



Australian Society of
Exploration Geophysicists

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PREVIEW



NEWS AND COMMENTARY

Vale Peter Milligan

New geophysical data released
for Queensland's NW Mineral Province

Exploration expenditure increases

A world without mining

Mapping groundwater in Laos

FEATURES

Preview of *The Australian
continent: A geophysical
synthesis*

Developing metadata
standards for time series
magnetotelluric data

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ASEG CORPORATE PLUS MEMBER

Velseis Pty Ltd
Tel: +61 7 3376 5544
Email: info@velseis.com



ASEG CORPORATE MEMBERS

Archimedes Financial Planning
Contact: Noll Moriarty
Tel: 1300 387 351
Email: Noll.Moriarty@ArchimedesFinancial.com.au



Santos Ltd
Tel: +61 8 8116 5000
Web: https://www.santos.com



Southern Geoscience Consultants Pty Ltd
Tel: +61 8 6254 5000
Email: geophysics@sgc.com.au
Web: http://sgc.com.au/



SAExploration (Australia) Pty Ltd
Contact: Jessica Buttimore
Tel: +61 7 3268 5611
Email: australia@saexploration.com
Web: http://www.saexploration.com/



FRONT COVER



Participants in a Geoscientists without Borders groundwater project in Laos. See *Environmental geophysics* in this issue for more information about this project.

Preview is available online at
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Editor

Lisa Worrall
Email: previeweditor@aseg.org.au

Associate Editors

Education: Michael Asten
Email: michael.asten@monash.edu
Government: David Denham
Email: denham1@inet.net.au
Environmental Geophysics: Mike Hatch
Email: michael.hatch@adelaide.edu.au
Minerals Geophysics: Terry Harvey
Email: terry.v.harvey@glencore.com.au
Petroleum Geophysics: Michael Micenko
Email: micenko@bigpond.com
Geophysical Data Management and Analysis:
Tim Keeping
Email: Tim.Keeping@sa.gov.au
Book Reviews: Ron Hackney
Email: ron.hackney@ga.gov.au

ASEG Head Office & Secretariat

Alison Forton
The Association Specialists Pty Ltd (TAS)
Tel: (02) 9431 8622
Email: secretary@aseg.org.au
Website: www.aseg.org.au

Publisher

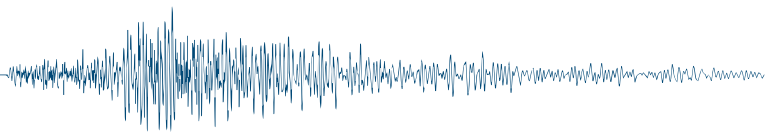
T&F Publishing

Production Editor

Kate Edmonds
Email: Kate.Edmonds@tandf.com.au

Advertising

Email: advertising@taylorandfrancis.com.au



Editor's desk



This issue of *Preview* includes not one but two feature articles. The first, by Brian Kennett, Richard Chopping and Richard Blewett, introduces us to their recently released book *The Australian continent: A geophysical synthesis*. The digital version of this book, and a supplementary image gallery, can be downloaded free of charge (see article for links) – an extraordinary resource available for plundering by us all! The second article,

by Alison Kirkby, expands on a proposal to establish metadata standards for time series MT. Feedback is invited, as the MT community wants to get this right.

In addition, our regular commentators continue to surprise and delight. David Denham (*Canberra observed*) gives us some good news on exploration expenditure before casting his beady eye over what the major parties are likely to offer the resources sector during the upcoming federal election. Michael Asten (*Education matters*) reports on the mentoring of early-career professionals in WA. Mike Hatch (*Environmental geophysics*) takes us inside a Geoscientists without Borders project mapping groundwater in Laos. Terry Harvey (*Minerals geophysics*) offers us an insight into a Brave New World without mining – a surprisingly brave contribution! Mick Micenko (*Seismic window*) advises on footprint removal. Tim Keeping (*Data trends*) considers machine learning and Dave Annetts (*Webwaves*), in a final salvo, adjures us to take password security seriously. Dave is leaving the position of ASEG Webmaster,

after four years, and his replacement will be introduced in the next issue of *Preview*. His replacement does deserve our sympathy as Dave will be a hard act to follow.

Finally, in a first for *Preview*, we are challenging our readers with a crossword. This crossword was devised by an ASEG Member, who wishes to remain anonymous so that he can't be bribed for the solution. And bribery is a possibility as the first ASEG Member to submit a correct entry will win two Hoyts E- CINEGIFT passes! Our crossword maestro is already working on the next ASEG crossword, and is certain to up the ante with more challenging clues, so consider this introductory crossword a warmup. The answers and the winner will be published in the next edition of *Preview*.

Enjoy!

Lisa Worrall
Preview Editor
previeweditor@aseg.org.au



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President's piece

Welcome to this edition of *Preview*. I want to spend a moment remembering a very special colleague and friend, Dr Peter Milligan. I met Peter in the early 90s and worked with him right up until late February. What a sad and sudden loss to the world-wide geophysical community. Peter was a quiet achiever. A few highlights: he led the production of the Magnetic Anomaly Map of the Australia, and the incorporation of the Australian magnetic map into the World Digital Magnetic Anomaly Map and published the first Elevation Image Map of Australia. Internationally, Peter has been associated with, and was on the Task Force and Executive Committee of, the World Digital Anomaly Map (WDMAM) under the Working Group V-MOD of the International Association of Geomagnetism and Aeronomy (IAGA). He was present at the first release of this map in Italy in 2007 and, in connection with world map development, attended subsequent meetings of the IAGA and the International Union of Geodesy and Geophysics. Peter was also very active in the magnetotelluric community, and since 2010 represented Australia at the Electromagnetic Induction workshops of the IAGA in Egypt, Australia (Darwin) and Germany. Peter was a long term ASEG ACT Branch committee member and Treasurer, editor, conference organiser and prolific scientific writer. His contributions to science, geophysics, and the exploration industry have been truly significant, world-wide and long lasting. He was a humble, approachable and kind, a mentor, friend and colleague. To those of you who feel his loss as keenly as I do, know you are not alone. *Vale* Peter Milligan.

This is my last President's Piece in *Preview*, thank you all very much for your support over the past 12 or so months. We will be welcoming Dr Ted Tyne in as our new President at the AGM in early April. Dr Tyne brings a wealth of experience in government, industry and academic networks to our Society. Many of you would know Ted from his various roles in the Geological Survey of NSW, in industry and as a former Director of the GSNSW. Ted retired in 2017 after 12 years as head of the South Australian Mineral Resources agency, and continues to support the industry as the independent Chair of SA's Magnetite Strategy. Please join with me in welcoming him to his new role.

A quick look back at the last year has me feeling very grateful. I have visited most State / Territory branches, met you at AEGC

in Sydney or at AGCC in Adelaide, spoken to you about geophysics, diversity or mentoring (or all three) and feel connected to you even if we only caught up by phone, email or zoom. In the past 12 months the Federal Executive have navigated safely into a new publication arrangement with Taylor and Francis, signed new memorandum of understandings with Korea and Japan, supported graduates with a new subsidised membership level, increased awareness of the Society through social media, and started a monthly membership newsletter. We updated the constitution for secure electronic voting, and removed gendered language. These two modernisations are best practice changes that will benefit the Society into the future. There has been significant, new and important updates made to the ASEG website, and we have grown our relationships with our affiliate organisations and associated societies - which I feel opened the opportunity for me to represent earth science and geography on the Science and Technology Board. Early in 2018 we had over 60 action items on our 'to do list', and this month there are less than 15. Running a not-for-profit organisation is definitely very exciting, but at times challenging!

One of the last things I hope to achieve as President is a Directors Forum. Previous Federal Executive directors and conference organisers are being invited to join the Forum, which will form a 'brains trust' to ensure the future success of the association. If you are a former director on the Federal Executive and would like to be a part of the Directors Forum please email secretary@aseg.org.au to register. The terms and references of the forum will be the first item the group will establish.

