will be published as GSWA Reports or Records and will inform other GSWA and external publications.

MRIWA project M446: Re–Os sulfide geochronology will continue acquisition of sulfide Re–Os and sericite Ar–Ar geochronology, and sulfide, osmium and lead isotopes will also be conducted to fingerprint metal sources. MRIWA project M470: Mineral systems on the margin of cratons will continue to acquire new hafnium, neodymium, oxygen and sulfur isotope data, and LA-ICP-MS trace element and U–Pb data from TIMA mounts and drillcore samples from the Albany–Fraser Orogen and Eucla basement.

A two-year collaborative research project on (U–Th)/He geochronology of secondary iron oxide minerals in duricrust will commence in 2018–19, to help understand the processes and timing of regolith formation (see GS64 Geoscience Mapping Through Cover).

New capabilities will be developed in the area of in situ geochronology and mineral chemistry by LA-ICP-MS and SHRIMP, including characterization of samples using a TIMA in the John de Laeter Centre at Curtin University and electron microprobe (EPMA) at the Centre for Microscopy and Microanalysis (CMCA) at UWA. The aim is to support studies of metamorphism and pressure–temperature–time (P–T–t) histories, by dating monazite, xenotime and other minerals, focusing initially on the King Leopold Orogen in the Kimberley, the South West Terrane of the Yilgarn Craton and the Albany–Fraser Orogen (see also GS53 Chief Geoscientist and Terrane Custodians).

An in-house geochronology and mineral chemistry database is being designed to store and provide access to geochronology, isotope, mineral chemistry and thermobarometric data. Information will be released to the public via GeoVIEW.WA, and will improve the ways in which data can be interrogated and downloaded (see also GS53 Chief Geoscientist and Terrane Custodians and GS54 Geochronology and Isotope Geology).

Products planned for release 2018–19

Lu–Hf, Sm–Nd and oxygen datasets released as part of the Compilation of geochronology information 2019

Lu–Hf, Sm–Nd and oxygen datasets released to online applications (GeoVIEW.WA and GeoChem Extract)

Zircon trace element datasets released to online applications

External journal articles, conference abstracts and contributions to GSWA publications

Planned work program and products 2019–20

The planned work program for 2019–20 and beyond will be similar to that for 2018–19. New samples for geochronology and isotope studies will be collected during the normal course of GSWA fieldwork to address specific geological problems.

ES47 Petroleum, Coal and CO₂ Geosequestration

Manager: Deidre Brooks

Team members: Norman Alavi, Heidi Allen, Iain Copp, Louisa Dent, Silvia Gamarra, Ameer Ghori, Peter Haines, Lorraine de Leuw, Sarah Martin, Arthur Mory, Leon Normore, Suzanne Simons, Charmaine Thomas, Yijie (Alex) Zhan

The objective of this program is to collect pre-competitive data to assist in determining Western Australia'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 Nambheet Formation
- improved correlation of conodont age dating with international time scales using new geochronology (CA-IDTIMS) 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 and has received wide acclaim from industry, academia and international geological surveys; a Digital Core Atlas for Theia 1 was released at the end of June 2018 and Senagi 1 Digital Core Atlas will be ready for release by the end of 2018–19 financial year.

Assessment of the parameters influencing reservoir quality in the Permian sandstones of the northern Perth Basin, particularly in the region of the significant Waitisia 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 that will provide new pre-competitive data and aim to improve the structural and stratigraphic definition of the Canning, Carnarvon and Perth Basins include:

- continued contribution to a project involving the acquisition of new passive seismic data in the Perth Basin (ES31) with results expected in 2018–19

- completion of the reprocessing of selected 2D seismic lines in the Kidson Sub-basin, Cobb Embayment and northwestern Canning Basin
- completion of the reprocessing of selected 2D seismic lines in the Southern Carnarvon Basin and the Coolcalalaya Sub-basin of the northern Perth Basin
- completion of a revised SEEBASE (depth to basement) product over the Carnarvon Basin by FrogTech
- planning for a possible joint DMIRS–GA stratigraphic well in the Kidson Sub-basin
- completion of a new regional 2D seismic survey, jointly funded by GA (funded through ES31) and GSWA across the Canning Basin structural elements of the Ryan Shelf, Kidson Sub-basin, Waukarlycarly Embayment, Anketell Shelf and southern tip of the Wallal Embayment; the seismic line also traverses the Paterson Orogen and Pilbara Craton.

Following on from seismic acquisition, stratigraphic drilling may be 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.

A project to document the coal resources of Western Australia is underway. The first two Records to be published in 2018–19 review the exploration history and estimated lignite resource volumes in both the southwest of Western Australia, including the Eucla Basin and the Mesozoic coal seams of the northern Perth Basin. Work is nearing completion on a Record that focuses on the coal resources of the Canning Basin.

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 the EIS. In addition, the Energy Geoscience and Carbon Strategy branch will continue to supply expertise and assistance to the program of collaborative work on the South West CO₂ Geosequestration Hub, which is managed by Dominique Van Gent (DMIRS). Digital Core Atlases for each of the four Harvey wells will be compiled during 2018–19.

Outcomes of work program 2017–18

Canning Basin

Some of the main activities and outcomes from studies in the Canning Basin in 2017–18 include the following:

- Acquisition of the Kidson Sub-basin seismic survey commenced in June 2018 and was completed in early August 2018. This survey consists of one deep crustal seismic line 872 km long, acquired along the existing road between the Kiwirrkurra community in the east and Marble Bar in the west.
- Reprocessing of selected 2D seismic lines in the Kidson Sub-basin, Cobb Embayment and northwestern Canning Basin commenced.
- GSWA continued participation in the collaborative core analysis project of the Lower Ordovician cored in Olympic 1 and Senagi 1, drilled by Buru Energy; and Theia 1, drilled by Finder Exploration in 2015. The core analysis is now complete and work on interpreting the results and incorporating the implications into the regional prospectivity assessment and geological framework of the Canning Basin is continuing into 2018–19.
- To support the collaborative core analysis project, a new interactive digital product has been developed during the last two years, known as the Digital Core Atlas. An atlas of all core included in the collaborative core analysis project will be compiled, with interactive links at each depth where analysis results have been received. The first atlas covered the core in Olympic 1 and was published during 2016–17. The Theia 1 Digital Core Atlas was released at the end of 2017–18 and work continues into the new financial year on compiling the core atlas for Senagi 1.
- GSWA Report 182 on the 2017 Canning Basin SEEBASE study and GIS digital data package was published.
- Work continued on a Record assessing the coal resources of the Canning Basin.

Carnarvon Basin

Some of the main activities and outcomes from studies in the Carnarvon Basin in 2017–18 include the following:

- A project to update the SEEBASE product over the Carnarvon Basin commenced.
- Reprocessing of selected 2D seismic lines in the Southern Carnarvon Basin and the Coolcalalaya Sub-basin of the northern Perth Basin commenced.

Eucla Basin

The main activity and outcome from studies in the Eucla Basin in 2017–18 is an assessment of the lignite resources of the Eucla Basin and southwest Western Australia; a record of the results of this project will be published in 2018–19.

Perth Basin

Some of the main activities and outcomes from studies in the Perth Basin in 2017–18 include the following:

- An assessment of the Mesozoic coal resources of the Perth Basin was completed. A Record of the results of this project will be published in 2018–19.
- A collaborative core analysis project with Mitsui (formerly known as AWE) on Permian sandstone reservoirs from the northern Perth Basin continued.

Products released 2017–18

Report 182 2017 Canning Basin SEEBASE study and GIS data package

Theia 1, Canning Basin, Digital Core Atlas

Planned work program and products 2018–19

Regional geological, geophysical and petroleum geochemical studies for the Canning, Perth and Carnarvon Basins will continue during 2018–19 and beyond, including EIS-funded studies for petroleum systems, coal and CO₂ geosequestration. These projects include the:

- completion of a review of significant coal resources of Western Australia within three discrete published 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 Waitisia Field wells drilled in the northern Perth Basin, and a petrophysical review of CO₂ geological storage potential of the reservoir quality units intersected in Olympic 1, Theia 1 and Senagi 1 in the Canning Basin
- completion and release of seismic reprocessing of legacy 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
- collaboration with GA on the completion of the acquisition a new 2D regional deep crustal seismic line across the Kidson Sub-basin, with completion of acquisition in August 2018; release of the processed data is anticipated to be in May 2019
- compilation of a Digital Core Atlas for each of the Harvey wells (1, 2, 3 and 4) in the Perth Basin
- completion of the SEEBASE product for the Carnarvon Basin.

Canning Basin

The planned outcomes from studies in the Canning Basin in 2018–19 are to:

- complete seismic reprocessing of and release vintage 2D seismic lines in the Kidson Sub-basin, Cobb Embayment and the northwest portion of the Canning Basin

- commence interpretation of the newly reprocessed 2D seismic lines in the Kidson Sub-basin, Cobb Embayment and the northwest portion of the Canning Basin
- complete the Digital Core Atlas for the Canning Basin petroleum well Senagi 1, which was included in the collaborative core analysis projects, with expected publication release in 2019–20
- continue to investigate regional correlations and hydrocarbon potential of the lower to middle Ordovician Goldwyer and Nambheet formations
- define the Nambheet Formation reference section and release a Record in 2019–20 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
- complete the assessment of the CO₂ sequestration potential of the Ordovician intersected in Theia 1 and Olympic 1, and the Devonian in Senagi 1 in the Canning Basin based on the results from the collaborative core analysis project and release a Record of the results in 2019–20
- complete compilation of and release a Record documenting the coal resources of the Canning Basin
- complete acquisition of a new 2D regional deep crustal seismic line along the Kiwirrkurra and Telfer Roads across the southern Canning Basin, Paterson Orogen and northern Pilbara Craton, in collaboration with GA with the aim of releasing processed results in May 2019.

Perth Basin

The planned outcomes from studies in the Perth Basin in 2018–19 are to:

- continue collaborative core analysis projects with Mitsui (formerly AWE) which has acquired core in Waitsia 3 within 2016–17, with results feeding into regional studies
- release a Record on the Mesozoic coal resources of the Perth Basin
- compile and release the Digital Core Atlas for each of the four Harvey wells
- review results obtained from a passive seismic traverse.

Southern Carnarvon Basin

The planned outcomes from studies in the Carnarvon Basin in 2018–19 are to:

- complete and release seismic reprocessing of vintage 2D seismic lines in the Southern Carnarvon Basin and the Coolcalalaya Sub-basin of the northern Perth Basin
- commence interpretation of the newly reprocessed 2D seismic lines and incorporate the results into a wider interpretation project to improve the definition of the stratigraphy and structure of the onshore portion of the basin
- complete and release the revised SEEBASE product over the Carnarvon Basin.

Products planned for release 2018–19

Digital Core Atlases, Harvey 1, 2, 3 and 4, Perth Basin (interactive digital products)

Mesozoic coal resources of the northern Perth Basin (Record)

Lignite resources of the Eucla/Bremer Basin (Record)

Release of new pre-competitive data: revised SEEBASE product over the Carnarvon Basin

Release of new pre-competitive data: new reprocessed vintage 2D seismic data in the Canning and Southern Carnarvon Basins and the Coolcalalaya sub-basin of the Perth Basin

Release of new pre-competitive seismic data: processed results of the Kidson Sub-basin seismic survey

ES50 Strategic Industry Research Program

Manager: Charlotte Hall

Team members: MRIWA and CSIRO

This program currently funds the expansion of research into greenfields exploration with funding support by the EIS to MRIWA of \$350 000 per annum since 2009–10. The types of projects that are sponsored by the EIS, and the sponsorship value that each project receives, is at the discretion of MRIWA.

