A Geological Survey of Western Australia Newsletter

APRIL 2018 NUMBER 86

Fieldnotes

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

ISSN 1325-9377 ISBN 978-1-74168-818-4 (PRINT)
ISSN 1834-2272 ISBN 978-1-74168-817-7 (PDF)

Visit our Home Page at: www.dmp.wa.gov.au/GSWA

Western Australia remains a highly rated investment destination

The Fraser Institute, an independent, nonpartisan Canadian policy think tank annually surveys mining companies worldwide, with 91 jurisdictions surveyed in 2017. The survey was sent to approximately 2700 managers and executives from mining and exploration companies. A total of 360 responses was received with an unknown number of these providing perceptions of Western Australia as a destination for mining investment.

Western Australia's ranking on the survey's Investment Attractiveness Index — a composite of policy perceptions and minerals potential — dropped to fifth in 2017 from third in 2016.

Finland was rated as the most attractive jurisdiction for mining investment in 2017, followed by Saskatchewan, Nevada, and the Republic of Ireland.

Western Australia has maintained its position as one of the five most-attractive jurisdictions for mining investment in the world for seven consecutive years.

At fifth in the world, Western Australia remains the highest ranked Australian jurisdiction for investment attractiveness, followed by Queensland (12th), South Australia (14th), Northern Territory (27th), New South Wales (46th), Tasmania (50th) and Victoria (71st).

While care must be taken in interpreting the results of the survey, the fall in Western Australia's investment attractiveness ranking was primarily due to a decline in its score on the Policy Perception Index to 83.5 in 2017 from 93.2 in 2016. As a result, Western Australia ranked 17th in the world for policy perceptions, down from eighth in 2016.

The Policy Perception Index is a composite measure of the attractiveness of mining policies in a jurisdiction. It captures perceptions on each of the following: uncertainty concerning the administration, interpretation and enforcement of existing regulations; environmental regulations; regulatory duplication and inconsistencies; taxation; uncertainty concerning disputed land claims and protected areas; infrastructure; socioeconomic agreements; political stability; labour issues; geological databases; and security.

Western Australia's lower Policy Perception Index score and ranking reflects increased concern over political stability, socioeconomic agreements/community development conditions and the taxation regime. These concerns may include the ban on uranium mining for future mining leases, and proposed changes to gold royalty arrangements.

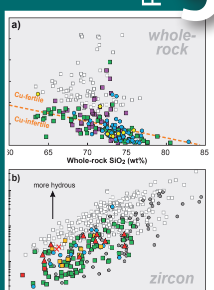
continued on page 3

WHAT'S INSIDE?

Geological Survey of Western Australia

PAGE 5

PAGE 9



PAGE 11

The winds of change

The State Government's Machinery of Government reforms have merged the bulk of the Department of Mines and Petroleum with the Department of Commerce to create the Department of Mines, Industry Regulation and Safety (DMIRS).

One of five new groups in the department's new organizational structure, the Resource and Environmental Regulation Group has been created through the transfer of personnel and functions from the former Mineral Titles, Petroleum, Environment, and Geological Survey Divisions into the new Resource Tenure, Resource and Environmental Compliance, and Geoscience and Resource Strategy Divisions.

Please see Figure 1 for the new Directors and their contact numbers.

Phil Gorey
Acting Deputy Director General
Resource and Environmental Regulation

t 9222 3290
m 0409 302 024
e phil.gorey@dmirs.wa.gov.au

Rick Rogerson
Executive Director
Resource Tenure

t 9222 3170
m 0417 588 019
e rick.rogerson@dmirs.wa.gov.au

- Titles and land access approvals including assistance with Native Title approvals
- Tenure operational policy and guidelines
- Maintenance of resource cadastre system

Karen Caple
Acting Executive Director
Resource and Environmental Compliance

t 9222 3447
m 0447 193 039
e karen.caple@dmirs.wa.gov.au

- Title management and compliance with conditions
- Petroleum operational compliance
- Environmental compliance
- Royalties, financial compliance
- Administration of the Mining Rehabilitation Fund (MRF)

Jeff Haworth
Executive Director
Geoscience and Resource Strategy

t 9222 3291
m 0428 424 315
e jeffrey.haworth@dmirs.wa.gov.au

- Acquisition, delivery and promotion of pre-competitive geoscience information (GSWA)
- Resource strategy and policy
- Abandoned mines
- Exploration Incentive Scheme (EIS)
- Mineralisation assessments and core libraries

RBO4 18.04.18

Figure 1. Contact details for the restructured department

continued from page 1

The State's score for the Best Practice Mineral Potential Index (which is akin to perceptions of underlying geological prospectivity) was down slightly to 83.6 in 2017 from 86.0 in 2016. This resulted in a ranking of fourth in 2017, down from first in 2016.

Western Australia has been ranked in the top 10 jurisdictions for pure minerals potential for seven out of the last eight years, which is considered to be a very good result.

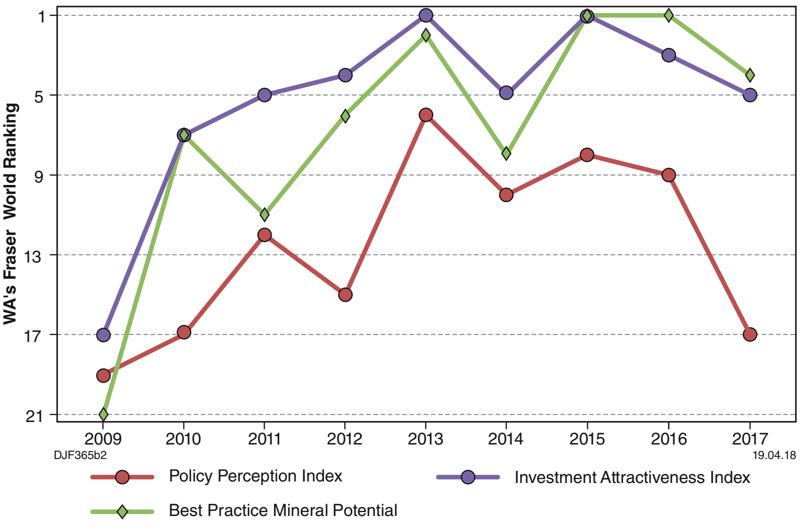


Figure 1. Western Australia's Fraser Institute Survey of Mining Companies rankings, 2009–17

For the first time, Queensland has overtaken Western Australia in the Best Practice Mineral Potential Index. This may reflect Geoscience Australia's $100 million *Exploring for the Future* program, which has so far concentrated on north Queensland and the Northern Territory, seeking extensions to Mount Isa and McArthur River-style mineralization.