I applaud the State and Territory branches who run events, organise conferences and mentor our Members. The value you provide to our Members is gold. Thank you for your time volunteering, and for making our learned Society relevant, dynamic, diverse and skilled. Thank you also to our valued, long time, corporate sponsors; Velseis, Santos, Archimedes and Southern Geoscience.

The ASEG AGM is early April in 2019, and we will be saying thank you to Katherine McKenna, Andrea Rutley and Kim Francombe for their many years of support, time and expertise on the Fed Ex. We welcome some new members

to the Fed Ex, so look out for an update in the next edition. A big thank you as always to Lisa Worrall and her editorial team for delivering *Preview* magazine, and to the web team for modernising the delivery of *Preview* using 'flip book'. A big thank you to Mark Lackie for driving *Exploration Geophysics*. Thank you also to TAS, in particular Alison Forton, for all of your secretariat support – priceless!

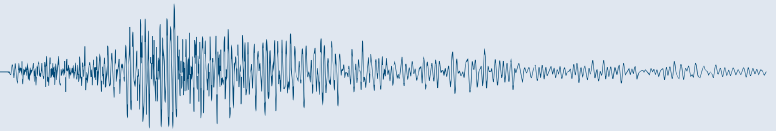
There is a lot of good news too, with Rio Tinto announcing its Winu Project in the Paterson region, just one of what felt like a large number of good news reports to the ASX. The Federal Government's release of Australia's National Resources Statement is more good news. If you haven't read it, here is the link <https://www.industry.gov.au/data-and-publications/australias-national-resources-statement>. Excitement around critical commodities is growing, with Australia being a major player on the world stage. Minister Canavan released a Critical Minerals report <https://www.ga.gov.au/criticalminerals> in mid-March, it is an interesting read. The Minerals Council of Australia also reported "In 2018, Australia's mineral exploration expenditure totalled \$2.2 billion – an increase of 24% – with gold attracting most of this investment. Gold exploration accounted for 41% of all mineral exploration expenditure or \$891 million." I hope that this means great opportunities for us all.

A super big thank you to the current Federal Executive – what a great team to work with. Remember 2020 is our 50th anniversary, I can't wait!

Marina Base over and out.



Marina Costelloe
ASEG President
president@aseg.org.au



ASEG federal executive 2017–18

Marina Costelloe: President
Tel: (02) 6249 9347
Email: president@aseg.org.au

Ted Tyne: President Elect (Publications Committee Co-Chair, ASEG Research Foundation)
Tel: 0434 074 123
Email: president-elect@aseg.org.au

Megan Nightingale: Secretary (Young Professionals Network)
Tel: 0438 861 556
Email: fedsec@aseg.org.au

Danny Burns: Treasurer (Finance Committee Chair)
Tel: 0407 856 196
Email: treasurer@aseg.org.au

Andrea Rutley: Past President (Promotions Committee Chair)
Tel: (07) 3834 1836
Email: pastpresident@aseg.org.au

Katherine McKenna: (International Committee)
Tel: 0400 594 220
Email:

Kim Frankcombe (AGC Representative, Conference Advisory Committee and Technical Standards Committee)
Tel: (08) 6201 7719
Email: kfrankcombe@iinet.net.au

Marina Pervukhina (Professional Development Committee Chair, State Branch Representative, Specialist and Working Groups Liaison)
Tel: (08) 6436 8746
Email: branch-rep@aseg.org.au

David Annetts (Web Committee Chair)
Tel: (08) 6436 8517
Email: david.annetts@csiro.au

Kate Robertson (Communications Committee)
Tel: (08) 8429 2564
Email: communications@aseg.org.au

Leslie Atkinson (Membership Committee)
Tel: 0414 804 028
Email: membership@aseg.org.au

Andrew Squelch (Education Committee Chair)
Tel: (08) 9266 2324
Email: education@aseg.org.au

Standing committee chairs

Finance Committee Chair: Danny Burns
Tel: 0407 856 196
Email: treasurer@aseg.org.au

Membership Committee Chair: Leslie Atkinson
Tel: 0414 804 028
Email: membership@aseg.org.au

State Branch Representative: Marina Pervukhina
Tel: (08) 6436 8746
Email: branch-rep@aseg.org.au

Conference Advisory Committee Chair: Michael Hatch
Email: cac@aseg.org.au

Honours and Awards Committee Chair: Andrew Mutton
Tel: 0408 015 712
Email: awards@aseg.org.au

Publications Committee Chairs: Danny Burns and Ted Tyne
Tel: 0407 856 196 and 0434 074 123
Email: publications@aseg.org.au

Technical Standards Committee Chair: Tim Keeping
Tel: (08) 8226 2376
Email: technical-standards@aseg.org.au

ASEG History Committee Chair: Roger Henderson
Tel: 0406 204 809
Email: history@aseg.org.au

International Affairs Committee Chair: Nick Direen
Tel: –
Email: international@aseg.org.au

Professional Development Committee Chair: Marina Pervukhina
Tel: (08) 6436 8746
Email: continuingeducation@aseg.org.au

Education Committee Chair: Andrew Squelch
Tel: (08) 9266 2324
Email: education@aseg.org.au

Web Committee Chair: David Annetts
Tel: (08) 6436 8517
Email: david.annetts@csiro.au

Research Foundation Chair: Philip Harman
Tel: 0409 709 125
Email: research-foundation@aseg.org.au

Communications Committee Chair: Kate Robertson
Tel: (08) 8429 2564
Email: communications@aseg.org.au

Specialist groups

Near Surface Geophysics Specialist Group President: David Annetts
Tel: (08) 6436 8517
Email: nsgadmin@aseg.org.au

Young Professionals Network President: Megan Nightingale
Tel: 0438 861 556
Email: ypadmin@aseg.org.au

ASEG branches

Australian Capital Territory
President: Grant Butler
Tel: (02) 6249 9640
Email: actpresident@aseg.org.au
Secretary: Phil Wynne
Tel:
Email: actsecretary@aseg.org.au

New South Wales
President: Mark Lackie
Tel: (02) 9850 8377
Email: nswpresident@aseg.org.au
Secretary: Steph Kovach
Tel: (02) 8960 8443
Email: nswsecretary@aseg.org.au

Queensland
President: Ron Palmer
Tel: 0413 579 099
Email: qldpresident@aseg.org.au
Secretary: James Alderman
Tel: –
Email: qldsecretary@aseg.org.au

South Australia & Northern Territory
President: Kate Robertson
Tel: (08) 8429 2564
Email: sa-ntpresident@aseg.org.au
Secretary: Ben Kay
Tel: –
Email: sa-ntsecretary@aseg.org.au

NT Representative:
Tania Dhu
Tel: 0422 091 025
Email: nt-rep@aseg.org.au

Tasmania
President: Mark Duffett Tel: (03) 6165 4720
Email: taspresident@aseg.org.au
Secretary: Matthew Cracknell
Tel: 0409 438 924
Email: tassecretary@aseg.org.au

Victoria
President: Seda Rouxel
Tel: 0452 541 575
Email: vicpresident@aseg.org.au
Secretary: Thong Huynh
Tel: –
Email: vicsecretary@aseg.org.au

Western Australia
President: Heather Tompkins
Tel: +61 413 687 050
Email: wapresident@aseg.org.au
Secretary: Matt Owers
Tel:
Email: wasecretary@aseg.org.au

The ASEG Secretariat
Alison Forton The Association Specialists Pty Ltd (TAS) PO Box 576, Crows Nest, NSW 1585
Tel: (02) 9431 8622
Fax: (02) 9431 8677
Email: secretary@aseg.org.au

Executive brief

The Federal Executive of the ASEG (FedEx) is the governing body of the ASEG. It meets once a month, via teleconference, to see to the administration of the Society. This brief reports on the monthly meetings that were held in February and March 2019. We hope you find these short updates valuable. If there is more you would like to read about on a regular basis please contact Megan on fedsec@aseg.org.au

Finances

The Society's financial position at the end of January 2019:

Year to date income: \$100 496

Year to date expenditure: \$14 393

Net Assets: \$831 452

Membership

At the time of this report, the Society had 671 Members. This is up 0.3% from the same time last year. Overall membership numbers are down with 32% of Members yet to renew in 2019. If you're reading this and you haven't renewed your membership yet – please do! Thanks to all our renewed Members and Corporate Members for their continued support in 2019.