At the beginning of July 2017 MRIWA projects that were supported directly or indirectly by EIS/GSWA and had been executed, or were already in progress are:

- **M424** Multiscale dynamics of hydrothermal mineral systems
- **M436** Distal footprints of giant ore systems: Capricorn Western Australia case study (indirect)
- **M446** 4D evolution of Western Australian ore systems (WA4D): Re–Os sulfide geochemistry
- **M448** 4D evolution of Western Australian ore systems (WA4D): rutile – pathfinder to ores
- **M462** Multiscaled near-surface exploration using ultrafine soils
- **M465** Deep crustal-scale structure, geological evolution and multi-commodity prospectivity analysis in the Halls Creek Orogen, Kimberley region, Western Australia (indirect)
- **M470** Mineral systems on the margin of cratons: Albany–Fraser Orogen/Eucla basement case study
- **M476** An integrated multiscale study of crustal structure and prospectivity of the eastern Yilgarn Craton and adjacent Albany–Fraser Orogen

Products 2017–18

No EIS sponsored projects were completed in 2017–18. However, projects close to completion include:

- **M488** – awaiting submission of a PhD Thesis, whereby it will be logged as complete
- **M462** – the final report was submitted near the end of the financial year and awaiting final sponsors meeting.

Projects accepted by the MRIWA board and requiring execution

- **M521** Lithospheric and crustal-scale controls on multi-stage basin evolution: impacts on mineralizing systems
- **M532** Geology, mineralogy and metallurgy of eMaterials deposits in Western Australia

(For a full list of GSWA collaborative projects, see Appendix C.)

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APPENDICES



Appendix A

GSWA maps, books and datasets released 2017–18

Geological maps

1:100 000 Geological Series maps

NINGHAN, WA Sheet 2339
by *TJ Ivanic*

1:250 000 Geological Series maps

LANSDOWNE, WA Sheet SE 52-5
by *C Phillips, D Maidment and N de Souza Kovacs*

MACDONALD, WA Sheet SF 52-14
by *PW Haines, N de Souza Kovacs, CV Spaggiari, GR Eacott and HJ Allen*

Non-series maps

Aboriginal land, conservation areas, mineral and petroleum titles and geology, Western Australia — 2018
by *KJ Ridge*

Energy infrastructure, 2018

Interpreted regolith–landform geology of the Ngururupa area, northeastern Western Australia
by *N de Souza Kovacs*

Major resource projects, Western Australia — 2018

Mines — operating and under development, Western Australia — 2018
by *RW Cooper, CA Strong, NL Wyche, LJ Day and JA Jones*

Resource projects, Goldfields region — 2017

Plates

Depths below mean sea level and surface — Top Precambrian basement, Base Grant-Reeves unconformity and Fitzroy Transpression unconformity
by *Y Zhan*

Isopach maps of pre-Permian and Permian strata
by *Y Zhan*

Two-way time and average velocity — Top Precambrian basement, Base Grant-Reeves unconformity and Fitzroy Transpression unconformity
by *Y Zhan*

Publications

Reports

- Report 173 The Liveringa Group, Canning Basin: correlating outcrop to subsurface
by *LM Dent*
- Report 174 A review of palynology from the Harvey region, southern Perth Basin, Western Australia
by *SK Martin*
- Report 176 Tectono-magmatic evolution of the Neoproterozoic Yalgoo dome (Yilgarn Craton): diapirism in a pre-orogenic setting
by *I Zibra, M Peternell, M Schiller, MTD Wingate and Y-J Lu*
- Report 177 Crustal and uppermost mantle structure of the east Albany–Fraser Orogen from passive seismic data
by *C Sippl, H Tkalcic, BLN Kennett, CV Spaggiari and K Gessner*
- Report 178 A seismic interpretation of the southwestern Canning Basin, Western Australia
by *Y Zhan*
- Report 179 Diamond exploration and prospectivity of Western Australia
by *M Hutchison*
- Report 181 New Hf isotope insights into the Paleoproterozoic magmatic evolution of the Mount Edgar Dome, Pilbara Craton: implications for early Earth and crust formation processes
by *N Gardiner, AH Hickman, CL Kirkland, Y-J Lu and TE Johnson*
- Report 182 2017 Canning Basin SEEBASE study and GIS data package
by *Frogtech Geoscience*
- Report 183 Metamorphosed Mesoproterozoic Cu-Mo-Ag mineralization: evidence from the Calingiri deposits, southwest Yilgarn Craton
by *MD Outhwaite*
- Report 185 The mapped stratigraphy and structure of the mining area C region, Hamersley province
by *DA Kepert*
- Report 186 Building the Archean continental crust: 300 Ma of felsic magmatism in the Yalgoo dome (Yilgarn Craton)
by *F Clos R Weinberg and I Zibra*
- Report 187 Detection and identification of rare earth elements using hyperspectral techniques
by *S Morin-Ka*

Records

- Record 2017/7 Towards a geochemical barcode for Eastern Goldfields Superterrane greenstone stratigraphy — preliminary data from the Kambalda–Kalgoorlie area
by *RH Smithies, PA Morris, S Wyche, M De Paoli and J Sapkota*
- Record 2017/8 The deep seismic reflection profile 11GA-Y01 in the west Musgrave Province: an updated view
by *R Quentin de Gromard, HM Howard, RH Smithies, MTD Wingate and Y Lu*
- Record 2017/9 Metamorphosed VMS mineralization at Wheatley, southwest Western Australia
by *LY Hassan*
- Record 2017/10 Alteration associated with the Austin–Quinns VMS deposits
by *LY Hassan*
- Record 2017/11 NW Biogeochemistry and Beyond Project
by *M Lintern, T Ibrahimi, T Pinchand and A Cornelius*
- Record 2017/12 Controls on hydrothermal alterations and gold mineralisation at Coyote deposit, Western Australia
by *H Roll*
- Record 2017/14 SGTSG 2017 Albany–Fraser Orogen pre-conference field trip: transect across an Archean craton margin to a Proterozoic ophiolite
by *R Quentin de Gromard, CV Spaggiari, M Munro, J Sapkota and M De Paoli*

- Record 2017/15 SGTSG mid-conference field trip guide: the western Nornalup Zone, Albany–Fraser Orogen, Western Australia
by N Timms
- Record 2017/16 Data methodologies applied in the Western Australian diamond exploration package
by M Hutchison
- Record 2017/17 SGTSG Denmark 2017 abstract volume: Biennial meeting of the Specialist Group in Tectonics and Structural Geology, Geological Society of Australia, 8–12 November 2017, Denmark, Western Australia
by MA Pearce
- Record 2018/2 GSWA 2018 extended abstracts: promoting the prospectivity of Western Australia
- Record 2018/3 Regolith chemistry of the Ngururrpa area, northeastern Western Australia
by PA Morris, N de Souza Kovacs and AJ Scheib
- Record 2018/4 A new Mesoproterozoic mafic intrusive event in the Capricorn Orogen
by OA Blay, SP Johnson, MTD Wingate, AM Thorne and CL Kirkland
- Record 2018/5 A petrographic and geochronological assessment of the gabbroic and metagabbroic rocks of the Fraser Zone, Albany–Fraser Orogen, Western Australia
by K Glasson
- Record 2018/6 SGTSG post-conference field trip guide: the Leeuwin Complex, Western Australia
by N Timms
- Record 2018/7 3rd Lithosphere workshop, 5–6 November 2017, The University of Western Australia
by W Gorczyk and K Gessner
- Record 2018/9 The tectonothermal evolution of a portion of the southern Fraser mobile belt, Western Australia
by JG Standing
- Record 2018/10 Geochemistry of Archean granitic rocks in the South West Terrane of the Yilgarn Craton
by RH Smithies, Y Lu, K Gessner, MTD Wingate and DC Champion

Non-series books

- Calendar 2018: Geological Survey of Western Australia
- Explanatory Notes of the Eastern Zone, Lamboo Province, Kimberley
- Fieldnotes: a Geological Survey of Western Australia newsletter 2017 July issue 83
- Fieldnotes: a Geological Survey of Western Australia newsletter 2017 October issue 84
- Fieldnotes: a Geological Survey of Western Australia newsletter 2018 January issue 85
- Fieldnotes: a Geological Survey of Western Australia newsletter 2018 April issue 86
- Geology of the Kennedy Range area
by AJ Mory and RM Hocking
- Structural Geology and Tectonics Specialist Group (SGTSG) program
- South West Hub Carbon Capture and Storage Project — Research Outcomes 2017

Datasets

Geological Information Series

- East Yilgarn, 2018 Geological Information Series
- Fortescue–Hamersley, 2018 Geological Information Series

Data packages

- 2017 Canning Basin SEEBASE study and GIS data package
by Frogtech Geoscience
- 2017 Conference of the Structural Geology and Tectonics Specialist Group of the Geological Society of Australia

Western Gawler Craton, 2017, 3D Geomodel Series
by RE Murdie, TW Wise, MJ Pawley and RA Dutch

Compilation of geochronology information, 2018

Compilation of HyLogger records, 2018

Diamond exploration and prospectivity of Western Australia

GSWA Open Day 2018

Merlinleigh Sub-basin, 2013, 3D Geomodel Series

Mount Brockman Syncline, 2006, 3D Geomodel Series

Petroleum Open Day, 2017

Record 2017/13 — Compilation of geophysical modelling records, 2017
by RE, Murdie and L, Brisbout

Theia 1, Canning Basin, Digital Core Atlas
by LS Normore, LM Dent and A Symonds

Western Australian Information for APPEA 2018, Adelaide

Posters

58 scientific posters

Appendix B

GSWA external publications on Western Australian geoscience 2017–18

- Aitken, ARA, Occhipinti, SA, Lindsay, MD, Joly, A, **Howard, HM, Johnson, SP**, Hollis, J, **Spaggiari, C, Tyler, IM**, McCuaig, TCM and Dentith, MC 2018, The tectonics and mineral systems of Proterozoic Western Australia: relationships with supercontinents and global secular change: *Geoscience Frontiers*, v. 9, p. 295–316.
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- He, W, Yang, L, **Lu, Y-J**, Jeon, H, Xie, S and Gao, X 2018, Zircon U–Pb dating, geochemistry and Sr–Nd–Hf–O isotopes for the Baimaxueshan granodiorites and mafic microgranulars enclaves in the Sanjiang Orogen: evidence for westward subduction of Paleo-Tethys: Gondwana Research, vol. 62, p. 112–126, doi:10.1016/j.gr.2018.03.011.
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Appendix C

GSWA collaborative research projects (current and historic) — 30 June 2018

Current projects

Current state of knowledge on the Mesozoic of Western Australia

Project Manager: Deidre Brooks

Partner researchers/institutions: Curtin University

GSWA contact: Don Flint

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 WA unearthed series.

Outputs — planned or actual

Publication as part of the WA unearthed booklet series

Seismic acquisition using distributed acoustic sensing in an urban environment

Project Manager: Prof Mike Dentith

Partner researchers/institutions: UWA

GSWA contact: Dr Klaus Gessner

Duration of project: 2017–18

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 as a comparative study that aims to demonstrate that instead of using seismic instruments, seismic monitoring can be undertaken using existing fibre-optic cable infrastructure. Distributed acoustic sensing is an emerging technology for seismic wavefield measurement that relies on conventional optical fibre cables to create 'virtual' strain-rate sensors at every few metres along the cable.

Outputs — planned or actual

GSWA Report

Ar/Ar dating of pyroxene

Project Manager: Dr Michael Wingate

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

GSWA contact: Dr Michael Wingate

Duration of project: 2017–19

Project description

This collaborative project aims 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)



Oxygen isotope analyses of zircons**Project Manager:** Dr Michael Wingate**Partner researchers/institutions:** UWA/CMCA**GSWA contact:** Dr 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)

Earth composition and evolution — preservation of legacy collections**Project Manager:** Prof Brent McInnes**Partner researchers/institutions:** John de Laeter Centre, Curtin University**GSWA contact:** Dr Michael Wingate**Duration of project:** Ongoing**Project description**

This project's objective is to secure, digitize and make publicly available the physical specimens and associated data records in the McNaughton SHRIMP sample mount collection.