Western Australia's score for its geological databases also declined. Among survey respondents, 92% considered that Western Australia's geological databases encouraged investment, or were not a deterrent to investment, in the State. This was down from 100% in 2016. As a result, Western Australia's ranking for its geological databases dropped to 17th in the world in 2017, down from first in 2016. However, rankings of the geological databases and systems within the Department of Mines, Industry Regulation and Safety (DMIRS) have not significantly changed over the last year.

An overview of Western Australia's global ranking, together with a comparison of its performance relative to the other Australian states and territories, on several of the survey's key measures since 2009 is provided at Figure 1 and Tables 1 and 2.

For more information, contact Don Flint (don.flint@dmirs.wa.gov.au).

Table 1. Western Australia's rankings in Fraser Institute mining company surveys for the period 2010–11 to 2017

	Ranking relative to jurisdictions worldwide								*Ranking relative to Australian jurisdictions*							
	2010–11	**2011–12**	**2012–13**	**2013**	**2014**	**2015**	**2016**	**2017**	**2010–11**	**2011–12**	**2012–13**	**2013**	**2014**	**2015**	**2016**	**2017**
Number of jurisdictions surveyed	*79*	*93*	*96*	*112*	*122*	*109*	*104*	*91*	*7*	*7*	*7*	*7*	*7*	*7*	*7*	*7*
Policy Perception Index	17	12	15	6	10	8	9	17	2	1	1	1	1	1	1	1
Best Practice Mineral Potential Index	7	11	6	2	8	1	1	4	1	1	1	1	1	1	1	2
Investment Attractiveness Index*	7	5	4	1	5	1	3	5	1	1	1	1	1	1	1	1
Quality of geological database	17	8	10	11	5	3	1	17	6	3	4	3	2	1	1	5

* Formerly 'Composite Policy and Best Practice Mineral Potential Index'

Table 2. Fraser Institute's Policy Potential Index — Australian States only

Ranking	*2006–07*	*2007–08*	*2008–09*	*2009–10*	*2010–11*	*2011–12*	*2012–13*	*2013*	*2014*	*2015*	*2016*	*2017*
1	SA	SA	SA	SA	SA	NT WA	WA	WA	WA	WA	WA	WA
2	Qld	Tas	NT	NT	WA	SA	SA	SA	SA	SA	SA	SA
3	Tas	NT	WA	WA	NSW	NSW	NT	NT	Tas	NT	NT	Qld
4	Vic	WA	NSW	NSW	NT	Tas	Vic	Qld	NT	Qld	Tas	Tas
5											Qld	NT
6											Vic	Vic
7	WA										NSW	NSW

Towards a geochemical barcode for Eastern Goldfields Superterrane greenstone stratigraphy

As part of ongoing stratigraphic revisions of the Eastern Goldfields, the Geoscience and Resource Strategy Division is collecting high-quality, multi-element, geochemical data from diamond drillcore that samples the most geologically well-constrained, or best-understood, parts of greenstone stratigraphy in greenstone belts throughout the Eastern Goldfields Superterrane.

This project aims to establish a geochemical 'barcode' of the stratigraphy (including local variations) from better known sections of greenstone belts. It aims to establish whether current local and/or regional greenstone stratigraphies are valid, and the geological reasons for local and regional stratigraphic variations. It also aims to provide a reasonable geochemical proxy for stratigraphy that will allow users to better establish where a particular lithology or lithological association fits in a local or regional stratigraphy.

The first phase of this project was undertaken in the Kalgoorlie–Kambalda region (Fig.1). From these results, it is clear that the broad stratigraphic groups that make up the Kalgoorlie–Kambalda stratigraphy can normally be distinguished geochemically. However, detailed geochemical sampling has identified stratigraphic complexities and several potential problems with using geochemistry in assigning individual analyses or even groups of analyses of greenstones to a particular stratigraphic unit. The success of any geochemical approach to assigning greenstone stratigraphy critically depends on how well a local and regional stratigraphy has been geochemically characterized.

GSWA Record 2017/7 Towards a geochemical barcode for Eastern Goldfields Superterrane greenstone stratigraphy — preliminary data from the Kambalda–Kalgoorlie area is available as a free downloadable PDF from <www.dmp.wa.gov.au/ebookshop>.

For more information, contact Hugh Smithies (hugh.smithies@dmirs.wa.gov.au).

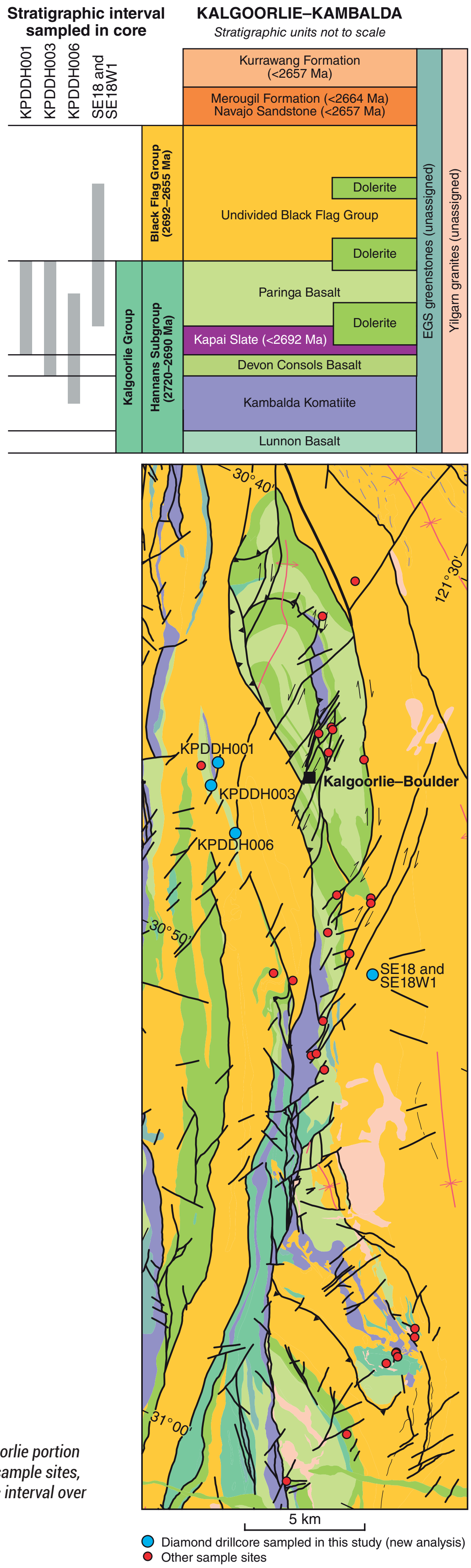


Figure 1. Interpreted bedrock geology of the Kalgoorlie portion of the preliminary study area, showing locality of sample sites, including diamond drillholes, and the stratigraphic interval over which the various drill cores were sampled

Seeing past metamorphism towards future discoveries

A common endeavor of mineral explorers is to characterize the physical and chemical attributes of known deposits in order to identify the key pathfinder features for future discoveries. However, in many instances the primary features of these deposits may be difficult to recognize due to subsequent modification by deformation, metamorphism, or hydrothermal alteration. Lee Hassan has recently examined this issue with studies of the mineralogy and petrochemistry of three base metal sulfide deposits in the Yilgarn Craton, using drillcore and a combination of conventional microscopy, whole-rock geochemical analysis, spectral studies using the HyLogger, and scanning electron microscopy with microprobe.