There are many avenues to stay connected with ASEG including this brilliant magazine, our fantastic website and our wonderful newsletter. You can also follow us on social media – search for Australian Society of Exploration Geophysics. We are on LinkedIn, Twitter and Facebook.

Please also remember early and mid-career members can join the ASEG Young Professional Network <https://www.aseg.org.au/about-aseg/aseg-young-professionals>.

Survey

In the near future you will receive a short membership survey. Your feedback is important to the Federal Executive and we appreciate you taking the time to complete the survey.

Megan Nightingale

Secretary

fedsec@aseg.org.au

Notice of Annual General Meeting (AGM)

The 2019 AGM of the Australian Society of Exploration Geophysicists (ASEG) will be held at Geoscience Australia in Canberra on April 4 2019. The meeting will be hosted by the ACT Branch. Details will be supplied via email. Drinks will be available from 16.00 and the meeting will begin at 16.30.

The business of the Annual General Meeting will be:

- To confirm the minutes of the last preceding general meeting;
- To receive from the Federal Executive reports on the activities of the Society during the last preceding financial year;
- To receive and consider the financial accounts and audit reports that are required to be submitted to Members pursuant to the Constitution and to law;
- To consider and if agreed approve any changes to the ASEG Constitution;
- To report the ballot results for the election of the new office holders for the Federal Executive;
- To confirm the appointment of auditors for 2018.

The AGM will be preceded by a scientific presentation. Dr Steve Hill, Chief Scientist at Geoscience Australia, will be the guest speaker and there are plans underway to have the talk live-streamed.

Invitation for candidates for the Federal Executive

Members of the Federal Executive serve in an honorary capacity. They are

all volunteers and ASEG Members are encouraged to consider volunteering for a position on the Executive or on one of its committees. Current members are listed in *Preview*; please contact one of them if you wish to know more about volunteering for your society. Self-nominations are encouraged.

In accordance with Article 8.2 of the ASEG Constitution '... The elected members of the Federal Executive are designated as Directors of the Society for the purposes of the [Corporations] Act.'

The Federal Executive comprises up to 12 members, and includes the following four elected members:-

- (i) a President,
- (ii) a President Elect,
- (iii) a Secretary, and
- (iv) a Treasurer.

These officers are elected annually by a general ballot of Members. Dr Ted Tyne was elected as President-Elect in 2018 and as such will stand for the position of President.

The following offices are also recognised:

- (i) Vice President,
- (ii) the Immediate Past President (unless otherwise a member of the Federal Executive),
- (iii) the Chair of the Publications Committee,
- (iv) the Chair of the Membership Committee,

- (v) the Chair of the State Branch Committees, and
- (vi) up to three others to be determined by the Federal Executive.

These officers are appointed by the Federal Executive from the volunteers wishing to serve the Society.

Nominations for all positions (except Past President) are very welcome. Please forward the name of the nominated candidate and the position nominating for, along with the names of two Members who are eligible to vote (as Proposers), to the Secretary:

Megan Nightingale

ASEG Secretary
Care of the ASEG Secretariat
PO Box 576
Crows Nest
NSW, 1585
Tel: (02) 9431 8622
Fax: (02) 9431 8677
Email: fedsec@aseg.org.au

Nominations must have been received via post, fax or email no later than COB Tuesday 7th March 2019. Positions for which there are multiple nominations will then be determined by ballot of Members and the results declared at the Annual General Meeting.

Proxy forms and further details of the meeting will be sent to Members prior to the meeting by email, and made available to Members on the Society's website.



Welcome to new Members

The ASEG extends a warm welcome to 20 new Members approved by the Federal Executive at its February and March meetings (see Table).

First name	Last name	Organisation	State	Country	Membership type
Claudia	Bowman	Monash University	VIC	Australia	Student
Ristch	Camille	Newmont Australia	WA	Australia	Active
Ross	Chandler	University of Sydney	NSW	Australia	Student
Thomas	Cotter	University of Queensland	QLD	Australia	Student
Joshua	Denholm	University of Tasmania	TAS	Australia	Student
Tom	Dronfield	Resource Potentials	WA	Australia	Graduate
Alex	Ip	Geoscience Australia	ACT	Australia	Active
Caitlin	Jarvis	Curtin University	WA	Australia	Student
Louis	Johansson	University of Sydney	NSW	Australia	Student
Thomas	Klein	Bowdens Silver Pty Ltd	NSW	Australia	Active
Irene	Koutsoumbis	University of Sydney	NSW	Australia	Student
Benjamin	Kowaluk	University of Tasmania	TAS	Australia	Student
Gracjan	Lambert	Red Emperor Resources	WA	Australia	Active
Emma	Lewis	University of Queensland	QLD	Australia	Student
Jiabin	Liang	Curtin University	WA	Australia	Student
Angela	Rodrigues	Monash University	VIC	Australia	Student
Teagan	Romyn	University of Adelaide	SA	Australia	Student
Matthew	Sultani	University of Melbourne	VIC	Australia	Student
Cheesin	Tan	HiSeis Pty Ltd	WA	Australia	Active
Owen	Welsh	University of Queensland	QLD	Australia	Student

ASEG national calendar: technical meetings, courses and events

Date	Branch	Event	Presenter	Time	Venue
4 Apr	ACT	National AGM	Steve Hill	1600	Sir Harald Raggatt Theatre, Geoscience Australia, Symonston
10 Apr	WA	Tech night	Wayne Pennington	TBA	TBA
17 Apr	NSW	AGM	Marina Costelloe	1730	99 on York Club, 99 York Street, Sydney
25 Apr	WA	IMP	Self awareness workshop	TBA	TBA
8 May	WA	Tech night	TBA	TBA	TBA
15 May	NSW	AGM	Doug Morrison	TBA	99 on York Club, 99 York Street, Sydney
30 May	WA	IMP	Networking event	TBA	TBA
12 Jun	WA	Tech night	Tim Dean	TBA	TBA
19 Jun	NSW	AGM	John Triantafilis	TBA	99 on York Club, 99 York Street, Sydney
27 Jun	WA	IMP	Mentors only panel session	TBA	TBA
18 Jul	WA	IMP	Mentees only panel session	TBA	TBA
18 Aug	WA	IMP	Communication and public speaking	TBA	TBA
31 Oct	WA	IMP	Leadership and decision making workshop	TBA	TBA
5 Dec	WA	IMP	Close out event and wrap up	TBA	TBA

TBA, to be advised (please contact your state Branch Secretary for more information).

ASEG Young Professionals Network: An update

The joint ASEG/PESA QLD Mentoring Programme was launched on Friday 15 February. We'd like to extend a very BIG THANK YOU to our amazing ASEG President Marina Costelloe for attending the launch and sharing her story and her views on successful mentoring. The information Marina provided was invaluable and empowering, and was delivered in a compelling manner. We would recommend all who have an opportunity to see Marina present in the future, or to attend her workshop to be held at the upcoming AEGC this September, to do so. The QLD Mentoring programme has matched eight mentor/mentee pairs and will run through until the end of September 2019. A mid-year networking event is scheduled for May 2019, more updates to come throughout the year.