Outputs — planned or actual

Report of number of physical samples archived in the collection

Report against the number of sample records uploaded into data portals and repositories

MinEx CRC (20170070)**Project Manager:** Dr Ian Tyler**Partner researchers/institutions:** Multicollaborative project**GSWA contact:** Dr Ian Tyler**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.

Outputs — planned or actual

TBD

ARC linkage project LP170100985: Enabling 3D stochastic geological modelling (LOOP)**Project Manager:** Dr Klaus Gessner**Partner researchers/institutions:** Monash University**GSWA contact:** Dr Klaus Gessner**Duration of project:** 3 years (2018–21)**Project description**

We will develop a new open-source '3D implicit geo-structural 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

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

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

Outputs — planned or actual

Co-branded GSWA Reports and Records

***MRIWA project 521: Lithospheric and crustal-scale controls on multistage basin evolution: impacts on mineralizing systems*****Project Manager:** Dr Weronika Gorczyk and Prof Mark Jessell**Partner researchers/institutions:** MRIWA (UWA / First Quantum Minerals / Fortescue Metals Group)**GSWA contact:** Dr Catherine Spaggiari**Duration of project:** 2018–22**Project description**

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

Outputs — planned or actual

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

***ARC Linkage project LP130100722: Earth’s best-preserved Archean boninites: do they finally resolve the Archean mantle plume–plate controversy?*****Project Manager:** A/Prof Derek Wyman (University of Sydney)**Partner researchers/institutions:** Jack Lowrey (PhD candidate, University of Sydney; GSWA)**GSWA contact:** Dr Tim Ivanic**Duration of project:** 2014–18**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.

MRIWA project M446: 4D evolution of Western Australian ore systems: Re–Os sulfide geochronology**Project Manager:** Prof Neal McNaughton**Partner researchers/institutions:** Prof Neal McNaughton, Dr Svetlana Tesselina, Dr Fred Jourdan, Vitor Barrote (PhD candidate) (John de Laeter Centre, Curtin University); Thermo Fisher Scientific**GSWA contact:** Dr Michael Wingate**Duration of project:** 2016–19**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 the 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:** Prof Neal McNaughton**Partner researchers/institutions:** Prof Neal McNaughton, A/Prof Noreen Evans, Dr Fred Jourdan, Jennifer Porter (PhD candidate) (John de Laeter Centre, Curtin University); Independence Group NL**GSWA contact:** Dr Michael Wingate**Duration of project:** 2015–18**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 the 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 and 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

ARC Centre of Excellence CE11E0070: core to crust fluid systems**Project Manager:** Prof Suzanne O'Reilly (Macquarie University)**Partner researchers/institutions:** Prof Simon Wilde (Curtin University), Prof Campbell McCuaig (CET, UWA), A/Prof Chris Kirkland (CET, Curtin), Dr Huaiyu Yuan (Macquarie University, CET)**GSWA contacts:** Dr Ian Tyler, Dr Klaus Gessner, Dr 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.

Hollis, JA, Kemp, AIS, Tyler, IM, Kirkland, CL, Wingate, MTD, Phillips, C, Sheppard, S, Belousova, E and Greau, Y 2014, Basin formation by orogenic collapse: Zircon U–Pb and Lu–Hf isotope evidence from the Kimberley and Speewah Groups, northern Australia: Geological Survey of Western Australia, Report 137, 46p.

Hollis, JA, Kirkland, CL, Spaggiari, CV, Tyler, IM, Haines, PW, Wingate, MTD, Belousova, EA and Murphy, RC 2013, Zircon U–Pb–Hf isotope evidence for links between the Warumpi and Aileron Provinces, west Arunta region: Geological Survey of Western Australia, Record 2013/9, 30p.

Ivanic, TJ, Van Kranendonk, MJ, Kirkland, CL, Wyche, S, Wingate, MTD and Belousova, EA 2013, Juvenile crust formation and recycling in the northern Murchison Domain, Yilgarn Craton: evidence from Hf isotopes and granite geochemistry: Geological Survey of Western Australia, Report 120, 34p.

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.

Kirkland, CL, Johnson, SP, Smithies, RH, Hollis, JA, Wingate, MTD, Tyler, IM, Hickman, AH, Cliff, JB, Belousova, EA, Murphy, RC and Tessalina, S 2013, The crustal evolution of the Rudall Province from an isotopic perspective: Geological Survey of Western Australia, Report 122, 30p.

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, Tessalina, 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, Perth, WA, 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.

Mapping sulfur sources in selected Precambrian terranes of Western Australia to enhance predictive targeting for gold and base metal mineralization

Project Manager: A/Prof Marco Fiorentini

Partner researchers/institutions: CET, UWA

GSWA contact: Dr Trevor Beardsmore

Duration of project: 2014–17

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



Geological studies of gabbroic rocks intruding the Arid Basin in the Albany–Fraser Orogen**Project Manager:** Dr Tim Johnson**Partner researchers/institutions:** A/Prof Chris Clark, A/Prof Chris Kirkland (Curtin University)**GSA contact:** Dr 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
- to compare these to the metamorphic P–T of the sedimentary rocks (i.e. Snowys Dam Formation) of the Fraser Zone
- to 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).

K–Ar dating of fault rocks**Project Manager:** Dr Huntly Cutten**Partner researchers/institutions:** Horst Zwingmann (Kyoto University); Tonguc Uysal, Andrew Todd (ARRC, CSIRO)**GSA contact:** Dr Huntly Cutten, Dr Michael Wingate**Duration of project:** 2015–18**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; GSA 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.

Crustal evolution of Western Australia**Project Manager:** A/Prof Chris Kirkland**Partner researchers/institutions:** Curtin University**GSA contact:** Dr Michael Wingate**Duration of project:** 2015–18**Project description**

The project aims are:

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

Outputs

- co-branded GSA 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.

Paleoproterozoic mafic magmatism of the Kimberley Basin, Western Australia



Project Manager: Dr David Maidment

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

GSWA contact: Dr David Maidment

Duration of project: 2012–15 (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, Perth, 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.

Narryer Terrane isotopes project

Project Manager: Stephen Wyche

Partner researchers/institutions: Prof Tony Kemp (UWA)

GSWA contact: Stephen Wyche

Duration of project: 2012–16

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.

MRIWA project M470: Mineral systems on the margin of cratons: Albany–Fraser Orogen / Eucla basement case study

Project Manager: A/Prof Chris Kirkland

Partner researchers/institutions: A/Prof Chris Kirkland, A/Prof Chris Clark, Dr Katy Evans, Prof 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.
- Sulfides 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

Structural and metamorphic evolution of the east Albany–Fraser Orogen

Project Manager: Dr Catherine Spaggiari

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

GSWA contact: Dr 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, v. 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.

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

Procedural publications

Linkswww.dmp.wa.gov.au/hylogger***Metamorphic history of the Mougooderra Formation, Yilgarn Craton, Western Australia*****Project Manager:** Chris Yakymchuk**Student:** Stacey Parmenter**Partner researchers/institutions:** University of Waterloo**GSWA Contact:** Dr Tim Ivanic, Dr Fawna Korhonen**Project Duration:** 2016–18**Project description**

Using existing and new GSWA samples in the NINGHAN 1:100 000 map sheet area, the study aims to discriminate between contact and regional metamorphism around granitic domes and plutons. Petrography and THERMOCALC modelling will provide constraints on the nature of metamorphic recrystallization of sedimentary rocks of the Mougooderra Formation. New garnet hafnium and neodymium isotopic dating of these samples will help to constrain the timing of metamorphism relative to dated granitic rocks.

Outputs — planned or actual

Masters thesis published as GSWA Record (2019)

Current projects with Geoscience Australia: National Collaboration Framework (NCF) activities

Project manager: Dr Ian Tyler

Partner researchers/institutions: Geoscience Australia

GSWA contact: Dr Ian Tyler, Don Flint

Duration of project: ongoing

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

EXPLORATION
INCENTIVE
SHEME

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

EXPLORATION
INCENTIVE
SHEME

Australian National Virtual Geophysical Laboratory (CMCG4003A-001388)

EXPLORATION
INCENTIVE
SHEME

Canning Basin CO₂ storage project (CMCG4003A-PA6)

EXPLORATION
INCENTIVE
SHEME

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

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

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

EXPLORATION
INCENTIVE
SHEME

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

EXPLORATION
INCENTIVE
SHEME

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

COMPLETED PROJECTS

The distal footprints of giant ore systems: UNCOVER Australia project



Project Manager: Dr Rob Hough (CSIRO)

Partner researchers/institutions: Prof Campbell McCuaig (CET/UWA), Prof Steven Reddy (Curtin)

GSWA contact: Dr Ian Tyler, Dr Simon Johnson

Duration of project: 2013–17

Project description

This project commenced in August 2013 and aims to begin to address the key technical risks impeding future greenfields exploration. It is a collaboration between CSIRO, UWA (through the CET), Curtin University and GSWA, in partnership with approximately 10 junior and one major exploration company. The project aligns with the Australian Academy of Sciences UNCOVER initiative to boost exploration geoscience research in Australia, and the federal government's National Exploration Strategy UNCOVER Australia Project (RP04-063).

Outputs

Co-branded GSWA/CSIRO/MRIWA reports

MRIWA Project M462: Multiscaled near-surface exploration using ultrafine soils



Project Manager: Ryan Noble

Partner researchers/institutions: Ryan Noble (CSIRO)

GSWA Contact: Dr Paul Morris

Duration of project: 2016–18

Project description

The project aims to greatly refine analytical methods and enhance surface exploration success with sampling and analysing micro and nano particulate metals and fine particle size fractions in local site orientation surveys as well as broad regional sample sets in Australia (Yamarna greenstone belt, Paterson Province and northeast Yilgarn margins and northern Yandal edge). Samples from previous orientation surveys from CSIRO, industry and previous or current regional soil surveys (GSWA or industry) will be subject to a variety of size separation analyses and assessed in relation to other physical (e.g. texture), mineralogical (e.g. iron oxides, kaolinite), biological (e.g. organic carbon) and chemical (e.g. pH, electrical conductivity) properties of the samples. Microparticulate and nanoparticulate metals will be characterized and assessed with respect to known mineralization to understand mobility in a landscape evolution context.

Outputs

Peer-reviewed journal papers; conference proceedings; MRIWA/CSIRO/GSWA Report

Evolution of the Fraser Zone, Albany–Fraser Orogen: implications for Ni–Cu sulfide potential

Project Manager: Dr Catherine Spaggiari

Partner researchers/institutions: Wolfgang Maier (Cardiff University), Oliver Kiddie (Creasy Group), A/Prof Chris Kirkland and Dr Katy Evans (Curtin University), Steve Barnes (CSIRO)

GSWA contact: Dr Catherine Spaggiari

Duration of project: Ongoing

Project description

Assessment of the petrogenesis of mafic and ultramafic rocks of the Fraser Zone, sulfur transport and isotope studies, with links to basin evolution, metamorphism and structure. Only the southern third of the highly prospective Fraser Zone is exposed, so this project utilizes company-donated drill cores to map the Fraser Zone under cover, and examine host rock relationships to the Nova–Bollinger nickel–copper deposit.