The Yuinmery deposit in the northwestern Youanmi Terrane (Fig. 1) is the least metamorphosed example, with most rocks having experienced lower greenschist facies conditions. Primary textures are consequently commonly preserved and provide evidence that base metal sulfide minerals (chalcopyrite, sphalerite, and galena) were initially deposited in an ancient sea-floor environment, around hydrothermal vents, with some sulfides filling the matrix of hyaloclastites beneath the sea floor — it is a typical Archean volcanic-hosted massive sulfide (VMS) deposit. Proximal hydrothermal alteration associated with base metal mineralization is now indicated by iron-rich talc in banded iron-formation (BIF), whereas ferroan chlorite indicates a more distal hydrothermal alteration signature. Other minerals that are locally associated with mineralization include quartz, Ca-poor amphiboles, apatite, ferroan dolomite, white and brown micas, stilpnomelane, hisingerite, and tourmaline. The base metals, and commonly associated Au, Te, and Bi, provide robust geochemical vectors.

Base metal mineralization at Austin–Quinns, to the southeast of Meekatharra in the Youanmi Terrane, occurs in a package of felsic volcanic rocks and banded iron-formations that are metamorphosed to at least greenschist facies conditions. Mineralization is still recognized as VMS style, but primary synvolcanic hydrothermal alteration mineralogy is more cryptic than at Yuinmery.

The primary origin of the base metal sulfides at the Kingsley (or Wheatley) deposit in the South West Terrane is even more controversial. Mineralization occurs in rocks that have been metamorphosed to amphibolite facies conditions. Sillimanite, kyanite, staurolite, and spessartine-rich garnet in gneisses located in the footwall of mineralization are interpreted to be metamorphosed argillic hydrothermal alteration consistent with synvolcanic (VMS) mineralization. Zn-rich metamorphic minerals such as gahnite and zincian staurolite provide useful vectors to mineralization. Laterite lag sampling demonstrates that Cu, Zn, Pb and Bi are enriched in areas proximal to hypogene mineralization.

An important conclusion from this work is that primary signatures of these ancient hydrothermal fluid systems may persist in rocks metamorphosed to at least amphibolite facies conditions. Metamorphic mineral zonation patterns defined by aluminosilicate minerals, particularly those that are enriched in base metals, are useful for identifying mineralogical and chemical gradients to VMS mineralization.

Figure 1. Location of the selected VMS deposits. In the Yilgarn Craton, green polygons represent greenstone belts while pink polygons indicate granites. Other colours are representative of Proterozoic and Phanerozoic rocks that surround the Yilgarn Craton (data sourced from the MINEDEX database, March 2018)

For more on this topic, the following publications by LY Hassan are available as downloadable PDFs on <www.dmp.wa.gov.au/ebookshop>:

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

GSWA Record 2017/10 Alteration associated with the Austin–Quinns VMS prospects, northern Yilgarn Craton

GSWA Report 131 The Yuinmery volcanogenic massive sulfide prospects: mineralization, metasomatism and geology

For more information, contact Paul Duuring (paul.duuring@dmirs.wa.gov.au).

Conference in Denmark a success

The biennial conference for the Specialist Group in Tectonics and Structural Geology (SGTSG) of the Geological Society of Australia was held in the small town of Denmark on the south coast of Western Australia 8–12 November 2017. The Geoscience and Resource Strategy Division (GRSD) (formerly known as the Geological Survey of Western Australia) provided logistical support and has published the abstract volume and three field guides from the meeting as GSWA Records. These Records are available on the Department of Mines, Industry Regulation and Safety (DMIRS) eBookshop (www.dmp.wa.gov.au/ebookshop) and via the SGTSG website (www.sgtsg.org). The conference was attended by 125 people, far exceeding expectations, with a mix of academics, postgraduate students, people from the resources industry and various government organizations, from as far as Ghana, Britain, Germany, China, the US, and New Zealand, as well as from various parts of Australia. The aim of the conference was to bring together the research community in structural geology, tectonic processes and geodynamics to discuss the latest research and developments in these fields.

Scientific highlights from the conference

Eight keynote speakers led the way into each topic over the four days of talks and poster presentations. Walter Mooney (USGS) gave a modern view of the Earth's lithosphere by reviewing current issues in lithospheric studies such as secular variations in lithospheric properties, and the fine structure of lithospheric mantle and its implications. Craig O'Neill (Macquarie University) opened the session on continental assembly and presented 'The long road to plate tectonics', where he discussed planetary geology and early Earth tectonics, models of fault rheology and internal planetary temperature and their effects on tectonic activity.

The session on microstructures was led by Janos Urai (RWTH Aachen University, Germany) who presented 'Deformation mechanisms and microstructure evolution in mudrocks', with application to petroleum exploration, predicting the performance of nuclear waste repositories, and the understanding of mudrock deformation in fault zones. Ken McClay (Royal Holloway University of London) opened the session on extensional tectonics and presented the '4D evolution of accretionary wedges — examples and models', showing analysis of deepwater fold and thrust belts and gravitational collapse of the frontal limbs of the folds. This session also included a presentation by Nicolas Molnar (Monash University) on '3D analogue experiments of rotational extension: how propagating rifts interact with pre-existing linear rheological heterogeneities', which was a highlight and aptly awarded the best student talk. Caroline Perring (BHP) presented 'Structural controls on the genesis of the Mt Whaleback martite microplaty-hematite deposit, Hamersley Province, WA' to open the session on structural processes in mineralization.

Another highlight was the session on strain localization and fluids, which addressed new insights into the rheological properties of materials, their response to deformation, and the development of important tectonic and economic structures. The session commenced with Tom Mitchell (University College London) who presented 'Cumulative co-seismic fault damage and feedbacks on earthquake rupture' addressing how damage zones are created, what their properties are, and how they feed back into the seismic cycle through combined field, experimental and theoretical studies. In the final sessions, the latest insights into the major topic of tectonics were explored, with excellent presentations from Dietmar Müller (University of Sydney) on 'Unravelling and applying the rules of plate tectonics for the last billion years' and Jacqueline Halpin (University of Tasmania) on 'Uncovering terra incognita: new insights into the evolution of Antarctica and constraints for ice sheet models'. The tectonics sessions highlighted the application of new research into geodynamics to models of plate tectonic reconstructions.