Members socialising after the launch of the joint ASEG/PESA QLD Mentoring Programme.

The combined ASEG/PESA YP group in Victoria will be hosting a Seismic and Sequence Stratigraphy course from April 15–17. The course is free to YPs and will be presented by Rob Kirk, who is a recognised expert in the field (<https://www.robkirkconsultants.com.au/>).

Also, we've reserved Tuesday 2 April from 6pm to review our mentoring scheme and plan YP activities for the rest of the year. This will begin at the Karoon Energy offices and be followed by networking and drinks at a nearby watering hole sponsored

by QIntegral, a new Melbourne-based geophysical service provider.

Megan Nightingale and Jarrod Dunne
ASEG Young Professionals Network
ypadmin@aseg.org

2019 ASEG Honours and Awards: Nominations closing soon



A reminder to all Members that nominations are open for the next series of ASEG Awards, which are scheduled to be presented in conjunction with AEGC 2019, which will be held 2–5 September 2019 in Perth,

Western Australia. Nominations will be closing in July.

All ASEG Members as well as State and Federal executives are invited to nominate those they consider deserving for the following awards:

ASEG Gold Medal

Honorary Membership

Grahame Sands Award

Lindsay Ingall Memorial Award

Early Achievement Award

ASEG Service Awards

Details of all award criteria and nomination guidelines can be found on the ASEG website at: <https://www.aseg.org.au/about-aseg/honours-awards>

Further information and *pro forma* nomination forms are also available by emailing the Chair, ASEG Honours and Awards Committee: awards@aseg.org.au

Andrew Mutton
Honours and Awards Committee Chair
awards@aseg.org.au



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Australasian Exploration Geoscience Conference
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Incorporating the AIG, ASEG, PESA, and WABS

**The Leading Exploration
Geoscience Conference
in Asia-Pacific**

ASEG Branch news

Australian Capital Territory

After a quiet January holiday period, we hosted two speakers in the first week of February. Dr **Tim Dean** of Curtin University, WA, gave us a detailed and critical summary of the cutting-edge equipment currently available to the land seismic industry, both source and receiver. Tim's extensive collection of hardware was of great interest to the group and was an eye-opener for those who had not been involved with seismic acquisition recently.

Later in the week we had a visit from **Geoff McNamara** of MSATT Astronomy, a programme with a dedicated observatory at Mount Stromlo (the McNamara-Saunders Astronomical Teaching Telescope), offering students in Years 9 to 12 the opportunity to undertake extended student-centred projects in astronomy. Geoff also heads



Tim Dean and his collection of seismic receiver/recorder hardware

the Science Mentors ACT programme, which gives public school students in this age range the chance to work with professionals in science and engineering by undertaking real-world projects with well-defined goals. The programme is expanding from its initial implementation at Melrose High School and Geoff hopes to entice as many career scientists as possible to participate and allow the programme to grow. The examples of student work which he was able to illustrate were very impressive.

In mid-March we hosted a talk by SEG Honorary Lecturer, Professor **Boris Gurevich**, of Curtin University on the subject of "Seismic attenuation, dispersion, and anisotropy in porous rocks: Mechanisms and Models".

In early April Geoscience Australia will provide facilities for the ASEG Federal Executive AGM for the second year running as **Marina Costelloe's** successful term as president comes to a close. The guest speaker will be the new GA Chief Scientist Dr **Steve Hill**

Grant Butler
actpresident@aseg.org.au

New South Wales

In February, **Clive Foss** from CSIRO Mineral Resources presented a talk entitled, "A magnetization study of some iron meteorites". Clive went through what we knew about the magnetism of iron meteorites and then introduced us to the magnetometer that CSIRO has developed to measure drill core. Clive

introduced the meteorites that had been loaned from the Australian Museum for this study. The magnetometer allowed the measurement of the magnetism of the meteorites without having to take samples from them (thus keeping the Museum very happy), and so many measurements were taken in many orientations. Clive discussed the results from two of the meteorites, one with a dominant induced magnetisation and the other with a strong remanent magnetisation. Clive offered his thoughts on why, and shook his head about other findings. Much discussion followed, the talk being enjoyed by all.

An invitation to attend NSW Branch meetings is extended to interstate and international visitors who happen to be in town at that time. Meetings are generally held on the third Wednesday of each month from 5:30pm at Club York. Meetings notices, addresses and relevant contact details can be found at the NSW Branch website. The next Branch meeting will be held on 17 April, **Marina Costelloe**, the ASEG President will be giving the presentation, all are welcome.

Mark Lackie,
nswpresident@aseg.org.au

Stephanie Kovach
nswsecretary@aseg.org.au

Queensland

Queensland made good start on its activities in 2019. Once school holidays were over, and we were all back at our desks, we kicked off with the mentor programme followed by two technical talks with another two scheduled before Easter.

Janelle Simpson and her team did a great job in getting the mentoring programme up and running, and it was launched on Friday 15 February. Well done Janelle and your team. Great many thanks also to ASEG President **Marina Costelloe** who came up for the launch and gave an inspirational talk on mentorship with many interesting and also personal anecdotes. Thank you Marina for supporting our launch and getting it off to a great start!

Our first technical talk was on Thursday 19 February when **Keith Millis**, Lead Geophysicist at SA Exploration gave a talk on compressive seismic imaging (CSI), a



Clive Foss eyeing a bottle of red after giving his most enjoyable and enlightening talk.



Rapt audience during Tim Dean's presentation to the QLD Branch

technique used in medical imaging and digital cameras which has shown that perfect reconstruction is still possible even when Shannon-Nyquist sample rate criteria are not satisfied. Keith described and gave examples of the impact of CSI, blended acquisition and broad bandwidth. The evening was a success and attracted over 30 attendees, further enhanced by SA Exploration generously sponsoring the evening and drinks!

Our second technical talk for the year was given by Dr **Tim Dean**, Research Fellow at Curtin University on Tuesday 5 February. Tim gave an interesting talk on advances in land seismic acquisition technologies and brought with him an impressive collection of different geophones – allegedly the largest (and, as admitted, possibly the only) collection in existence. Tim's talk described the technical innovation that has been ongoing, even during dramatic falls in the oil price and, consequently, company revenue. As Tim pointed out, innovation has also occurred in other areas of acquisition technology, including seismic sources and the widely adopted GPS positioning systems. The evening attracted over 30 attendees and many lingered after question time to have a chat with Tim.

We welcomed the SEG 2019 Pacific South Honorary Lecturer **Boris Gurevich**, Curtin University and CSIRO on Tuesday 19 March. Boris gave a talk on "Seismic attenuation, dispersion and anisotropy in porous rocks: Mechanism and models". Finally, we are planning our AGM for the week leading up to Easter, with a talk by **Eric Battig**, Superintendent Geophysics with BHP Coal. We will advertise this talk and ask for nominations for the ASEG Qld Committee shortly.

The ASEG Queensland Branch has started to use an online booking system for RSVPs to our meetings, with two out

of three Members responding via this system the second time it was used.

Ron Palmer
qldpresident@aseg.org.au

South Australia & Northern Territory

In January the ASEG SA/NT Branch Committee met to discuss our plans for 2019, and it looks like another busy but exciting year! Last year we had a total of 20 events, varying from technical evenings to technical lunches, to more social events such as the SCINEMA science movie night and the annual wine tasting. We intend to keep providing a wide array of interesting events for our Members, and to introduce a few new ones in 2019, such as a bad science movie marathon later this year (email me your bad movie suggestions – *The Core*, anyone?!) and some science outreach events such as Science Alive, along with more lunchtime talks, which seem to be popular.

Our AGM was held at lunchtime February 11 at the Ayers House, with guest



Marina Costelloe, Geoscience Australia and ASEG President, presenting at the AGM of the ASEG SA Branch.