Outputs

Maier, WD, Smithies, RH, Spaggiari, CV, Barnes, S-J, Kirkland, CL, Kiddie, O and Roberts, MP 2016, The evolution of mafic and ultramafic rocks of the Mesoproterozoic Fraser Zone, Albany–Fraser Orogen, and implications for Ni–Cu sulfide potential of the region: Geological Survey of Western Australia, Record 2016/8, 49p.

Maier, WD, Smithies, RH, Spaggiari, CV, Barnes, SJ, Kirkland, CL, Yang, S, Lahaye, Y, Kiddie, O and MacRae, C 2016, Petrogenesis and Ni–Cu sulphide potential of mafic–ultramafic rocks in the Mesoproterozoic Fraser Zone within the Albany–Fraser Orogen, Western Australia: Precambrian Research, v. 281, p. 27–46, doi:10.1016/j.precamres.2016.05.004.

Albany–Fraser magnetotelluric survey**Project Manager:** Dr Ian Tyler**Partner researchers/institutions:** Prof Mike Dentith (CET, UWA)**GSWA contact:** Dr Catherine Spaggiari**Duration of project:** 2011–15**Project description**

Acquisition and interpretation of deep crustal MT data, as well as 3D data modelling in the east Albany–Fraser Orogen.

Outputs

Spaggiari, CV and Tyler, IM (compilers) 2014, Albany–Fraser Orogen seismic and magnetotelluric (MT) workshop 2014: Extended abstracts: Geological Survey of Western Australia, Record 2014/6 (preliminary edition).

Spratt, J, Dentith, M, Evans, S, Spaggiari, CV, Gessner, K and Tyler, IM 2015, A magnetotelluric survey across the Albany–Fraser Orogen and adjacent Yilgarn Craton, southwestern Australia, *in* Albany–Fraser Orogen seismic and magnetotelluric (MT) workshop 2014 *edited by* CV Spaggiari and IM Tyler: Geological Survey of Western Australia, Record 2014/6, p. 7–11.

ARC linkage project LP 140100267: Reducing 3D geological uncertainty via improved data interpretation methods**Project Manager:** Prof Mark Jessell (CET, UWA)**Partner researchers/institutions:** Prof Eun-Jung Holden (CET, UWA)**GSWA contact:** Dr Klaus Gessner**Duration of project:** 2013–17**Project description**

Reducing 3D geological uncertainty via improved data interpretation methods is an ARC-funded collaborative project focusing on the quantification of errors and uncertainties in geological modelling, and the development of the Integrated Exploration Platform, a GIS-plugin that applies advanced visualization techniques to geophysical data.

Outputs

Integrated Exploration Platform application via the CET website; Co-branded GSWA Records and Reports

Centre for Exploration Targeting, Integrated Exploration Platform: Centre for Exploration Targeting, University of Western Australia, Perth, <www.waexplorationplatform.wa.edu.au>.

Holden, E, Wedge, D, Nathan, D, Horrocks, T and Wong, JC 2016, Human, machine and data: data analytics for mineral explorers, *in* GSWA 2016 extended abstracts: promoting the prospectivity of Western Australia: Geological Survey of Western Australia, Record 2016/2, p. 12–14.

Wong, JC, Holden, E, Kovesi, P, Gessner, K and Murdie, RE 2016, Integrated Exploration Platform v2.5: an innovative visual analytics plug-in for ESRI ArcGIS: Geological Survey of Western Australia, Record 2016/3, 37p.

Wong, JC, Holden, E, Kovesi, P, Wedge, D, Nathan, D, Gessner, K and Murdie, RE 2016, Integrated Exploration Platform: software tools for multidata visualization and integrated interpretation, *in* GSWA 2016 extended abstracts: promoting the prospectivity of Western Australia: Geological Survey of Western Australia, Record 2016/2, p. 15–17.

Structure and physical properties of Archean granulites and fault rocks**Project Manager:** Dr Jie Liu**Partner researchers/institutions:** Dr Jie Liu, Prof Klaus Regenauer-Lieb (School of Earth and Environment, UWA)**GSWA contact:** Dr Klaus Gessner**Project Duration:** 2013**Project description**

Understanding the microstructure and physical properties of Archean granulites and fault rocks will help to better understand recently acquired seismic reflection data in the northern Yilgarn Craton and across the Youanmi Terrane – Eastern Goldfields Superterrane boundary. The work includes processing of synchrotron radiation-based X-ray micro-computed tomography to characterize a number of rock samples, including rare occurrences of granulite facies metamorphic rocks and brittle fault rocks of Archean age that may represent the oldest known products of earthquakes on Earth.

Outputs

Gessner, K, Zibra, I, Liu, J, Paesold, M, Toy, V, Xiao, X, Regenauer-Lieb, K and Menegon, L 2014, Using Synchrotron X-ray microtomography to image structure and porosity in sheared Neoproterozoic granite, Yilgarn Craton, Western Australia, Abstract No. 110, 22nd Australian Geological Convention: Geological Society of Australia; 2014 Australian Earth Sciences Convention (AESC), Newcastle, 7–10 July 2014, p. 151–152.

Eucla–Gawler seismic, gravity and magnetotelluric survey

Project Manager: Dr Catherine Spaggiari

Partner researchers/institutions: GA, GSSA, AuScope Earth Imaging

GSWA contact: Dr Catherine Spaggiari

Duration of project: 2014–17

Project description

Acquisition, processing and interpretation of the 870 kilometre-long deep crustal reflection seismic line 13GA-EG1, from the Madura Province in Western Australia to the Gawler Craton in South Australia. This line is a continuation of seismic line 12GA-AF3.

Outputs

Release of processed data (Western Australian component) at GSWA 2016 Open Day, February 2016:

Holzschuh, J 2015, L203 Eucla Gawler deep crustal reflection seismic survey, WA & SA 2013-14: Geoscience Australia, digital data product, <www.ga.gov.au/metadata-gateway/metadata/record/89637>.

Joint public release by GSWA, GSSA and GA of all acquired data and interpretation for entire Eucla–Gawler Survey as a range of abstracts and posters:

Exposing the Nullabor (session) *in* Uncover Earth's past to discover our future: Australian Earth Sciences Convention (AESC), 26–30 June 2016, Geological Society of Australia, <www.dmp.wa.gov.au/euclagawler>.

Co-branded GSWA/GSSA/GA non-series map (released GSWA open day 2017) and Report 177:

Sippl, C, Tkalčić, H, Kennett, BLN, Spaggiari, CV and Gessner, K 2018, Crustal and uppermost mantle structure of the east Albany–Fraser Orogen from passive seismic data: Geological Survey of Western Australia, Report 177, 51p.

Spaggiari, CV, Dutch, RA, Doublier, MP, Pawley, MJ, Thiel, S, Wise, TW, Kennett, BLN, Gessner, K, Smithies, RH, Holzschuh, J and Clark, DJ 2017, Geological interpretation of the Madura and Coompana Provinces along the Eucla–Gawler seismic and magnetotelluric line 13GA-EG1 (1:500 000 scale): Geological Survey of Western Australia, non-series map.

ARC linkage project LP130100413: Craton modification and growth: the East Albany–Fraser Orogen in 3D

Project Manager: Dr Catherine Spaggiari



Partner researchers/institutions: Dr Christian Sippl, A/Prof Hrvoje Tkalčić, Prof Brian Kennett (ANU)

GSWA contact: Dr Catherine Spaggiari

Duration of project: 2013–16

Project description

This is an ARC-funded collaborative project with the Seismology and Mathematical Geophysics research group at ANU's Research School of Earth Sciences. To delineate the 3D structure of the east Albany–Fraser Orogen and the lithospheric structure below, an array of passive seismic stations, the Albany–Fraser Experiment (ALFREX), is deployed from 2013–16 across the boundary of the Yilgarn Craton and the Albany–Fraser Orogen.

Outputs

Conference proceedings; GSWA Report 177; peer-reviewed journal papers

Sippl, C, Tkalčić, H, Kennett, BLN, Spaggiari, CV, Gessner, K, Brisbourn, LJ and Murdie, R 2018, Crustal and uppermost mantle structure of the east Albany–Fraser Orogen from passive seismic data: Geological Survey of Western Australia, Report 177, 51p.

Sippl, C, Kennett, BLN, Tkalčić, H, Spaggiari, C and Gessner, K 2016, New constraints on the current stress field and seismic velocity structure of the eastern Yilgarn Craton from mechanisms of local earthquakes: Australian Journal of Earth Sciences, v. 62, no. 8, p. 921–931.

Sipl, C, Kennett, BLN, Tkalčić, H, Gessner, K and Spaggiari, CV, 2017, Crustal surface-wave velocity structure of the east Albany–Fraser Orogen, Western Australia, from ambient noise recordings: *Geophysical Journal International*, v. 210, no. 3, p. 1641–1651.

Sipl, C, Brisbout, LJ, Spaggiari, CV, Kennett, BLN, Tkalčić, H, Murdie, R and Gessner, K 2017, Crustal structure of a Proterozoic craton boundary: East Albany–Fraser Orogen, Western Australia, imaged with passive seismic and gravity anomaly data: *Precambrian Research*, v. 296, p. 78–92.

Narryer Terrane structural project

Project Manager: Stephen Wyche

Partner researchers/institutions: Cees Passchier (University Mainz, Germany)

GSWA contact: Ivan Zibra

Duration of project: 2014–16

Project description

This project involves detailed mapping of structure and metamorphism in the southern part of the Narryer Terrane, adjacent to the Murchison Domain of the Youanmi Terrane.

Outputs

GSWA report and external papers

Murchison quartz crystal preferred orientation project

Project Manager: Stephen Wyche

Partner researchers/institutions: Dr Mark Peternell (Johannes Gutenberg University, Mainz, Germany)

GSWA contact: Ivan Zibra

Duration of project: 2013–15

Project description

This project involves quartz crystal preferred orientation studies in Murchison shear zones. GSWA to contribute with thin sections and analyses.

Outputs

GSWA report and external papers

Schiller, M 2016, Microstructural evolution of the Yalgoo Dome (Western Australia): *Geological Survey of Western Australia, Record 2016/5*, 83p.

West Yilgarn Craton metamorphic project

Project Manager: Stephen Wyche

Partner researchers/institutions: Dr Ben Goscombe (ITAC)

GSWA contact: Stephen Wyche

Duration of project: 2008–17

Project description

Extension of the East Yilgarn metamorphic project commenced during the predictive mineral discovery Cooperative Research Centre (pmd*CR). This project will document metamorphic patterns and event histories across the Yilgarn Craton. Dr Goscombe will supply a range of data including geochronology, microprobe data, petrographic information, imagery, maps and reports.

Outputs

This project produced a very large volume of interpreted metamorphic P–T data, many with specific age constraints, and an extensive range of metamorphic mineral assemblage descriptions. Collectively, these data will form the basis for a metamorphic map of the Yilgarn Craton.

Yalgoo dome structural project, Monash University**Project Manager:** Roberto Weinberg**Partner researchers/institutions:** Monash University**GSWA contact:** Dr Ivan Zibra**Duration of project:** 2013–15**Project description**

The Monash-based PhD and honours projects are designed to provide original contributions. They will include components of both field and laboratory/office work. The field activities will be mainly focused on detailed structural mapping in key domains of the Yalgoo dome, with the aim of producing an ideal structural cross-section through the dome to constrain its 3D architecture and evolution through time. The structural work will be augmented by sampling directed at microstructural, geochemical, petrological and geochronological investigations.

Outputs

Caudery, JN 2014, Structural evolution of the Yalgoo Dome, Yilgarn Craton, Western Australia: Geological Survey of Western Australia, Record 2014/4, 89p.

Fenwick, MJ 2014, Structural evolution of the Yalgoo Dome, Yilgarn Craton, Western Australia: a core perspective: Geological Survey of Western Australia, Record 2014/16, 93p.