Pre-conference field trip: transect across an Archean craton margin to a Proterozoic ophiolite (GSWA Record 2017/14)

The GRSD Albany–Fraser team led 22 participants from a mix of academia (national and international), industry and government on a six-night trip from Kalgoorlie to Denmark. The trip commenced with an overview of Archean greenstones, led by the Kalgoorlie office geologists, and progressed southeast through the reworked Archean rocks of the Albany–Fraser Orogen visiting exposures of the Northern Foreland, Biranup, Fraser and eastern Nornalup Zones (Figs 1, 2). Particular emphasis was placed on tectonic unit bounding shear zones, such as the Fraser Shear Zone, and their kinematic evolution. One of the aims was to compare structures and related magmatic features visible in the field with their signatures in the various regional geophysical datasets available, which provided the crustal-scale context for the outcrops visited. This led to discussion of one of the fundamental aspects of structural geology of the role of scale, from microstructure, to outcrop scale, to crustal scale and the geodynamic implications. A highlight was a day trip from Esperance to Point Malcolm, southwest of Israelite Bay, where spectacularly deformed rocks of the Malcolm Metamorphics are exposed. These rocks are interpreted as part of a Proterozoic ophiolite complex overlying the craton margin, the rest of which lies beneath the Eucla Basin. The field guide contains an overview of the east Albany–Fraser Orogen and details of key localities that were visited.

Figure 1. Renowned structural geologist Rod Holcombe discusses kinematics on the Newman Shear Zone, Fraser Range, east Albany–Fraser Orogen

Figure 2. Structural geologists examining the interplay of complex magmatic processes and deformation at Afghan Rock, east Albany–Fraser Orogen

Mid-conference field trip: the western Nornalup Zone, Albany–Fraser Orogen, Western Australia (GSWA Record 2017/15)

This excursion was led by Nick Timms (Curtin University) to explore three coastal localities from Denmark to Albany. It was attended by about 120 people, providing an excellent opportunity to socialize and discuss favourite topics of field geology (Fig. 3). The field guide contains an overview of the geology of southwest Western Australia and the western Albany–Fraser Orogen, which remarkably is less well studied than its eastern counterpart. Just west of Denmark, at Parry Beach (Hillier Bay), upper amphibolite facies paragneisses and orthogneisses are spectacularly deformed and preserve early subhorizontal structures. Other localities include granitic rocks and overlying Tertiary limestone of the Plantagenet Group at Lowlands Beach, and metagranite and cordierite-bearing pelitic metasedimentary rocks at Whalehead Cove, Albany.

Figure 3. Getting up close with deformed granites of the west Albany–Fraser Orogen at Whalehead Cove, Albany

Post-conference field trip: the Leeuwin Complex, Western Australia (GSWA Record 2018/6)

This excursion was also led by Nick Timms (Curtin University) over three days in the Margaret River region. The field guide presents an overview of the evolution of the southwestern margin of Western Australia, including a compilation of geochronological data for the southwest. A detailed account of the Leeuwin Complex is provided, including recent work and a 'new view' from well-presented aeromagnetic images and interpretations, magnetic susceptibility readings, field observations, and structural synthesis. The assembly of the different domains of the Leeuwin Complex, and the implications for Gondwana assembly, and also breakup, are discussed. The field localities cover the entire region, from Cape Leeuwin through to exposure of the Bunbury Basalt at Bunbury. This trip provided participants an opportunity to catch up with the latest work and ideas, which highlighted the differences in age and tectonic history between the various crustal entities that make up the Leeuwin Complex. It was also an opportunity to view and discuss complexities in gneissic rocks.

The following publications related to the conference are available as free downloadable PDFs from <www.dmp.wa.gov.au/ebookshop>:

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

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

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

For more information, contact Catherine Spaggiari (catherine.spaggiari@dmirs.wa.gov.au).

Geophysical verification of geological cross-sections

Every map shows more than just the surface geology. It may not be apparent, but when geologists draw cross-sections for 1:100 000 or 1:250 000 scale maps, they are thinking about the three-dimensional structure of the area. They express this by creating a geological cross-section down to a depth of 4 km. What constraints do they have? Dips and strikes of the rocks give an estimation of the general orientation of the geological bodies but how far down do these constraints go? Are repeated units representative of synclines, anticlines or faults? Are there likely to be units present at depth, which are not seen at the surface?

Geologists can test their hypotheses using forward modelling of high-resolution airborne magnetic surveys and gravity data. Different rocks have different densities and hence, the gravitational attraction varies over them with high-density rocks producing a positive gravity anomaly. Likewise some rocks are magnetic and cause distinctive features in the magnetic image over an area. In forward modelling, the gravity or magnetic anomaly along a profile is extracted. Geologists then try to match the geological concept in the section to the gravity or magnetic anomaly. Sometimes additional data, such as hand-specimen density or magnetic-susceptibility measurements, add other constraints to the model.

GSWA Record 2017/13 is the first volume of forward-modelled sections compiled from recently published 1:100 000 Geological Map series and selected deep crustal seismic reflection lines.

Each profile contains a short geological and structural introduction, a brief résumé of some of the modelling parameters and an explanation of the forward-modelled geology. Figure 1 shows the cross-section from the map, the extracted observed gravity and magnetic anomalies along the section line, the density and susceptibility profiles, and the anomalies calculated from the density and susceptibility models. This is so comparisons can be made about how closely these models come to fitting the observed data. Of course, no model is perfect. There are always ambiguities and trade-offs between spatial extent and depth of distinct features and their density and susceptibility, but what is presented is a consistent model which fits as closely as possible to all known constraints and hypotheses.

A second volume of forward-modelled sections covering the latest 1:100 000 and 1:250 000 Geological Series maps will be published in 2018.

Record 2107/13 Compilation of geophysical modelling records, 2017 is available as a free downloadable PDF from <www.dmp.wa.gov.au/ebookshop>.

For more information, contact Ruth Murdie (ruth.murdie@dmirs.wa.gov.au).