Keith Millis, Nabeel Yassi and Bruce McFarlane, SAExploration, after Keith's talk at the Coopers Alehouse.



Bonnie Lowe-Young, PESA SA-NT President giving some words of advice to the mentors/mentees

speaker **Marina Costelloe**. Marina is the Seismic and MT acquisition team leader at Geoscience Australia, and the ASEG Federal President, and gave a wonderful talk, "The Australian Society of Exploration Geophysicists: The President, diversity and science." She gave some interesting and honest insights into the ASEG, but also about her career and her passion for science, diversity, and how to pair the two. A recording of her talk can be found on the ASEG YouTube channel. The AGM saw us elect a new Secretary, **Ben Kay**, and farewell our previous Secretary **Mike Hatch**, thanks Mike for your work!

February 27 saw **Keith Millis** from SAEExploration present an informative

and innovative talk on "Compressive Seismic Imaging (CSI)," at the Coopers Alehouse. The talk prompted a lot of interesting discussion which could have continued well into the night. He was accompanied by **Nabeel Yassi** and **Bruce McFarlane** from SAEExploration who were happy to chat about the work that SAEExploration are doing on CSI.

On March 5 we held a meet-and-greet evening at the Cumby Hotel for the ASEG, PESA, SPE and YPP 2019 Mentor programme. This was a great opportunity for participants in the programme to meet their mentor/mentee and for general networking. The programme for 2019 has commenced, and will end in November

this year. Keep your eye out for expressions of interest for the 2020 Mentor programme to be advertised later this year.

A huge thanks as always to our sponsors, Department for Energy and Mining, Beach Energy, Vintage Energy, Heathgate Resources, Minotaur Exploration and Zonge. We couldn't put on so many valuable events for our Members without them. If you are interested in sponsoring the SA/NT ASEG Branch in 2019, please contact our Treasurer Adam Davey sa-nttreasurer@aseg.org.au.

The SA/NT Branch has our own Facebook page now, search for "Australian Society of Exploration Geophysicists SA/NT Branch" on Facebook, for updates on events and local geophysical news.

As always, very happy to hear any feedback or suggestions at sa-ntpresident@aseg.org.au.

Hope to see you soon at an ASEG event soon.

Kate Robertson
sa-ntpresident@aseg.org.au

Tasmania

The Tasmanian Branch of the ASEG held its AGM at the UTas Geology Lecture Theatre on the evening of Thursday 28 February. **Tara Martin** and **Matthew Cracknell** were welcomed to the Branch Committee as Treasurer and Secretary respectively, joining **Mark Duffett** who is



Richard Chopping presenting to the ASEG Tasmanian Branch AGM.

continuing as President. Branch Members then settled back in the company of ASEG Federal President **Marina Costelloe**, together with the local chapters of the Geological Society of Australia and the Australian Institute of Geoscientists, to enjoy **Richard Chopping's** presentation on his new book co-authored with **Brian Kennett** and **Richard Blewett**, "The Australian Continent: A Geophysical Synthesis". Following a vote of thanks from Marina Costelloe, the sister societies proceeded outside on a perfect Hobart evening for a BBQ.

ASEG Tasmania's next event was co-hosted at the same venue with the GSA. On Thursday 21 March, after drinks and nibbles, **Paul Winberry** from Central Washington University talked about his application of seismic methods to understanding the future of Antarctica's ice sheets.

The following week, Wednesday 27 March, ASEG/SEG Pacific South Honorary Lecturer **Boris Gurevich** of Curtin University and CSIRO gave his presentation "Seismic attenuation, dispersion, and anisotropy in porous rocks: Mechanisms and Models". This presentation doubled as a highlight of the UTas School of Earth Sciences seminar series.

An invitation to attend Tasmanian Branch meetings is extended to all ASEG Members and interested parties. Meetings are usually held in the CODES Conference Room, University of Tasmania, Hobart. Meeting notices, details about venues and relevant contact details can be found on the Tasmanian Branch page on the ASEG website. As always, we encourage Members to also keep an eye on the seminar programme at the University of Tasmania / CODES, which routinely includes presentations of a geophysical and computational nature as well as on a broad range of earth sciences topics.

Mark Duffett
taspresident@aseg.org.au

Victoria

The Victorian Branch of the ASEG experienced an unusually long intermission over the summer months, and with good reason, as Melbourne endured its warmest January on record. Notwithstanding the scorching heat and sweltering nights so far in early 2019, your

Branch Committee managed to entice some of its Members to abandon the relative safety and comfort of their air-conditioned dwellings to attend the very first technical meeting night of the year.

On 21 February, we greeted an adopted West Australian, Mr. **Jeremie Giraud**. Jeremie has just submitted his PhD thesis to the University of Western Australia. As an entrenched native of Perth, Jeremie quickly dismissed our unbearable heat as balmy, and went on that night to deliver his presentation; "Integration of geological uncertainty into geophysical inversion by means of local gradient regularization", without so much as breaking a sweat. Well played, Jeremie. Well played. We were flabbergasted to hear that your integrated workflow approach, which helps reduce interpretation uncertainty, worked so well in your test area of the Yilgarn. This probably explains why the MinEx CRC and Loop Consortium want you to work with them. Hmm ... we, wish you all the best, buddy!

As the night wore down and beverages were discontinued, most of the attendees unwillingly withdrew to their humble abodes. In a stroke of genius, your Branch Committee members decided to take advantage of the dwindling numbers and called forth a flash AGM in the hope of reducing any fallout from protests to our exemplary running of your Branch last year. Your Secretary noted that a quorum was present, and two resolutions were proposed for the AGM. For Resolution 1, your current President, Secretary and Treasurer all put forward their names for re-election and, without any opposition, were unanimously re-elected for another frightening year. For Resolution 2, we nominated Mr. **Theo Aravanis** to the Committee as events co-ordinator and functional support. On a show of hands and one iPhone, the resolution was passed. Mr Theo Aravanis was, until recently, Rio Tinto's Chief Geophysicist. We welcome Theo to our Committee! Someone should eventually let Theo know that this role is entirely *gratis*.

On 13 February (not a Friday), we held the joint ASEG-PESA-SPE Summer Social event. It was certainly an enjoyable night despite the moderately low turnout this year. Thanks to everyone that attended. Interestingly, some of our Members chose that night to express concerns that the Summer Social was being held too late in, well ... summer. We reminded our Members that the Summer Social

was a tripartite event and agreeing to dates in an already busy schedule is becoming increasingly difficult, hence our acquiescence. As we look further ahead to the Winter Social we are considering combining the Summer AND Winter Socials, to be hosted at the Equator, during both equinoxes and at the International Date Line somewhere in the Pacific. We enjoy constructive feedback. Keep it coming ... to our Secretary.

The presenter at our March technical meeting was Professor **Boris Gurevitch** of Curtin University, this year's Pacific South Honorary Lecture, and we are gearing up for a busy couple of months ahead. Your Committee members hope to secure **Richard Chopping** and **Marina Costelloe** (ASEG President) to present at an upcoming Branch technical meeting night, so look out for our updates!

And finally, in a coup for the Victorian Branch, we will be hosting a very, very special evening in May that you will not want to miss! All we can say at this stage is that South Australia won't be the only ASEG branch to offer certain state-produced beverages to its Members.

An invitation to attend Victorian Branch meetings is extended to interstate and international visitors who happen to be in Melbourne at the time. Meetings are generally held on the third Thursday of each month from 5:30 pm in the Kelvin Club, 18–30 Melbourne Place, Melbourne. Meeting notices, addresses and relevant contact details can be found on the Victorian Branch page of the ASEG website.