Yalgoo dome structural project, Macquarie University**Project Manager:** Sandra Piazzolo**Partner researchers/institutions:** Macquarie University**GSWA contact:** Dr Ivan Zibra**Duration of project:** 1 year**Project description**

A Macquarie-based masters project designed to examine structures and field relationships in the Yalgoo dome.

Outputs

Master of Science thesis to be published as a GSWA Record:

Tomkins, AE 2015, Tectonite type: their formation and significance, map production, field relationships and petrography: Geological Survey of Western Australia, Record 2015/4, 113p.

ARC linkage project LP130100922: Chronostratigraphic and tectonothermal history of the northern Capricorn Orogen: providing a framework for understanding mineralizing systems**Project Manager:** Prof Birger Rasmussen**Partner researchers/institutions:** Prof Birger Rasmussen, Dr Janet Muhling, Nishka Piechocka, Imogen Fielding (Curtin University)**GSWA contact:** Dr Simon Johnson**Duration of project:** 2014–17**Project description**

This project combines innovative geochronology with targeted field mapping to date sedimentary successions, metamorphic events, crustal fluid flow and hydrothermal mineralization along the recently acquired Capricorn seismic transect. The construction of a new and improved geological framework linked to deep seismic information has the potential to provide breakthroughs in our understanding of the history of this long-lived orogen and the ore deposits that it contains. The outcomes will identify the major structures and tectonic events controlling mineralization, underpinning the generation of successful exploration models.

Outputs

PhD theses; GSWA geochronology records; co-branded GSWA Reports and international journal papers

Fielding, IOH, Johnson, SP, Zi, J-W, Rasmussen, B, Muhling, JR, Dunkley, DJ, Sheppard, S, Wingate, MTD and Rogers, JR 2017, Using in situ SHRIMP U–Pb monazite and xenotime geochronology to determine the age of orogenic gold mineralization: An example from the Paulsens mine, southern Pilbara Craton: *Economic Geology*, v. 112, p. 1205–1230.

Piechocka, AM, Gregory, CJ, Zi, J-W, Sheppard, S, Wingate, MTD and Rasmussen, B 2017, Monazite trumps zircon: applying SHRIMP U–Pb geochronology to systematically evaluate emplacement ages of leucocratic, low-temperature granites in a complex Precambrian orogen: *Contributions to Mineralogy and Petrology*, v. 172:63, no. 8, 17p.

Stratigraphic contact analysis tool**Project Manager:** Prof Mark Jessell**Partner researchers/institutions:** Prof Mark Jessell, Dr Vitaliy Ogarko (3D Uncertainty Group, CET, UWA).**GSWA contact:** Dr Ian Tyler**Duration of project:** 2016–17**Project description**

Development of a tool that will allow GSWA to better analyse the stratigraphic relationships inferred in arbitrary geographic subsets of current GSWA digital map products, by way of topological analysis of the mapped relationships. This will provide GSWA with the ability to assess the local relationship between formations and groups in a graphical form, and to compare these to textual ENS content.

Outputs

Standalone software to analyse stratigraphic and fault relationships directly from GSWA digital maps; GSWA Report

NW biogeochemistry project – NW Yilgarn biogeochemistry and beyond**Project Manager:** Dr Mel Lintern**Partner researchers/institutions:** Dr Mel Lintern (CSIRO)**GSWA contact:** Dr Paul Morris**Duration of project:** 2015–16**Project description**

CSIRO will provide the following:

- A database covering available biogeochemistry surveys undertaken by CSIRO to date including northwest Yilgarn, northeast Yilgarn and site-specific studies in northern and southern Western Australia and Gawler Craton, South Australia.
- A GIS file that will consist of the compiled geochemical data of all available biogeochemical surveys conducted by CSIRO and include the northwest biogeochemistry data yet to be received, spatially located within Australia together with other relevant data sets such as geology.
- A final report to be issued at the conclusion of the project, which will contain an Atlas.

Outputs

Final report published as GSWA Record:

Lintern, M, Ibrahimi, T, Pinchand, T and Cornelius, A 2017, NW Biogeochemistry and Beyond Project: Geological Survey of Western Australia, Record 2017/11, 148p.

MRIWA report project M426: Predictive exploration for BIF-hosted iron deposits in the Yilgarn Craton, Western Australia**Project Manager:** A/Prof P Duuring**Partner researchers/institutions:** A/Prof Paul Duuring, Dr Yoram Teitler (CET, UWA)**GSWA contact:** Dr Trevor Beardsmore**Duration of project:** 2012–15**Project description**

The aim of this project is to determine the geological criteria that control the location of high-grade, BIF-hosted iron ore deposits in the Yilgarn, and evaluate which exploration methods are most useful for their discovery. This study will be undertaken as part of postgraduate studies.

Outputs

Chiarelli, L 2015, Alteration mineral zonation associated with high-grade BIF-hosted iron ore: mineral mapping using hyperspectral drillcore data: Geological Survey of Western Australia, Record 2015/3, 156p.

Second generation regional targeting products: data generation and integration**Project Manager:** Prof John Miller**Partner researchers/institutions:** A/Prof Sandra Occhipinti, Dr Mark Lindsey, Dr Alan Aitken (CET, UWA)**GSWA contact:** Dr Ian Tyler**Duration of project:** 2013–16**Project description**

Provision of exploration targeting products, including software and GIS products to encourage mineral exploration in Western Australia.

Outputs

Co-branded GSWA Reports and Records

Lindsay, MD, Occhipinti, SA, Aitken, ARA, Metelka, V, Hollis, JA, Tyler, IM 2016, Proterozoic accretionary tectonics in the east Kimberley region, Australia: Precambrian Research, v. 278, p. 265–282.

Lindsay, MD, Occhipinti, SA, Hollis, JA, Aitken, ARA, Metelka, V, Dentith, MC, Miller, J and Tyler, IM 2016, A geophysical investigation of the east Kimberley region, northern Western Australia: Geological Survey of Western Australia, Report 157, 36p.

Occhipinti, SA, Metelka, V, Lindsay, MD, Hollis, JA, Aitken, AR, Sheppard, S, Orth, K, Tyler, IM, Beardsmore, T, Hutchinson, M and Miller, JM 2016, Prospectivity analysis of the Halls Creek Orogen, Western Australia — using a mineral systems approach: Geological Survey of Western Australia, Report 159, 51p.

Occhipinti, SA, Metelka, V, Lindsay, MD, Hollis, JA, Aitken, AR, Sheppard, S, Orth, K, Tyler, IM, Beardsmore, T, Hutchinson, M and Miller, JM 2016, Prospectivity analysis of the Halls Creek Orogen, Western Australia — using a mineral systems approach, Geological Survey of Western Australia: Geological Survey of Western Australia, Report 159, digital data package.

Occhipinti, S A, Metelka, V, Lindsay, M D, Hollis, J A, Aitken, A R A, Tyler, I M, Miller, J M, McCuaig, T C, 2016, Multicommodity mineral systems analysis highlighting mineral prospectivity in the Halls Creek Orogen: Ore Geology Reviews, v. 72, p. 86–113.

Geological studies of the Browns Range HREE mineralization**Project Manager:** Dr Trevor Beardsmore**Partner researchers/institutions:** Prof Birger Rasmussen (Curtin University), Northern Minerals Ltd**GSWA contact:** Sidy Morin-Ka**Duration of project:** 2013–15**Project description**

The aims of this project were to determine: the age(s) of heavy REE (HREE) mineralization in the Browns Range region using xenotime geochronology; whether HREE mineralization is directly detectable using hyperspectral analysis; the distribution and composition of any associated hydrothermal alteration, using conventional thin-section petrography and the GSWA HyLogger.

Outputs

Co-branded GSWA Report

Yilgarn Pyrite Fingerprint Database**Project Manager:** Prof Ross Large (CODES, University of Tasmania)**Partner researchers/institutions:** Cooperative Research Centre for Metals Discovery, University of Tasmania**GSWA contact:** Dr Trevor Beardsmore**Duration of project:** 2012–15**Project description**

Production of a database and associated interrogative software package that provides a chemical fingerprint for pyrite of various mineral and ore associations in a selected district of the Yilgarn Craton.

Volcanic-hosted massive sulfide (VMS) exploration in the Yilgarn Craton**Project Manager:** Dr Steve Barnes**Partner researchers/institutions:** Dr Steve Hollis (CSIRO)**GSWA contact:** Steve Wyche, Dr Trevor Beardsmore**Duration of project:** 2013–15**Project description**

This project was part of the EIS/CSIRO Western Australian Regional Researcher Initiative aimed at rapid transfer of new geoscience concepts, skills and technologies into the Western Australian mineral exploration industry.

This entailed a prospectivity study of VMS potential in the Yilgarn Craton, with deposit-scale study of Nimbus zinc–silver(–gold) deposit, a deposit- to camp-scale study of VMS mineralization at Erayinia, and a regional-scale study of the southeast Gum Creek greenstone belt. This study made use of EIS drillcore, HyLogger data, petrography, SEM work, whole-rock and soil geochemistry, U–Pb zircon geochronology, geology and geophysics to establish vectors to mineralization.

Outputs

Co-branded GSWA/CSIRO reports; peer-reviewed journal papers; conference proceedings

Hollis, SP, Yeats, CJ, Wyche, S, Barnes, SJ, Ivanic, TJ, Belford, SM, Davidson, GJ, Roache, AJ and Wingate, MTD 2015, A review of volcanic-hosted massive sulfide (VHMS) mineralization in the Archaean Yilgarn Craton, Western Australia: tectonic, stratigraphic and geochemical associations: *Precambrian Research*, v. 260, p. 113–135.

Hollis, S, Yeats, CJ, Wyche, S, Ivanic, TJ, Gillespie, P, Mole, D, Pumphrey, A, Verbeeten, A, Tessalina, S, Belford, SM and Podmore, D 2015, VHMS mineralization in the Yilgarn Craton: greenstone prospectivity and new results from the Eastern Goldfields, *in* GSWA 2015 extended abstracts: promoting the prospectivity of Western Australia: Geological Survey of Western Australia, Record 2015/2, p. 16–18.

Deep Exploration Technologies Cooperative Research Centre (DET CRC)**Project Manager:** Dr Richard Hillis**Partner researchers/institutions:** DET CRC**GSWA contact:** Don Flint and Dr Ian Tyler**Duration of project:** 2010–18**Project description**

GSWA is an affiliate partner to the DET CRC. The DET CRC was established in 2010 to manage an eight-year program of research that aims to provide more successful, cheaper and safer ways to drill, analyse and target deep mineral deposits. The DET CRC has \$145 million of cash and in-kind funding from the Commonwealth Government of Australia and program participants, making it the world's best-supported independent research initiative in mineral exploration.

Links

Website: <http://detcrc.com.au>

Multiscale dynamics of hydrothermal mineral systems (MRIWA Project M424)**Project Manager:** Prof Alison Ord**Partner researchers/institutions:** Prof Alison Ord, Dr Weronika Gorczyk, Dr Bruce Hobbs, Dr Mark Munro (CET, UWA); MRIWA (Project M424)**GSWA contact:** Dr Klaus Gessner**Duration of project:** 2013–15**Project description**

The project examines the origin of giant hydrothermal deposits at scales ranging from mineral grain to lithospheric. The goal is to define measurable parameters that control the size of such systems and that can be used as mineral exploration criteria, in particular emphasizing: (i) criteria that distinguish a 'successful' from a 'failed' mineral system and (ii) vectors to mineralization within a successful system.

Outputs

Co-branded GSWA Records and Reports

Yilgarn Gold Exploration Targeting Atlas**Project Manager:** Stephen Wyche**Partner researchers/institutions:** Dr Walter Witt (CET, UWA)**GSWA contact:** Stephen Wyche**Duration of project:** 2010–15**Project description**

Production of an atlas that qualitatively and quantitatively assesses various structural, mineralogical and geochemical criteria for targeting gold in the Yilgarn Craton.