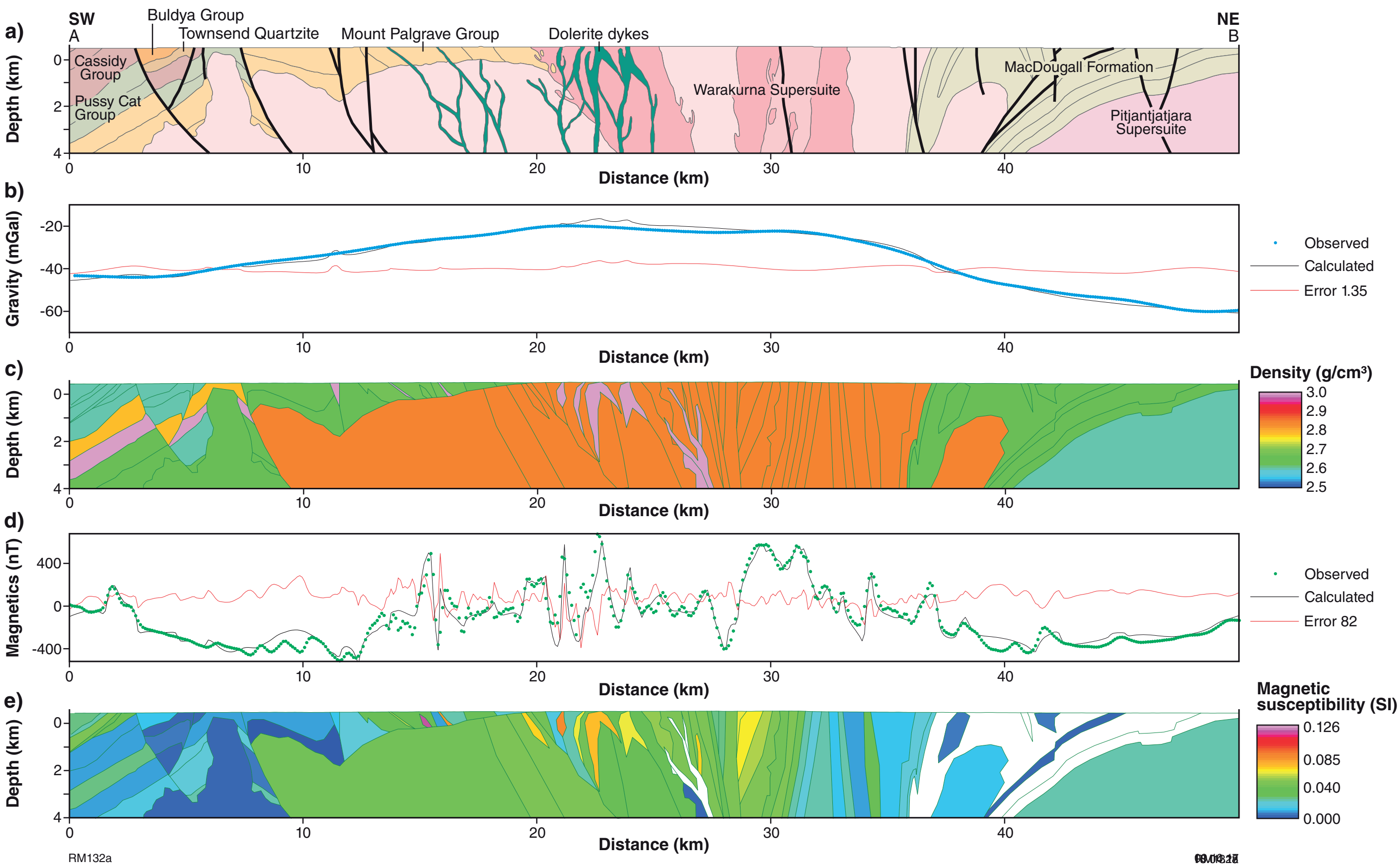


Figure 1. Profile of section A–B showing: a) lithological section from Golden Point Geological Series map; b) observed and calculated Bouguer anomaly profile with error line; c) section of density per lithology; d) observed and calculated magnetic anomaly profile with error line; e) section of magnetic susceptibility per lithology

Ore fertility indicators in Archean granites

In Phanerozoic porphyry Cu±Mo±Au systems, mineralized magmatic rocks have distinctive whole-rock and zircon geochemical signatures that can be attributed to high magmatic water and sulfur contents and high oxidation states, and can be used as ore fertility indicators.

Are these indicators applicable to Archean granites? The Geoscience and Resource Strategy Division (formerly known as the Geological Survey of Western Australia) is addressing this question by studying the whole-rock geochemical and zircon trace element compositions of Archean granitic rocks in Western Australia.

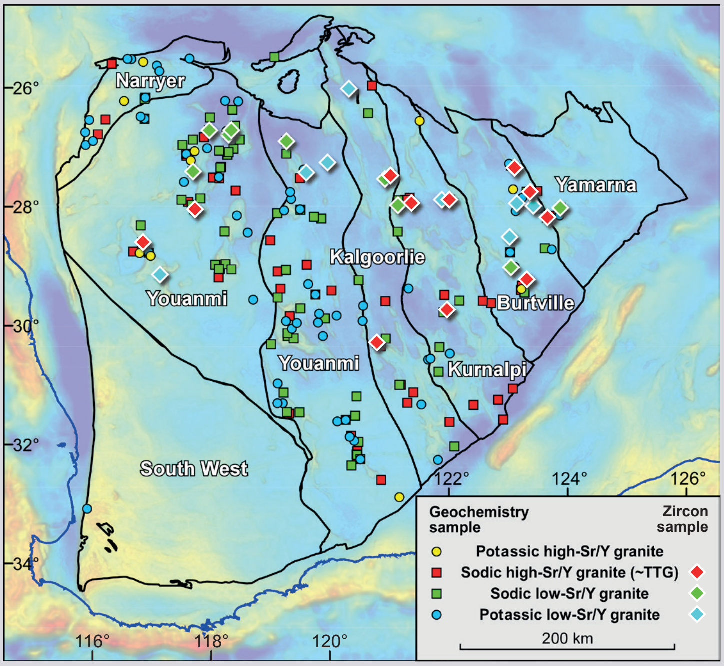


Figure 1. Granite whole-rock and zircon sample locations superimposed on a gravity image of the Yilgarn Craton, labelled by terrane