Seda Rouxel,
vicpresident@aseg.org.au

Thong Huynh
vicsecretary@aseg.org.au

Western Australia

The WA Branch launched the Industry Mentoring Programme in late March, co-hosted with PESA, Engineers Australia, the Petroleum Club of WA, the Society for Petroleum Engineers, the Society for Underwater Technology, Subsea Energy Australia, and Women in Subsea Engineering. We hope that this collaborative venture will provide our Members with broader networking and mentoring opportunities amongst a diverse group of professionals. The programme is free for ASEG Members and a summary of the events

Branch news

ASEG news

is provided below. Registrations for 2019 are now closed; however, we are accepting expressions of interest for our 2020 programme via wa-mentoring@aseg.org.au.

- Launch event – 27 March 2019
- Self-awareness workshop – 25 April 2019
- Networking event – 30 May 2019
- Mentors only panel session – 27 June 2019
- Mentees only panel session – 18 July 2019
- Communication & Public speaking workshop – 29 August 2019
- Leadership & decision-making workshop – 31 October 2019
- Close out event and wrap up – 5 December 2019

In February the Branch held our first tech night for 2019. **Richard Chopping** presented a talk based on the book “The Australian Continent: a geophysics synthesis”, a digital copy of which is available free of charge via <https://press.anu.edu.au/publications/authors-editors/richard-chopping>). This event was followed by our March tech night where SEG Honorary Lecturer **Boris Gurevich** presented on “Seismic attenuation, dispersion, and anisotropy in porous rocks: Mechanisms and Models”. The Young Professionals speaker night was also held in late March.

Upcoming WA events include:

- April 10 tech night – Professor **Wayne Pennington**, who will be speaking about “Our Evolving View of Time-Lapse Seismic Monitoring: 20 years of the same old Teal South data”
- May 8 tech night – TBC
- June 12 tech night – Dr **Tim Dean**, who will be speaking about “Recent advances in land seismic acquisition technology”.
- The tech night schedule is subject to change due to speaker availability. Please check the website for up-to date information.
- The WA Branch is excited about the events planned for 2019 and we look forward to seeing all our Members at these events and at the AEGC in September at Crown Burswood.

Heather Tompkins

wapresident@aseg.org.au



The new Industry Mentoring Programme logo



Richard Chopping presents to the WA Branch.



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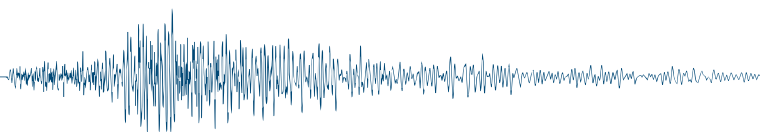
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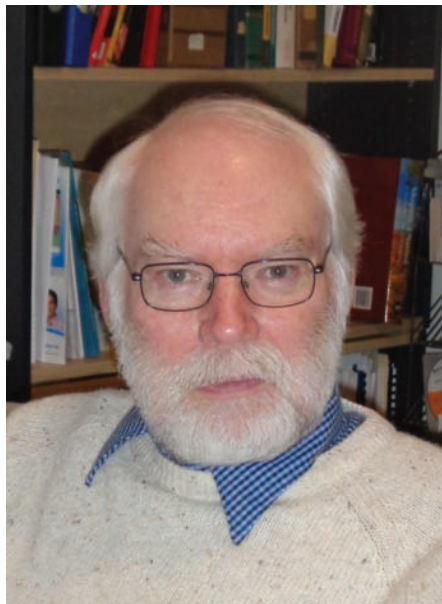
Australian Society of
Exploration Geophysicists



PESA
Petroleum Exploration
Society of Australia



Vale: Peter Milligan (1951–2019)



Peter Milligan

It is with much sadness that we note the death of Dr Peter Milligan on Saturday 2 March, following a short battle with cancer. Peter was a long term employee of Geoscience Australia and a long-time Member of the ASEG.

Peter joined the Bureau of Mineral Resources (BMR) in 1985 and retired from Geoscience Australia (GA) 29 years later in 2014. Over this time period Peter became an institution in the fields of geomagnetism, magnetotellurics, airborne surveying, and non-seismic geophysical data processing. Having taught maths and science at secondary schools prior to joining the BMR, he was well trained as a mentor and a tutor.

But more than this, he was incredibly generous with his time and knowledge. He would patiently share his insights or, if the need arose, jump straight in to help out. His presence would instantly bring a sense of confidence to any team that he joined since he demonstrated over and over that he could play a key part in bringing large projects to completion.

In the later part of his career Peter played a leading role in the expansion of magnetotelluric surveying within GA. But he may be best known for his contribution to the AWAGS long baseline aeromagnetic and radiometric traverse project, and the subsequent production of the 5th and 6th editions of the Magnetic Anomaly Grids of Australia in 2010 and 2015 respectively. These were massive undertakings. More than 30 million line km of low level airborne survey data from over 800 individual surveys were combined and levelled to produce a high fidelity grid of magnetic data that covers the entire continent. This was an internationally-recognised achievement, the envy of every geoscience organisation outside Australia. In more recent times Peter was back in GA working with the Groundwater Branch.

The Magnetic Map of Australia that Peter produced adorns the walls and pin-up boards of hundreds of geoscience organisations, businesses, universities, and consultancies. It has a prominent place in the foyer at GA – next time you visit cast your eye high up on the huge cloth banner that hangs against one of

the lift wells. The coloured TMI magnetic image of Australia must also have appeared in thousands of presentations given by GA staff. Despite this widespread distribution and usage, most would not be able to say who produced these products – Peter was the epitome of the quiet achiever and never sought out the recognition that he deserved.

Returning to GA in 2017, Peter worked in the Groundwater Branch for nearly two years. He contributed greatly on a number of projects including EFTF. Peter developed new inversion approaches and products for the use of airborne magnetics data in palaeovalley and near-surface environments for groundwater projects, while also providing advice and assessment on the use of gravity gradiometer and MT methods for groundwater resources in sedimentary basins.

Peter was an executive committee member of the Task Force of the World Digital Magnetic Anomaly Map, the recipient of an ASEG Service Certificate in 2016, author or co-author of numerous scientific publications, and the recipient of countless GA awards. To those who worked with him however, he was simply the quietest, kindest, happiest, most valued fellow team member of the geophysics section of GA that we have known. He will be sadly missed.

Peter is survived by his wife Ann, and his three children.

Richard Lane
Geoscience Australia
Richard.Lane@ga.gov.au

Collection for sale

The late Kevin Wake Dyster accumulated a large collection of instruments during his career (see Kevin's obituary in the February 2019 issue of *Preview*), which the estate would like to sell to his fellow professionals. Kevin's colleagues, Henk van Paridon and Ron Palmer, are assisting the estate and have established a website with pictures of the equipment for sale

http://www.energeo.com.au/geophysical_equipment_for_sale.html

Many more items will be added to the website as this large collection is assessed so, if you are interested, it would be a good idea to revisit the site over the coming months.

Some of the early highlights include gravity meters, EM34-3 XL, seismographs, magnetometers and surveying instruments. There are also many beautiful collectors' items.