Outputs

Witt, WK, Ford, A and Hanrahan, B 2012, Regional targeting criteria for gold in the Yilgarn Craton: which ones work and how well?, *in* GSWA 2012 extended abstracts: promoting the prospectivity of Western Australia: Geological Survey of Western Australia, Record 2012/2, p. 10–13.

Witt, WK, Ford, A and Hanrahan, B 2015, District-scale targeting for gold in the Yilgarn Craton: Part 2 of the Yilgarn Gold Exploration Targeting Atlas: Geological Survey of Western Australia, Report 132, digital data package.

Witt, WK, Ford, A and Hanrahan, B 2015, District-scale targeting for gold in the Yilgarn Craton: Part 2 of the Yilgarn Gold Exploration Targeting Atlas: Geological Survey of Western Australia, Report 132, 276p.

Witt, WK, Ford, A, Hanrahan, B and Mamuse, A 2013, Regional-scale targeting for gold in the Yilgarn Craton: Part 1 of the Yilgarn Gold Exploration Targeting Atlas: Geological Survey of Western Australia, Report data package 125.

Witt, WK, Ford, A, Hanrahan, B and Mamuse, A 2013, Regional-scale targeting for gold in the Yilgarn Craton: Part 1 of the Yilgarn Gold Exploration Targeting Atlas: Geological Survey of Western Australia, Report 125, 130p.

Witt, WK, Ford, A, Hanrahan, B and Mamuse, A 2013, Regional-scale targeting for gold in the Yilgarn Craton: Part 1 of the Yilgarn Gold Exploration Targeting Atlas: Geological Survey of Western Australia, Report 125 zipped data files.

More reports to follow.

COBRA project – Amadeus Basin: Central Oz basins resource assessment**Project Manager:** Dr Susanne Schmid**Partner researchers/institutions:** CSIRO**GSWA contact:** Dr Peter Haines**Duration of project:** 2014–15**Project description**

Assessment of the mineral and unconventional hydrocarbon potential of central Australian sedimentary basins by applying and bringing together new technology and systems thinking from hydrocarbon and minerals research.

Outputs

Foss, C, Austin, J and Schmid, S 2015, COBRA — Amadeus Basin project, gravity and magnetic study of the western Amadeus Basin, Western Australia: Geological Survey of Western Australia, Report 154, 34p.

Integrated spectral mapping of Au-hosted mineralization, Nanjilgardy Fault (CSIRO)**Project Manager:** Dr Martin Wells (CSIRO)**Partner researchers/institutions:** Dr Martin Wells, Dr Thomas Cudahy, Dr Carsten Laukamp (CSIRO)**GSWA contact:** Dr Lena Hancock**Duration of project:** 2013–15**Project description**

Collaborative EIS-funded study with CSIRO of the 3D architecture of the mantle-tapping Nanjilgardy Fault, and the gold mineralization and associated alteration spatially related to it. The final report was released in early 2016 as GSWA Report 56, and an extended abstract and presentation were delivered at GSWA's 2016 Open Day.

Outputs

Wells, M, Laukamp, C and Hancock, EA 2016, Integrated spectral mapping of precious and base metal related mineral footprints, Nanjilgardy Fault, Western Australia: Geological Survey of Western Australia, Report 156, 90p.

Wells, M, Laukamp, C and Hancock, EA 2016, Integrated spectral mapping of precious and base metal-related mineral footprints, Nanjilgardy Fault, Western Australia, in GSWA 2016 extended abstracts: promoting the prospectivity of Western Australia: Geological Survey of Western Australia, Record 2016/2, p. 26–30.

Wells, M, Laukamp, C and Hancock, E 2016, Reflectance spectroscopic characterisation of mineral alteration footprints associated with sediment-hosted gold mineralisation at Mt Olympus (Ashburton Basin, Western Australia): Australian Journal of Earth Sciences, v. 63, no. 8, p. 987–1002, doi:10.1080/08120099.2016.1264476.

Determine the age of gold mineralization at the Paulsens mine, northern Capricorn Orogen, using monazite and xenotime geochronology

Project Manager: Dr Simon Johnson

Partner researchers/institutions: P Tornatora (Northern Star Resources Ltd), Prof Birger Rasmussen (Curtin University), Dr Janet Muhling (UWA)

GSWA contact: Dr Simon Johnson

Duration of project: 2014–15

Project description

The primary aim of this study is to determine the age of gold mineralization at the Paulsens mine, using monazite and xenotime geochronology. However, a secondary aim is to provide further constraints on the age of stratigraphic units hosting the deposit as well as to determine the age of deformation and fabric formation throughout the region. These magmatic, depositional and structural events may be recorded by a variety of geochronometers including zircon, baddeleyite, monazite and xenotime.

Outputs

GSWA co-branded Report; GSWA geochronology records

Joint inversion of gravity and magnetic data along three Youanmi seismic traverses, Western Australia

Project Manager: Dr Luis Alonso Gallardo Delgado

Partner researchers/institutions: Dr Luis Alonso Gallardo Delgado (Centre for Scientific Research and Higher Education [CICESE], Mexico)

GSWA contact: Dr Klaus Gessner

Duration of project: 2013–14

Project description

This project involves joint inversion of the gravity and magnetic data existing along three seismic traverses (YU1, YU2 and YU3) that cross the northern part of the Yilgarn Craton, Western Australia to: (i) produce fully collocated density and magnetization sections along the three existing seismic profiles of the Youanmi survey; (ii) integrate the estimated distribution of density and magnetization contrasts into geospectral images of the subsurface; (iii) provide a preliminary geophysical description of the integrative images and its possible correlation to major granite–greenstone boundaries and ultramafic igneous complexes of the crossed terranes.

Outputs

Gessner K, Jones T, Goodwin JA, Gallardo LA, Milligan PR, Brett J, Murdie R 2013, Interpretation of magnetic and gravity data across the Southern Carnarvon Basin, and the Narryer and Youanmi terranes in Western Australia: multiscale edge detection (worms), forward modelling, and cross-gradient joint inversion, *in* Youanmi and Southern Carnarvon Seismic and Magnetotelluric (MT) Workshop 2013 *compiled by* S Wyche, TJ Ivanic and I Zibra: Geological Survey of Western Australia, Record 2013/6, p. 65–77.

ARC linkage project LP110200747 – Prospectivity of late Archean basaltic and gabbroic rocks associated with major gold and base metal deposits

Project Manager: Prof Ray Cas

Partner researchers/institutions: Monash University

GSWA contact: Stephen Wyche

Duration of project: Completed

Project description

Establishment of a new set of criteria for determining which Archean rock units are most likely to contain major gold and base metal deposits. GSWA to provide in-kind support over the life of the three-year project.

Outputs

Hayman, PC, Hull, SE, Cas, RAF, Summerhayes, E, Amelin, Y, Ivanic, TJ and Price, D 2015, A new period of volcanogenic massive sulfide formation in the Yilgarn: a volcanological study of the ca 2.76 Ga Hollandaire VMS deposit, Yilgarn Craton, Western Australia: *Australian Journal of Earth Sciences*, v. 62, p. 189–210.

Hayman, PC, Thébaud, N, Pawley, MJ, Barnes, SJ, Cas, RAF, Amelin, Y, Sapkota, J, Squire, RJ, Campbell, IH and Pegg, I 2015, Evolution of a ~2.7 Ga large igneous province: a volcanological, geochemical and geochronological study of the Agnew Greenstone Belt, and new regional correlations for the Kalgoorlie Terrane (Yilgarn Craton, Western Australia): *Precambrian Research*, v. 270, p. 334–368.

Albany–Fraser Orogen deep crustal seismic reflection and gravity survey

Project Manager: Dr Ian Tyler

Partner researchers/institutions: GA; AngloGold Ashanti; Independence Group NL, National Research Facility for Earth Sounding (ANSIR)

GSWA contact: Dr Catherine Spaggiari

Duration of project: 2011–15 (Completed)

Project description

The Albany–Fraser deep crustal seismic reflection survey was conducted across the southeastern margin of the Yilgarn Craton and the adjacent Albany–Fraser Orogen through to the Madura Province during April to June 2012. The seismic lines provide images of the deep crustal structure through to the Moho across the entire orogen.

Outputs

Geological Survey of Western Australia 2012, Albany–Fraser deep crustal seismic reflection survey 2012: Geological Survey of Western Australia, <www.dmp.wa.gov.au/Geological-Survey/Albany-Fraser-Orogen-deep-1511.aspx>.

Geoscience Australia, Onshore Seismic and Magnetotelluric project, <www.ga.gov.au/about/projects/resources/seismic>.

Spaggiari, CV and Occhipinti, SA 2014, Geological interpretation of the Albany–Fraser Orogen and southeast Yilgarn Craton seismic lines 12GA–AF1, 12GA–AF2, 12GA–AF3, 12GA–T1, in Albany–Fraser Orogen seismic and magnetotelluric (MT) workshop 2014: extended abstracts: Geological Survey of Western Australia, Record 2014/6, Plate 4.

Spaggiari, CV and Tyler, IM (compilers) 2014, Albany–Fraser Orogen seismic and magnetotelluric (MT) workshop 2014: extended abstracts: Geological Survey of Western Australia, Record 2014/6, 182p.

National Geochemical Survey of Australia

Project Manager: Dr Paul Morris

Partner researchers/institutions: GA

GSWA contact: Dr Paul Morris

Duration of project: Completed

Project description

GSWA to provide in-kind resources to conduct survey and to pay for geochemical analyses.

Outputs

Geoscience Australia, National Geochemical Survey of Australia Project, <www.ga.gov.au/about/projects/resources/national-geochemical-survey>.

Scheib, AJ 2013, The National Geochemical Survey of Australia — selected interpretations and discussion for Western Australian data: Geological Survey of Western Australia, Record 2013/4, 47p.

MERIWA project M414: Improved hydrogeochemical exploration in the northwest Yilgarn — adding value to underexplored areas

Project Manager: Dr David Gray

Partner researchers/institutions: CSIRO/MRIWA

GSWA contact: Dr Paul Morris

Duration of project: Completed

Project description

Earlier work by the authors had developed hydrogeochemical indicators for lithology, hydrothermal alteration and prospectivity analysis for the northern Yilgarn Craton. These methods were applied in the northwest Yilgarn Craton to develop a provisional mineral prospectivity view of the area. This region has a much lower density of demonstrated mineral resources than the northeast Yilgarn Craton, although the geology is similar. Overall, results for this study support previous research demonstrating the value of groundwater chemistry for defining lithological changes, hydrothermal alteration and mineralization.

Outputs

Gray, DJ, Reid, N and Noble, R 2016, Improved hydrogeochemical exploration in the northwest Yilgarn Craton: adding value to underexplored areas: Geological Survey of Western Australia, Record 2016/9, 100p.

Western Australia ASTER geoscience map

Project Manager: Dr Thomas Cudahy

Partner researchers/institutions: CSIRO (Centre for 3D Mineral Mapping)

GSWA contact: Dr Ian Tyler

Duration of project: Completed

Project description

CSIRO will use image processing and in-house software to process 1000 ASTER Level 1B scenes of Western Australia sourced initially from GA.

Outputs

CSIRO 2011, ASTER geoscience map of Western Australia: CSIRO, <<http://c3dmm.csiro.au>> (No longer available online – superseded)

Cudahy, T, Caccetta, M and Collings, S 2012, ASTER geoscience map of Western Australia, in GSWA 2012 extended abstracts: promoting the prospectivity of Western Australia: Geological Survey of Western Australia, Record 2012/2, p. 14–19.