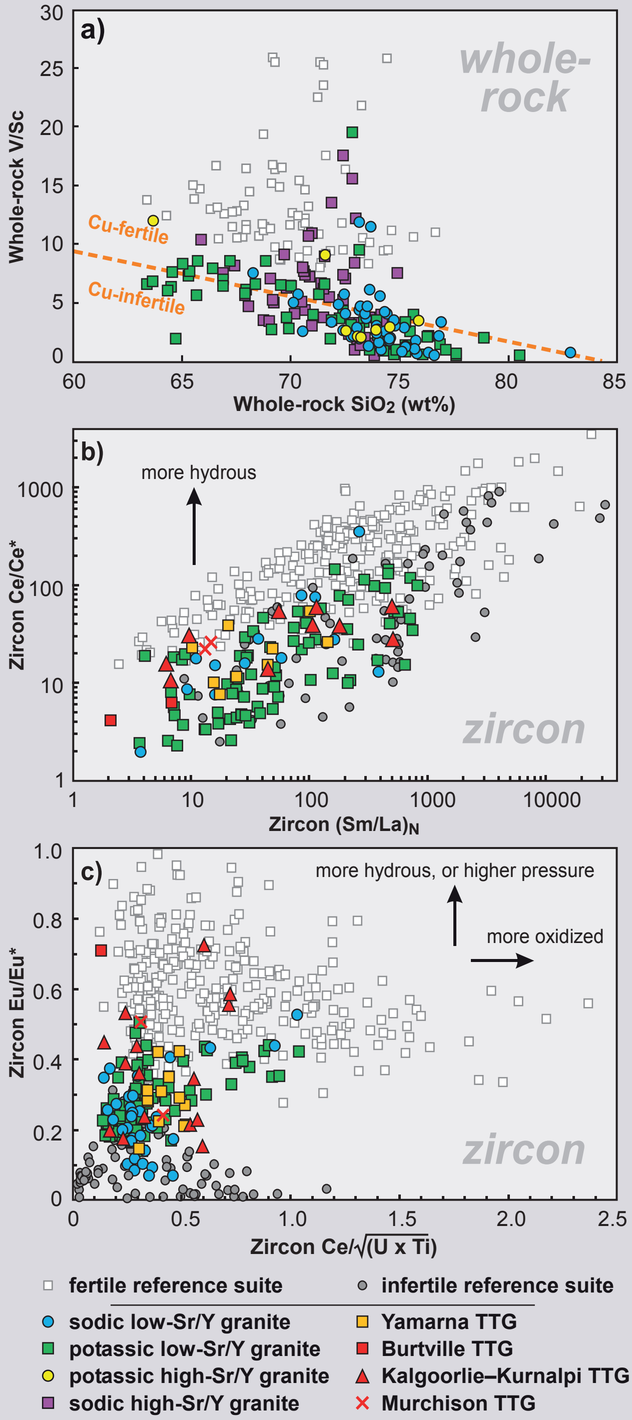


Figure 2. Granite whole-rock and zircon compositions of Yilgarn granites and Phanerozoic fertile and infertile suites

An initial comparison of 230 granites and 30 granite zircon samples from across the Yilgarn Craton (Fig. 1) with well-characterized Miocene Cu-mineralized granites in the Lhasa Terrane of southern Tibet (Lu et al., 2015, Geology, v. 43, p. 583– 586) indicates that many Yilgarn granites are less hydrous and less oxidized than Phanerozoic Cu-mineralized granites.

Systematic differences in whole-rock and zircon chemistry between Yilgarn granites and Phanerozoic fertile and infertile suites (Fig. 2) imply that different processes were involved in forming Archean granites. We suggest that Archean high-Sr/Y granites were formed mainly through infracrustal partial melting of mafic lower crust in the garnet stability field, whereas Phanerozoic fertile suites were formed by intracrustal amphibole-dominated fractionation of mafic magmas. Granites formed by the former process have lower potential for porphyry Cu mineralization due to insufficient water and the lack of copper and sulfur accumulation in the melt.

The study so far has not included Archean granites associated with mineralization. We are currently studying additional granites in the South West Terrane, and will extend analyses to porphyry-style mineralized granites in the Yilgarn and Pilbara Cratons, such as those at Boddington, Calingiri, Katanning and Coppin Gap. This will assess potential differences between mineralized and nonmineralized Archean granites, and may lead to ways of identifying additional granites that have potential for porphyry-style mineralization.

For more information, see **GSWA Record 2018/2 GSWA 2018 extended abstracts: promoting the prospectivity of Western Australia**, p. 18–23, or contact Yongjun Lu (yongjun.lu@dmirs.wa.gov.au).

Passive seismic study leads to detection of a Moho trough

The 70-station ALFREX (**AL**bany–**FR**aser **EX**periment) array was designed to extend across the northeasterly trending tectonic units that make up the east Albany–Fraser Orogen (AFO), with a roughly uniform station spacing of about 40 km. Seismic recording kits were deployed in two phases from November 2013 to January 2016 to record teleseismic signals from distant earthquakes, and the constant background reverberations caused by the interaction of land and ocean (ambient noise). The receiver function technique was used to examine crustal depth and velocities, and ambient noise tomography was performed to produce maps of phase and group velocities. Together, the processing and analysis of these datasets have produced the first detailed maps of crustal thickness, V_P/V_S ratios, and upper crustal surface-wave velocities for the region. In addition, several Common Conversion Point (CCP) stacking profiles show the details of regional Moho topography.

One of the most significant results is the detection of a region of thicker crust that is parallel, or slightly oblique to, the trend of the orogen (Fig. 1). The Moho geometry changes from a V-shaped trough in the north of the study area, to a one-sided, discontinuous geometry in the southwest. The maximum crustal thickness near the tip of the V is approximately 50 km, compared to 35–40 km in the Yilgarn Craton to the northwest, and below the eastern Nornalup Zone to the southeast, where the Moho is horizontal. Within the upper crust, the Fraser Zone exhibits elevated V_P/V_S ratios (~1.8) as well as a prominent high-wavespeed surface-wave velocity anomaly, both indicative of the presence of dense metamorphic rocks overlying the Moho trough in this region. The Fraser Zone extends to greater depths near its southern termination, compared to where it has been imaged with active seismic methods along the Trans-Australian Railway (seismic line 12GA-AF3; GSWA Record 2014/6).

In conjunction with constraints from active seismic and gravity data, these findings imply that the imaged Moho structure could be due to incomplete crustal wedge indentation during a compression event. That event was likely Stage I of the Albany–Fraser Orogeny, triggered by the accretion of the Loongana Arc from the east between 1389 and 1330 Ma. The imaged lower crustal geometry may explain the presence and extent of exhumed rocks of mid- to lower-crustal affinity of the Fraser Zone, as well as the westward cessation of voluminous granite intrusions of the Recherche and Esperance Supersuites.

GSWA Report 177 Crustal and uppermost mantle structure of the east Albany–Fraser Orogen from passive seismic data is available as a free downloadable PDF from <www.dmp.wa.gov.au/ebookshop>.

This work was a collaborative project with the seismology group at the Australian National University, funded through ARC Linkage Grant LP130100413 and the Western Australian Government Exploration Incentive Scheme (EIS).