Emeritus Professor Brian Kennett AO

As noted in the last issue of *Preview*, Emeritus Professor Brian Kennett, was recognised in Australia Day 2019 Honours List for distinguished service to the earth sciences as a leading academic and researcher, particularly in the field of seismology. He was appointed an Officer (AO) in the General Division of the Order of Australia

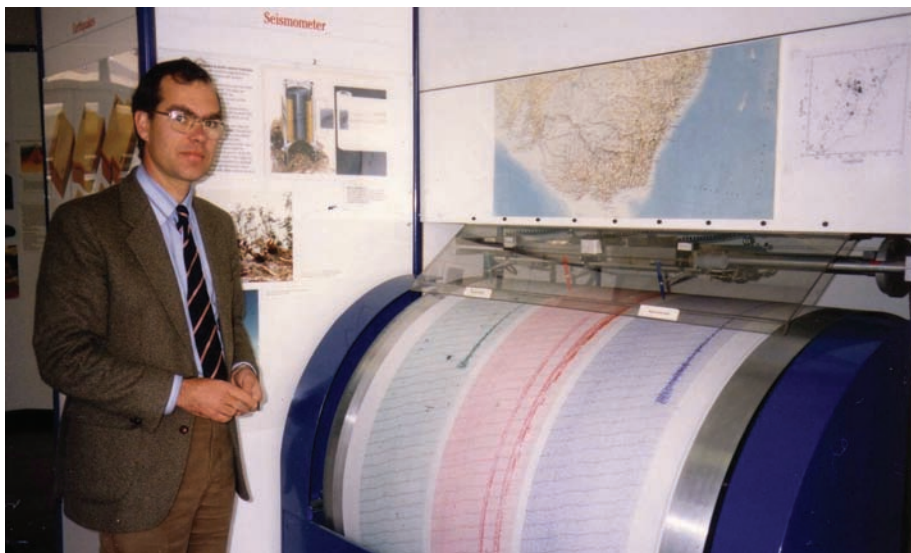
ASEG President Dr Marina Costelloe congratulated Professor Kennett on behalf of the ASEG, and invited him to share highlights of his career with ASEG Members via the pages of *Preview*.

This is Brian's story.

I was born and brought up in South London, England, and in 1996 gained an Open Scholarship to Emmanuel College at the University of Cambridge. I studied the Natural Sciences Tripos, gaining a first class in Theoretical Physics, and then took the Mathematical Tripos Part III gaining honours with distinction. I carried out my PhD research on theoretical seismology in the Department of Applied Mathematics and Theoretical Physics (DAMTP) in Cambridge. In 1974-1975 I spent a year at the University of California, San Diego, USA on a Lindemann Fellowship, working with Professor Freeman Gilbert. On my return to Cambridge I had a short term position in the Department of Geodesy and Geophysics supporting the marine geophysics activity led by Drummond Matthews. In 1976 I was appointed as a University Lecturer in DAMTP, and for the next 8 years, combined teaching mathematics with research in geophysics.

I arrived in Australia in 1984 as a Professorial Fellow at the Research School of Earth Sciences at the Australian National University. My appointment was to lead the Seismology program, adding theoretical expertise to an activity which had been largely observational. At the time of my arrival I sketched out a research concept of exploiting the regional earthquakes around Australia to look at the structure beneath the continent using both compressional and shear waves. It took over 25 years to bring this idea to fruition, but a net result is that we have good definition of the 3-dimensional structure beneath the region that has proved valuable in many contexts.

In 1985, with the aid of new instrumentation designed by Dr K



Brian Kennett with the former seismic recording drum in foyer of RSES building in July 1989

Muirhead, we started a programme of deployments of short period seismic instruments in northern Australia designed to study the structure of the upper mantle. My earlier experience in work at sea proved to be useful in coping with the demands of the Australian outback. Much of the early work was carried out from Tennant Creek in the Northern Territory, with help from the staff of the Warramunga array operated by ANU about 35 km out of town.

In 1992 we started to work with portable broad-band seismic recorders, initially four bought through the Major Equipment programme at ANU subsequently expanded to 12. With the arrival of Rob van der Hilst as a Research Fellow, an ambitious plan "SKIPPY" for coverage of the Australian continent in a multi-year campaign with a limited set of portable instruments was set in train. From 1993-1996 seven sets of deployments covered most of the continent, although hardware problems began to mount towards the end of the coverage. This modest cost exercise provided reconnaissance scale coverage of the 3-D shear wavespeed structures beneath the continent and surrounding oceans with better than 500 km resolution. Subsequent experiments built on the results of the SKIPPY project, and I designed and led a group of deployments aimed at understanding the edges and sutures of cratons particularly in Western Australia. This work involved deployments of

instruments over large, remote, areas of the continent. Much of my personal involvement was in the tropical north. As I acquired other responsibilities, the leadership of the field program in Australia, and later Antarctica, was taken over by Research Fellows, notably Anya Reading. The continuing campaign of experiments has seen over 200 broad-band sites occupied by 2015, which furnish resolution at about 200 km scale across the whole continent.

In addition, I helped to initiate, with Nick Rawlinson, an ongoing campaign of deployments of shorter-period instruments (typically 40 or so at a time) that has progressively covered most of southeastern Australia. The projects, collectively known as WOMBAT, now spread well in South Australia and Queensland with also good coverage of much of Tasmania. Support has come from a number of sources including ANU funding, ARC Discovery Grants and AuScope infrastructure funds. The station spacing of 50 km or less provides quite detailed information on mantle structure, and through the use of ambient noise methods has also provided useful constraints on crustal structure.

The style of mobile deployments established in Australia with SKIPPY has been very influential, and similar programs have been carried in a number of areas, e.g., Southern Africa. The project also was part of the inspiration for the major deployment of the USArray, which moved up to 400 stations like a



Brian Kennett getting somewhat damp whilst carrying out field work at the ANU Coastal Campus at Kioloa

shutter-blind across the USA over the 10 year period from 2005-2015.

The high quality portable instruments record continuously, and so a very large amount of data is available for subsequent analysis. A wide range of techniques have been used to look at structure beneath the Australian region. In the period from 1998-2005 there was particular emphasis on surface wave tomography, with both practical and theoretical advances made in the PhD projects of K Yoshizawa and S Fishwick, building on the work of former Postdoctoral Fellow E Debayle. The highly favourable distribution of earthquake sources around the Australia continent means that we have been able to use information from higher-frequency body waves to provide independent information and checks on the results from the surface wave work. The inferences from the various sources of data are very consistent and provide confidence in the accuracy of the results.

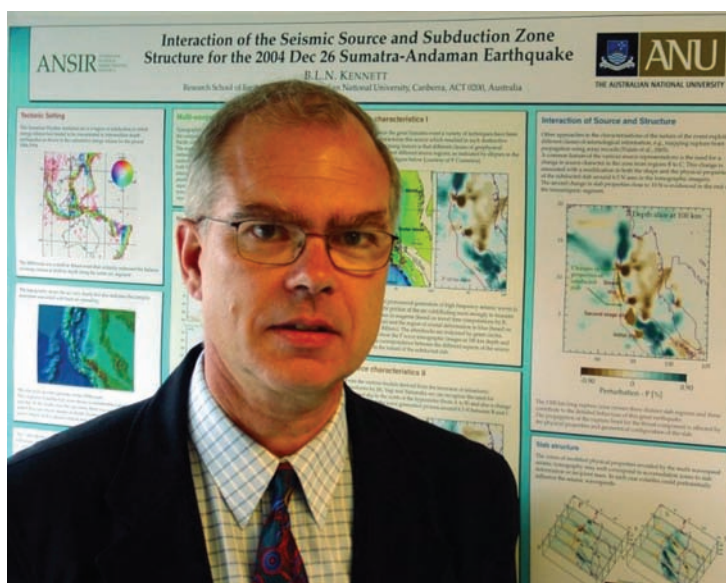
I became interested in the problems of earthquake location when I acquired responsibility for the southeast Australian network on arrival at ANU, and this also led into regional scale seismic tomography. Malcolm Sambridge and I developed a fully non-linear approach to event location tracking to the best solution in space-time. With improved earthquake location it was possible to determine a 3-D model of the P wave structure across the SE Australia using a sub-space projection method to reduce computational demands. This approach

has proved to be very powerful and has been extensively used for inversion of teleseismic data from the WOMBAT deployments.