Integration of physical process evidence into coastal adaption and planning

Project Manager: Bob Gozzard

Partner researchers/institutions: Department of Planning, Department of Transport, Damara P/L

GSWA contact: Bob Gozzard

Duration of project: Completed

Project description

Application and refinement of a multiscaled and multidisciplinary approach to coastal hazard and coastal landform stability assessment, by identifying and quantifying changes to coastal landforms within a hierarchy of compartments defined by geological and geomorphological criteria at different scales.

Outputs

Gozzard, JR 2011, WA Coast: Cape Naturaliste to Lancelin: Geological Survey of Western Australia, digital data product.

Gozzard, JR 2011, WA Coast: Lancelin to Kalbarri: Geological Survey of Western Australia, digital data product.

Gozzard, JR 2011, WA Coast: Rottnest Island: Geological Survey of Western Australia, digital data product.

Gozzard, JR 2011, Sea to Scarp: applied geology for land use planning in the southern Swan Coastal Plain: Geological Survey of Western Australia, digital data product.

Gozzard, JR 2012, WA Coast: Gascoyne: Geological Survey of Western Australia, digital data product.

Gozzard, JR 2012, WA Coast: Pilbara: Geological Survey of Western Australia, digital data product.

Earaheedy Basin – Environmental evolution of the Tooloo Subgroup

Project Manager: Dr Peir Pufahl

Partner researchers/institutions: Dr Peir Pufahl, Dr Eric Hiatt (Acadia University)

GSWA contact: Dr Franco Pirajno

Duration of project: Completed

Outputs

Akin, SJ 2014, Sedimentology and stratigraphy of the Paleoproterozoic Frere Formation, Western Australia: implications for the evolution of the Precambrian ocean: Geological Survey of Western Australia, Report 130, 133p.

External papers

Agouron Institute Pilbara drilling project

Project Manager: Roger Buick, Earth and Space Sciences and Astrobiology Program, University of Washington

Partner researchers/institutions: Ariel Anbar (Arizona State University), David Johnston (Harvard University), Jay Kaufman (University of Maryland), Andrew Knoll (Harvard University), Timothy Lyons (University of California, Riverside), Roger Summons (Massachusetts Institute of Technology), Dawn Sumner (University of California, Davis), Gordon Love (University of California, Riverside), Adriana Dutkiewicz (University of Sydney), Simon George (Macquarie University), Greg Webb (Queensland University of Technology), and Stephen Wyche and Kevin Ridge (GSWA). The project is funded by the Agouron Institute.

GSWA contact: Arthur Hickman

Duration of project: 2010–18 (drilling of the first three holes was completed in September 2012)

Project description

The project drilled short diamond drillholes (<450 m) into three Archean and Paleoproterozoic formations in the Pilbara region of Western Australia: (i) c. 3.15 Ga Coucal Formation (Coonterunah SUGroup of Warrawoona Group); (ii) <2.63 Ga Carawine Dolomite (Hamersley Group) and >2.63 Ga Jeerinah Formation (Fortescue Group); c. 2.59 Ga Marra Mamba Iron Formation (Hamersley Group) and >2.63 Ga Jeerinah Formation. The main purpose was to seek and investigate evidence of early life and environments, particularly associated with changing oxygen levels. A second purpose was to resolve the controversy about the age and origin of early Precambrian hydrocarbon biomarkers.

Outputs

Drillcores for scientific study; periodic reports to participating institutions; publication of research results

Links

Agouron Institute, Summary of Agouron project (2012), <<https://agourondrillingproject.wordpress.com>>

Buick, R 2009, Evidence of early life from drilling in the Pilbara, <<http://archenv.geo.uu.nl/pdf/Buick%20Finland%202009.pdf>>

ARC linkage project LP0883970 – Prospectivity of the Windimurra–Narndee layered complexes, Western Australia (Australian National University)

Project Manager: Prof Richard Arculus (Australian National University [ANU])

Partner researchers/institutions: John Mavrogenes, Oliver Nebel (ANU), Grahame Kennedy, Richard Langford (Maximus Resources, 2009 / Flinders Mines, 2010–12)

GSWA contact: Dr Tim Ivanic

Duration of project: 2009–12

Project description

The late Archean (~2.8 Ga) Windimurra–Narndee layered Igneous Complexes of the Yilgarn Craton of Western Australia collectively form the largest Archean ultramafic–mafic igneous intrusion in Australia. The petrology of the rock types is known in the very broadest outline, and a significant amount of exploration has taken place for gold, PGE, uranium, vanadium and a variety of base metals. But overall we lack detailed knowledge of the igneous stratigraphy, character and number of magmatic components and relationships of the Windimurra and Narndee Complexes, and their structural evolution. All of these are fundamental in terms of identification of probable zones of precious and base metal mineralization. The aims of this project are by building on previous studies to obtain these data, and construct a model for the origins, evolution and mineral prospectivity of the complexes.

Outputs

Ivanic, TJ, Wingate, MTD, Kirkland, CL, Van Kranendonk, MJ and Wyche, S 2010, Age and significance of voluminous mafic-ultramafic magmatic events in the Murchison Domain, Yilgarn Craton: Australian Journal of Earth Sciences, v. 57, p. 597–614.

Nebel, O, Arculus, RJ, Ivanic, TJ and Nebel-Jacobsen, YJ 2013, Lu–Hf isotopic memory of plume-lithosphere interaction in the source of layered mafic intrusions, Windimurra Igneous Complex, Yilgarn Craton, Australia: Earth and Planetary Science Letters, v. 380, p. 151–161.

Nebel, O, Arculus, RJ, Ivanic, TJ, Rapp, R and Wills, KJA 2013, Upper Zone of the Archean Windimurra layered mafic intrusion, Western Australia: Insights into fractional crystallisation in a large magma chamber: *Journal of Mineralogy and Geochemistry*, v. 191, no. 1, p. 83–107.

Van Kranendonk, MJ, Ivanic, TJ, Wyche, S, Wilde, SA and Zibra, I (compilers) 2010, A time transect through the Hadean to Neoproterozoic geology of the western Yilgarn Craton — a field guide: Geological Survey of Western Australia, Record 2010/19, 69p.

Exploration targeting products

Project Manager: Prof Mike Dentith

Partner researchers/institutions: Prof Campbell McCuaig, Prof Mike Dentith (CET, UWA)

GSWA contact: Dr Ian Tyler

Duration of project: Completed

Project description

Production of targeting products to help junior and mid-sized explorers translate GSWA datasets into ground acquisition and drill targets.

Outputs

Aitken, ARA, Joly, A, Dentith, MC, Johnson, SP, Thorne, AM and Tyler, IM 2014, 3D architecture, structural evolution, and mineral prospectivity of the Gascoyne Province: Geological Survey of Western Australia, Report 123, 94p.

Aitken, ARA, Joly, A, Dentith, MC, Johnson, SP, Thorne, AM and Tyler, IM 2014, 3D architecture, structural evolution, and mineral prospectivity of the Gascoyne Province: Geological Survey of Western Australia, Report 123, digital data package.

Joly, A, Dentith, MC, Porwal, A, Spaggiari, CV, Tyler, IM and McCuaig, TC 2013, An integrated geological and geophysical study of the West Arunta Orogen and its mineral prospectivity: Geological Survey of Western Australia, Report 113, 89p.

Joly, A, Aitken, ARA, Dentith, MC, Porwal, A, Smithies, RH and Tyler, IM 2014, Mineral systems analysis of the west Musgrave Province: regional structure and prospectivity modelling: Geological Survey of Western Australia, Report 117, 99p.

Joly, A, Aitken, ARA, Dentith, MC, Porwal, A, Smithies, RH and Tyler, IM 2014, Mineral systems analysis of the west Musgrave Province: regional structure and prospectivity modelling: Geological Survey of Western Australia, Report 117, digital data package.

Lindsay, MD, Aitken, AR, Ford, A, Dentith, MC, Hollis, JA and Tyler, IM 2015, Mineral prospectivity of the King Leopold Orogen and Lennard Shelf: analysis of potential field data in the west Kimberley region: Geological Survey of Western Australia, Report 142, 65p.

Lindsay, M, Aitken, A, Ford, A, Dentith, M, Hollis, J and Tyler, I 2016, Reducing subjectivity in multi-commodity mineral prospectivity analyses: Modelling the west Kimberley, Australia: *Ore Geology Reviews*, v. 76, p. 395–413.

ARC linkage project LP100100647 — Tectonic evolution and lode gold mineralization in the Southern Cross district, Yilgarn Craton: a study of the Mesoarchean to Neoproterozoic missing link

Project Manager: Assistant Prof Nicholas Thebaud

Partner researchers/institutions: Assistant Prof Nicholas Thebaud, Prof Mark Barley (CET, UWA)

GSWA contact: Stephen Wyche

Duration of project: Completed

Project description

Funded by an ARC Linkage grant, the aim of this project was to develop a superior tectonometamorphic model of the gold-endowed Youanmi Terrane in the Yilgarn Craton.

Outputs

Doublier, MP 2013, Geological setting of mineral deposits in the Southern Cross district — a field guide: Geological Survey of Western Australia, Record 2013/11, 55p.

West Kimberley magnetotelluric survey**Project Manager:** Prof Mike Dentith**Partner researchers/institutions:** CET, UWA**GSWA contact:** Dr David Maidment, Dr Julie Hollis**Duration of project:** Completed**Project description**

Acquisition of MT data across the Kimberley as part of the Kimberley Science and Conservation Strategy.

Outputs

Spratt, J, Dentith, MC, Evans, S, Aitken, ARA, Lindsay, M, Hollis, JA, Tyler, IM, Joly, A and Shragge, J 2014, A magnetotelluric survey across the Kimberley Craton, northern Western Australia: Geological Survey of Western Australia, Report 136, 92p.

ARC linkage project LP0883661 – Understanding the stratigraphic and structural architecture of late Archean basins and the context of their gold deposits**Project Manager:** Prof Ray Cas**Partner researchers/institutions:** Monash University**GSWA contact:** Stephen Wyche**Duration of project:** Completed**Project description**

The purpose of this project was to enhance the understanding of the stratigraphic and structural architecture of late Archean basins and the context of their gold deposits.

Outputs

Squire, RJ, Allen, CM, Cas, RAF, Campbell, IH, Blewett, RS and Nemchin, AA 2010, Two cycles of voluminous pyroclastic volcanism and sedimentation related to episodic granite emplacement during the late Archean: eastern Yilgarn Craton, Western Australia: Precambrian Research, v. 183, no. 2, p. 251–274.

Bentley Supergroup Volcanics**Project Manager:** Prof Ray Cas**Partner researchers/institutions:** Monash University**GSWA contact:** Dr Hugh Smithies**Duration of project:** Completed**Project description**

PhD study

Outputs

Smithies, RH, Howard, HM, Kirkland, CL, Werner, M, Medlin, CC, Wingate, MTD and Cliff, JB 2013, Geochemical evolution of rhyolites of the Talbot Sub-basin and associated felsic units of the Warakurna Supersuite: Geological Survey of Western Australia, Report 118, 74p.

ARC linkage project LP0883812 – Magnetostratigraphic and isotopic dating of Devonian Reef Complexes**Project Manager:** Prof Peter Cawood**Partner researchers/institutions:** Tectonics Special Research Centre (TSRC), UWA**GSWA contact:** Roger Hocking**Duration of project:** Completed**Project description**

This project involves magnetostratigraphic and isotopic dating and correlation of Devonian Reef Complexes (two years). GSWA to provide in-kind support.