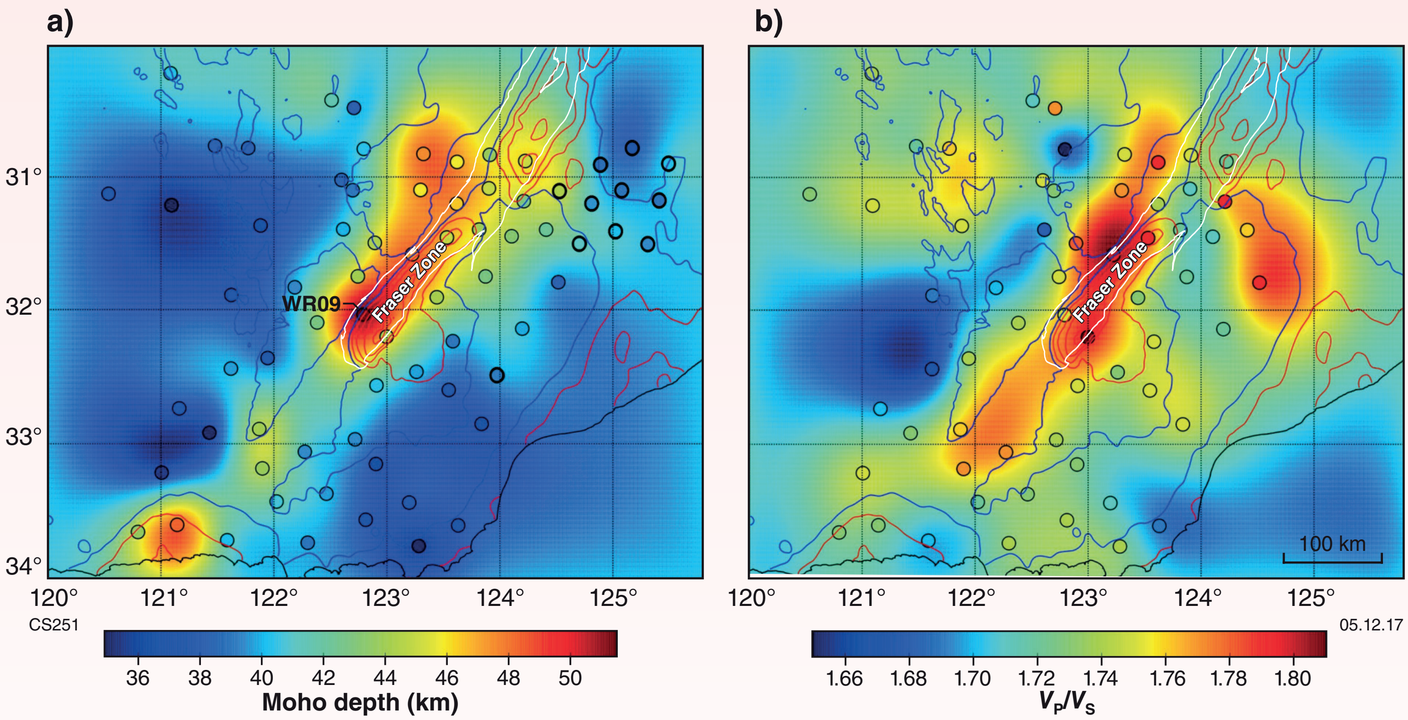


Figure 1. Comparison of interpolated Moho depth and V_P/V_S ratios: a) interpolated Moho depth map. Circles with a thick black outline denote stations for which the Moho depth estimate was calculated using autocorrelations rather than receiver functions; these stations do not have corresponding V_P/V_S ratio values; b) V_P/V_S ratio map. Coloured dots represent values obtained from seismic stations. Colours of the background map are an interpolation between these values. Bouguer gravity anomaly isolines are superimposed as blue (representing negative gravity anomalies) and red (representing positive anomalies) lines

EXPLORATION INCENTIVE SCHEME

Australian National University

ANSIR NATIONAL RESEARCH FACILITY FOR EARTH SOUNDING

Australian Government
Australian Research Council

GSWA regional geophysics surveys: 16 April 2018 update

Data downloads

Located data — Geophysical Archive Data Delivery System <www.ga.gov.au/gadds>.

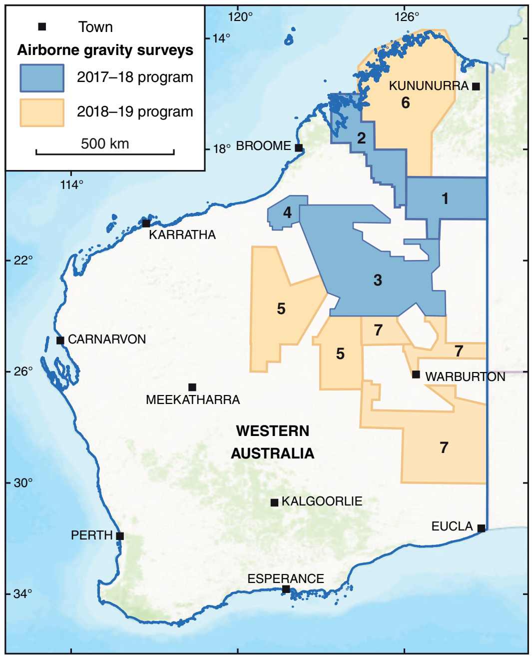
Grids and images — search in GeoVIEW.WA under Government Surveys layers.

Subscribe to the GSWA eNewsletter for alerts of preliminary and final data release dates. Go to <www.dmp.wa.gov.au/gswaenewsletter>.

Survey outline shapefiles are available online at <www.dmp.wa.gov.au/geophysics>.

For more information, contact David Howard (david.howard@dmirs.wa.gov.au).

EXPLORATION INCENTIVE SCHEME



SHDH68 13.04.18

ID	Area/Name	Line direction	Size (km)	Status	Start	End	Release
1	Tanami 2017	N-S	26 000	Release	15-06-17	13-08-17	12 Apr-18
2	NE Canning 2017	N-S	24 000	Release	17-08-17	15-11-17	12 Apr-18
3	Kidson 2017	N-S	70 000	Survey 90%*	21-07-17	(May-18)	(Jun-18)
4	Kidson extension 2018	E-W	5 500	Survey 80%	02-04-18	(Apr-18)	(Jun-18)
5	Little Sandy Desert 2018	N-S	52 000	Mobilization	(Apr-18)	(Oct-18)	(Feb-19)
6	Kimberley Basin 2018	N-S	61 000	Contract	(May-18)	(Nov-18)	(Feb-19)
7	Warburton – Great Victoria Desert 2018	E-W N-S	62 000	Contract	(May-18)	(Nov-18)	(Feb-19)

* Preliminary data as Bouguer anomaly grids and images available for part-area Kidson survey

Dates in parentheses are estimates.

GSWA Open Day 2018

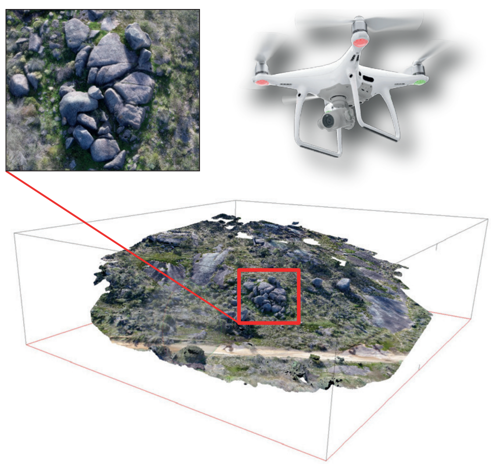
Another successful display of achievements in geoscience

This year's GSWA Open Day, held on Friday 23 February, hosted over 120 people from the Western Australian exploration and mining industries, and from local research organizations. Geoscientists were on hand in front of an extensive poster display to discuss their activities and the results of collaborative research. There were 11 presentations concerning a diverse array of work areas including new geological findings in the Yilgarn Craton, Pilbara Craton, Fortescue and Hamersley Basins and Canning Basin. Other talks focused on the occurrence of gold nuggets in the Kurnalpi Goldfield, the composition of zircon in Archean granites, airborne gravity mapping, and on the occurrence of battery metals and diamonds.