ARC linkage project LP100200127 – Constraining conditions and timing of orogeny and reworking in the west Musgrave Province**Project Manager:** Dr Hugh Smithies**Partner researchers/institutions:** Dr David Kelsey, Prof Martin Hand, Prof Alan Collins (University of Adelaide)**GSWA contact:** Dr Hugh Smithies**Project description**

Application of advanced geochronological and microstructural techniques to address significant uncertainties in the thermotectonic evolution of the west Musgrave Province.

Outputs

Howard, HM, Smithies, RH, Kirkland, CL, Kelsey, DE, Aitken, A, Wingate, MTD, Quentin de Gromard, R, Spaggiari, CV and Maier, WD 2015, The burning heart — the Proterozoic geology and geological evolution of the west Musgrave Region, central Australia: *Gondwana Research*, v. 27, no. 1, p. 64–94.

Walsh, AK, Kelsey, DE, Kirkland, CL, Hand, M, Smithies, RH, Clark, C and Howard, HM (2015) P–T–t evolution of a large, long-lived, ultrahigh-temperature Grenvillian belt in central Australia: *Gondwana Research*, v. 28, no. 2, p. 531–564, doi:10.1016/j.gr.2014.05.012.

Walsh, AK, Raimondo, T, Kelsey, DE, Hand, M, Pfitzner, HL and Clark, C 2013, Duration of high-pressure metamorphism and cooling during the intraplate Petermann Orogeny: *Gondwana Research*, v. 24, 3–4, p. 969–983, doi:10.1016/j.gr.2012.09.006.

Musgrave Province: Honours student mapping**Project Manager:** Dr Hugh Smithies**Partner researchers/institutions:** Dr David Kelsey, Prof Martin Hand, Prof Alan Collins (University of Adelaide)**GSWA contact:** Dr Hugh Smithies**Duration of project:** Completed**Project description**

Honours projects as required

Outputs

Belperio, M 2009, Age constraints and deformation history of the Shag Hill mylonites, western Musgraves: *Geological Survey of Western Australia, Record 2009/13*, 51p.

Coleman, P 2009, Intracontinental orogenesis in the heart of Australia: structure, provenance and tectonic significance of the Bentley Supergroup, western Musgrave Block, Western Australia: *Geological Survey of Western Australia, Record 2009/23*, 50p.

King, RJ 2009, Using calculated pseudosections in the system NCKFMASHTO and SHRIMP U–Pb zircon dating to constrain the metamorphic evolution of paragneisses in the Latitude Hills, West Musgrave Province, Western Australia: *Geological Survey of Western Australia, Record 2009/15*, 67p.

Raimondo, T 2009, A kinematic, metamorphic, geochemical and geochronological framework for intracratonic reworking in the western Musgrave Block, central Australia: *Geological Survey of Western Australia, Record 2009/12*, 68p.

Walker-Hallam, A 2009, Complex strain in mylonites from the western Musgraves, north of the Mann Fault, Western Australia: *Geological Survey of Western Australia, Record 2009/14*, 33p.

Seismic framework of the northwestern part of the Canning Basin**Project Manager:** Jeff Haworth**Partner researchers/institutions:** Prof Mike Dentith, Prof Annette George (UWA)**GSWA contact:** Jeff Haworth**Duration of project:** Completed**Project description**

Collaborative research involving a PhD student to research the seismic framework of the northwestern part of the Canning Basin.

Outputs

Parra-Garcia, M, Sanchez, G, Dentith, MC and George, AD 2014, Regional structural and stratigraphic study of the Canning Basin, Western Australia: Geological Survey of Western Australia, Report 140, 215p.

Parra-Garcia, M, Dentith, MC and George, AD 2015, Regional structural and stratigraphic study of the Canning Basin, Western Australia: Geological Survey of Western Australia, Report 140, digital data package.

West Musgrave magnetotelluric survey

Project Manager: Prof Mike Dentith

Partner researchers/institutions: Prof Mike Dentith, Dr Alan Aitken (CET, UWA)

GSWA contact: Dr Hugh Smithies

Duration of project: Completed

Project description

Mapping of deep crustal and upper mantle structures across the west Musgrave Province.

Outputs

Aitken, ARA, Dentith, MC, Evans, SF, Gallardo, LA, Joly, A, Thiel, S, Smithies, RH and Tyler, IM 2013, Imaging crustal structure in the west Musgrave Province from magnetotelluric and potential field data: Geological Survey of Western Australia, Report 114, 81p.

Aitken, ARA, Dentith, MC, Evans, SF, Gallardo, LA, Joly, A, Thiel, S, Smithies, RH and Tyler, IM 2013, Imaging crustal structure in the west Musgrave Province from magnetotelluric and potential field data: Geological Survey of Western Australia, Report 114, digital data (zipped).

ARC linkage project LP0990455 – Developing a new tectonothermal and mineralization history for the Capricorn Orogen, Western Australia: assisting mineralization in greenfield terrains

Project Manager: Prof Birger Rasmussen

Partner researchers/institutions: Prof Birger Rasmussen, Dr Ian Fletcher, Dr Janet Muhling, Dr Stephen Sheppard, UWA, Curtin University

GSWA contact: Dr Simon Johnson

Duration of project: 3 years (2009–12)

Project description

Dating of low-temperature phosphate minerals to investigate timing of deposition, deformation, low- to medium-grade metamorphism and hydrothermal mineralization.

Outputs

Johnson, SP, Sheppard, S, Rasmussen, B, Wingate, MTD, Kirkland, CL, Muhling, JR, Fletcher, IR and Belousova, E 2010, The Glenburgh Orogeny as a record of Paleoproterozoic continent-continent collision: Geological Survey of Western Australia, Record 2010/5, 54p.

Johnson, SP, Sheppard, S, Rasmussen, B, Wingate, MTD, Kirkland, CL, Muhling, JR, Fletcher, IR and Belousova, EA, 2011, Two collisions, two sutures: Punctuated pre-1950 Ma assembly of the West Australian Craton during the Ophthalmian and Glenburgh Orogenies: Precambrian Research, v. 189, p. 239–262.

Korhonen, FJ, Johnson, SP, Fletcher, IR, Rasmussen, B, Sheppard, S, Muhling, JR, Dunkley, DJ, Wingate, MTD, Roberts, MP and Kirkland, CL 2015, Pressure–temperature–time evolution of the Mutherbukin Tectonic Event, Capricorn Orogen: Geological Survey of Western Australia, Report 146, 64p.

Rasmussen, B, Fletcher, IR, Muhling, JR, Thorne, AM, Cutten, HN, Pirajno, F and Hell, A 2010, In situ U–Pb monazite and xenotime geochronology of the Abra polymetallic deposit and associated sedimentary and volcanic rocks, Bangemall Supergroup, Western Australia: Geological Survey of Western Australia, Record 2010/12, 31p.

Zi, J, Rasmussen, B, Muhling, J, Johnson, SP, Thorne, AM, Korhonen, FJ and Cutten, HN, 2015, In situ U–Pb geochronology of xenotime and monazite from the Abra deposit in the Capricorn Orogen, Australia: dating hydrothermal mineralization and fluid flow in a long-lived crustal structure: Precambrian Research, v. 260, p. 91–112.

Nullabor Limestone project

Project Manager: Prof Noel James

Partner researchers/institutions: Department of Geological Sciences, Queen's University, Kingston, Ontario

GSWA contact: Roger Hocking

Duration of project: Completed

Project description

Cenozoic evolution of the Nullarbor Plain.

Outputs

Miller, CR 2012, Cenozoic evolution of the Nullarbor Plain paleokarst, southern Australia: Geological Survey of Western Australia, Report 119, 200p.

O'Connell, LG 2011, Sedimentology of the Miocene Nullarbor Limestone; southern Australia: Geological Survey of Western Australia, Report 111, 211p.

MERIWA project M389 – 4D interpretation of the Proterozoic west Tanami and its minerals systems

GSWA contact: Ian Tyler

Duration of project: Completed

Project description

Sponsorship of project M389: west Tanami, involving 4D interpretation of the Proterozoic West Tanami and its minerals systems.

MERIWA project M405 – Application of zircon double-dating to diamond exploration

Project Manager: Prof Brent McInnes

Partner researchers/institutions: CSIRO, John de Laeter Centre of Isotope Research

GSWA contact: Ian Tyler

Duration of project: Completed

Project description

Proposal to conduct field trials in the Kimberley for the application of zircon double-dating to diamond exploration — GSWA commitment to purchase extra days of SHRIMP.

Outputs

McInnes, BIA, Evans, NJ, McDonald, BJ and Mayers, C 2011, Application of U–Th–Pb–He double dating techniques to diamond exploration: Minerals and Energy Research Institute of Western Australia, Report 292, 72p.

MERIWA project M409 – In-place leaching of oxidized gold ores

Project Manager: Dr Ivor Roberts

Partner researchers/institutions: CSIRO

GSWA contact: Dr Lee Hassan

Duration of project: Completed

Project description

As part of sponsorship of project M409, this study developed novel systems for recovering gold from currently uneconomic oxide gold resources in Australia by using a modified in situ leaching method. Three lixiviant systems were studied and gold was recovered using an ion exchange resin. A literature review identified microbial processes which may hold potential for leaching of oxide gold ores.

Outputs

Jeffrey, M, Zhang, H, Benvie, B, Martiens, E, Prommer, H, Swart, F, Greskowiak, J, Johnston, C, Kaksonen, A, Parr, J and Roberts, P 2011, In-place leaching of oxidised gold ores: Minerals and Energy Research Institute of Western Australia, Report 291, 122p.

MRIWA project M411 – Greenfields geochemical exploration in a regolith-dominated terrain: the Albany–Fraser Orogen / Yilgarn Craton margin**Project Manager:** Dr Catherine Spaggiari**Partner researchers/institutions:** CSIRO minerals Downunder Flagship – Dr Ignacio González-Álvarez, Dr Ravinder Anand, Dr Rob Hough, Dr Walid Salama, Dr Carsten Laukamp, Dr Marcus Sweetapple, Dr Yusen Ley-Cooper, Iris Sonntag, Dr Melvyn Lintern, Tania Abdat, Monica leGras, Dr John Walshe**GSWA contact:** Dr Catherine Spaggiari**Duration of project:** Completed**Project description**

This project examined techniques to aid greenfields geochemical exploration in a regolith-dominated terrain. Research included regolith and whole-rock geochemistry and trace element mobility, regolith stratigraphy, petrography, remote sensing data analysis and electromagnetic data interpretation.

Outputs

González-Álvarez, I, Anand, RR, Hough, R, Salama, W, Laukamp, C, Sweetapple, MT, Ley-Cooper, Y, Sonntag, I, Lintern, M, Abdat, T, leGras, M and Walshe, J 2014, Greenfields Geochemical Exploration in a Regolith-dominated Terrain: the Albany–Fraser Orogen/Yilgarn Craton Margin: Minerals Research Institute of Western Australia, Report 305, 204p.

González-Álvarez, I, Anand, R, Hough, R, Salama, W, Laukamp, C, Sweetapple, M, Ley-Cooper, Y, Sonntag, I, Lintern, M, Abdat, T, leGras, M and Walshe, J 2014, Greenfields geochemical exploration in a Regolith-dominated Terrain: the Albany–Fraser Orogeny/Yilgarn Craton margin: Geological Survey of Western Australia, Report 144, 213p.

Completed Projects with Geoscience Australia: NCF activities**Project Manager:** Dr Rick Rogerson**Partner researchers/institutions:** GA**GSWA contact:** Dr Ian Tyler; Don Flint

EIS — Western Australian regional 100 m magnetic and gamma-ray spectrometric surveys 2015–22 (WARMS100) (CMCG4003A – 000782)



EIS — Eucla–Gawler deep crustal seismic reflection, gravity and magnetotelluric survey, processing and interpretation (G4003APA6)



Canning coastal deep crustal seismic reflection and gravity survey, processing and interpretation (G4003APA7)



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