Raphael Quentin de Gromard attracted much interest with a live demonstration of high-resolution 3D photogrammetry models of outcrops obtained from a Remotely Piloted Aircraft (RPA or drone). Around 70 people viewed the demonstration, which exhibited the great potential of this new tool to improve mapping and structural analysis.

Attendees were given the opportunity to interact directly with online systems including the Data and Software Centre and the interactive map viewers, GeoVIEW.WA and GeoMap.WA. They were also shown how to use the search capabilities of the mineral drillholes and geochemistry databases, and were able to ask individual questions and provide feedback on the online systems.

Find all GSWA Open Day presentations and a link to posters on our website at <www.dmp.wa.gov.au/gswaopenday>.



Product releases

ISSN 1325-9377 ISBN 978-1-74168-818-4 (PRINT)
ISSN 1834-2272 ISBN 978-1-74168-817-7 (PDF)

• REPORTS •

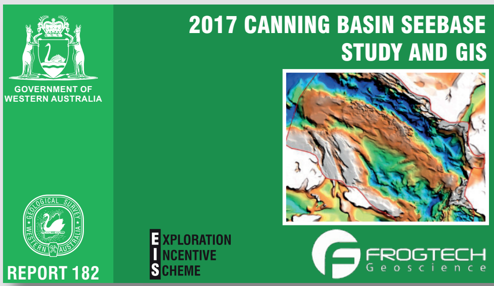
Report 174 A review of palynology from the Harvey region, southern Perth Basin, Western Australia
by Martin, SK

Report 176 Tectono-magmatic evolution of the Neoarchean Yalgoo dome (Yilgarn Craton): diapirism in a pre-orogenic setting
by Zibra, I, Peternell, M, Schiller, M, Wingate, MTD, Lu, Y-J and Clos, F

Report 177 Crustal and uppermost mantle structure of the east Albany–Fraser Orogen from passive seismic data
by Sippl, C, Tkalcic, H, Kennett, BLN, Spaggiari, CV, Gessner, K, Brisbout, L and Murdie, RE

Report 181 New Hf isotopes into the Paleoarchean magmatic evolution of the Mount Edgar Dome, Pilbara Craton: implications for early Earth and crust formation processes (with accompanying ZIP file containing related data files)
by Gardiner, N, Hickman, AH, Kirkland, CL, Lu, Y-J, Johnson, TE and Wingate, MTD

Report 183 Metamorphosed Mesoarchean Cu–Mo–Ag mineralization: evidence from the Calingiri deposits, southwest Yilgarn Craton
by Outhwaite, MD



• RECORDS •

Record 2018/2 GSWA 2018 extended abstracts: promoting the prospectivity of 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
by Glasson, K

Record 2018/6 Post-conference field trip guide: the Leeuwin Complex, Western Australia
by Timms, N

• MAPS •

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

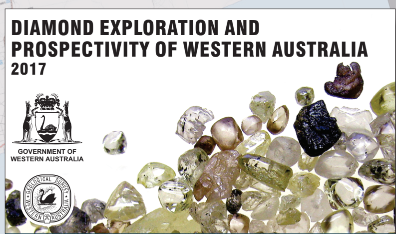
Major resource projects, Western Australia – 2018
by Cooper, RW, Wyche, NL, Strong, CA, Day, LJ, Jones, JA and Irimies, F

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

• DATA PACKAGES•

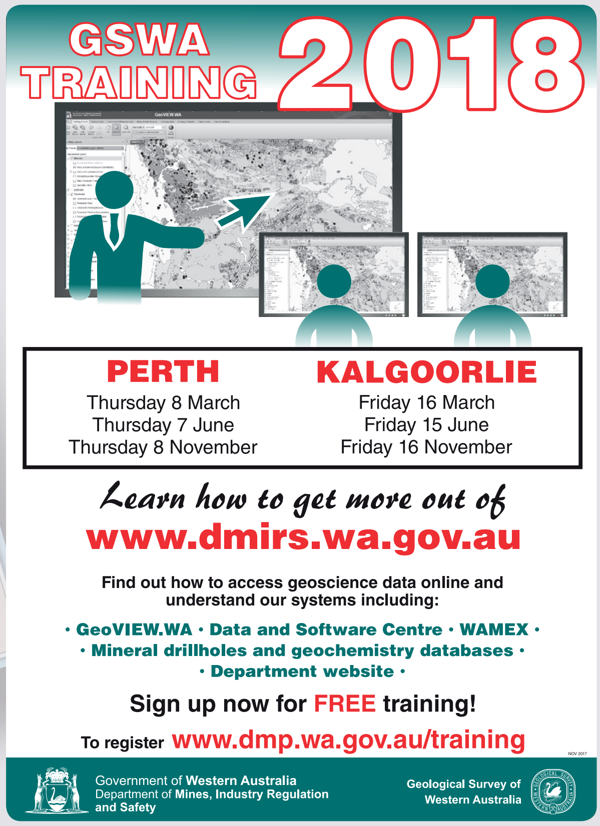
Diamond exploration and prospectivity of Western Australia
by Hutchison, M

Includes:
Report 179 Diamond exploration and prospectivity of Western Australia
Record 2017/16 Data methodologies applied in the Western Australian diamond exploration package



2017 Canning Basin SEEBASE study and GIS data package
by Frogtech Geoscience

Includes:
Report 182 2017 Canning Basin SEEBASE study and GIS data package (and accompanying ZIP file containing extra data)



The Geological Survey of Western Australia (GSWA) has released almost 5000 geological products including books, maps and data packages. These can be found on our website at <www.dmp.wa.gov.au/GSWApublications>.

Maps, USB data packages, and selected premium publications are available to purchase as hard copies via the online cart on the eBookshop at <www.dmp.wa.gov.au/ebookshop>. Alternatively, these products can be purchased from the Information Centre, First Floor, Mineral House, 100 Plain Street, East Perth, WA 6004, Australia, Phone: +61 8 9222 3459; Fax: +61 8 9222 3444.
Records, Reports, Bulletins and non-series books cannot be purchased in hard copy but are all available as PDFs to view, and as a free download.