Alongside the regional studies, efforts have been made to look at high-resolution body wave tomography on a global scale starting with the PhD project of Sri Widiyantoro, jointly supervised with Rob van der Hilst. In this work a detailed set of regional models of 3-D P wavespeed were developed for the major subduction zones around the globe, and then a full global model was created. By undertaking joint inversion of P and S wave arrival time information,

a new style of images in terms of bulk-sound speed and shear wavespeed were developed for the whole Earth, which provided new information on the nature of heterogeneity at smaller scales. The tomography results have been greatly aided by the development of self-consistent global models for radial earth structure working with Dr E R Engdahl at the US Geological Survey in Golden, Colorado. The iasp91 model, published in 1991, allowed better locations to be found for many seismic events, particularly in depth. As a result, a new set of empirical travel times for the major seismic phases were built, and these formed the basis of the improved ak135 model published in 1995. These reference models have become the standard for body wave tomography, and are now used by all the major international agencies for earthquake location.

With the improved travel time models it became worthwhile to revisit methods for global earthquake location, and a number of different procedures were developed based on homing-in on the best solution in 4-dimensional space-time. The most consistently effective approach uses the Neighbourhood Algorithm developed by Malcolm Sambridge, and this is now employed within the location procedure used by the International Seismological Centre. Coupled with ray-tracing in a full 3-D model the Neighbourhood Algorithm approach has proved to be very effective at the continental scale since, e.g., it is possible to take into account the very fast wavespeeds beneath western Australia.



Brian Kennett in 2005 with a poster on great Sumatran Earthquake

From 2010-2012 I coordinated the effort to produce an Australian Seismological Reference Earth Model (AuSREM) based on the full range of information on the continent. The first product was a new compilation of results on the depth to Moho incorporating extensive information from receiver function studies and reflection seismic profiles. Michelle Salmon took charge of the assembly of the available data on crustal structure and we collaborated on building a P wavespeed model from refraction and receiver function results, with additional constraints from S wavespeed determined from ambient noise tomography that provided a continent-wide background to link the point observations. An SV wavespeed model was built for the mantle by combining the results from several prior studies using surface wave tomography, with additional constraints on P and S wavespeed from body-wave studies. The full digital 3-D model with 0.5 degree horizontal resolution specified at depth intervals of 5 km in the crust and 25 km in the mantle was released in late 2012, with detailed papers on the mode of construction appearing in 2013. As was hoped, the AuSREM model has been used in many ways, e.g., to produce a new density model and to look at the association of resources with seismic velocity variations. The model also has been used directly for earthquake location across the continent.

An update to the Moho model for the Australian continent was made in 2013 to include new results from reflection profiling, with a further update in 2017 to incorporate results from another 4000 km of reflection profiling, extensive new portable seismic deployments in Western Australia, and results from stacked autocorrelograms at seismic stations – particularly from the dense deployments in southeastern Australia. Although the general pattern is similar to the Moho map produced in 2011, extensive areas of thicker crust have been revealed in the western part of Central Australia and south of Mt. Isa where earlier coverage was sparse. It is hoped that a new synthesis exploiting the full range of available information will be completed in 2019.

In the course of my career at the Research School of Earth Sciences I have worked on many aspects of seismology, particularly in understanding issues relating to seismic wave propagation.



Brian Kennett receiving the 2017 Lehmann medal from the AGU president

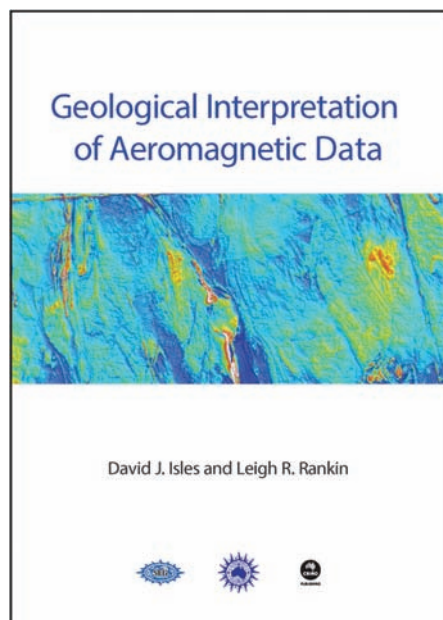
I have tried to convey this experience to a broader audience in the two volume book set *The Seismic Wavefield* (2001, 2002) which covers most aspects of intermediate and high frequency seismology applied to the Earth. This work is complemented by *Geophysical Continua* (2008) paper, co-authored with H-P Bunge of the University of Munich that links to the dynamic environment of the Earth. I have also cooperated with colleagues at Geoscience Australia to produce a comprehensive summary of the suite of full-crustal reflection profiles across the Australian continent, accompanied with geological strip maps. The second edition *Deep Crustal Seismic Reflection Profiling Australia 1978–2015* was published in 2016. A further volume *The Australia Continent: A Geophysical Synthesis* appeared in 2018, in which the full range of continental scale geophysical results for the continent are presented in a common format. This volume is the subject of an article that also appears in this issue of *Preview*. Both these works are published through ANU press with free access to the digital versions.

As part of a Masters Course on Physics of the Earth at ANU, I prepared a course on how to plan develop research projects, which I later expanded into a short book: *Planning and Managing Scientific Research: a guide for the beginning researcher*. This book has been also made freely available through ANU Press and achieved wide distribution.

My work has been recognised through election as; a Fellow of AGU (1988), Fellow of the Australian Academy of Sciences (1994), Honorary Fellow of the Royal Astronomical Society (1996) and Fellow of the Royal Society, London (2005). I received a Humboldt Research Award in 2004 that was held at the University of Munich spread over 3 years, with productive collaborations on both the lithosphere/asthenosphere system and the deep Earth. I was awarded the Murchison Medal of the Geological Society of London in 2006, the Gutenberg Medal in Seismology of the European Geosciences Union in 2007, and the Gold Medal for Geophysics from the Royal Astronomical Society, London in 2008. I also received the Jaeger Medal for Earth Sciences from the Australian Academy of Sciences in 2006, and in 2011 the Academy's highest honour in the Physical Sciences – the Flinders Medal and Lecture. In 2017 I was awarded the Inge Lehmann Medal by the American Geophysical Union for my work on the deep Earth.

I retired fully in 2016, after four years in a part-time position and was appointed as an Emeritus Professor by the Australian National University. I still sustain a varied research effort, mostly in structural seismology, but at a lower level of intensity than before.

Brian Kennett AO
Emeritus Professor
Brian.Kennett@anu.edu.au



Dave Isles and Leigh Rankin's classic book on aeromagnetic interpretation can now be downloaded as an e-book from the ASEG's website and is freely available to both Members and non-Members.

Dave and Leigh expect that the increase in accessibility of this e-book will strengthen and broaden the interest in aeromagnetism, particularly through the geological fraternity. The book was designed to encourage a more complete integration of geology in the interpretation process, and came at a time when the explosion of pre-competitive airborne magnetic/radiometric surveys worldwide had reached peak levels.

The book has its roots in a course first devised by Dave Isles and Alasdair Cooke, in 1988, while they were the interpretation team for airborne survey contractor, Aerodata Holdings. With strong support from Aerodata founder, Pat Cunneen, who termed the endeavour "Aerodata University", Dave and Alasdair teamed up with



Course on interpretation of aeromagnetic data being run on site.

E-book on geological interpretation of aeromagnetic data now free!

Rick Valenta from Monash University and formalised a 3-day course that has now been presented over 250 times worldwide and attracted around 3000 participants. One highlight of the course history includes presenting to 45 AGSO (now Geoscience Australia) geoscientists in November 1991, an event that Dave believes significantly contributed to AGSO's role in the National Geoscience Mapping Accord. Courses were subsequently run in all mainland state geological surveys, and the uptake from exploration companies worldwide has grown steadily. Leigh Rankin became the main co-presenter in 1994, after attending one of the early courses and applying his newfound skills to the massive South Australian Exploration Initiative airborne data set over the Gawler Craton. Leigh had resigned from the SA Geological Survey and joined World Geoscience, which was Aerodata's international airborne survey off-shoot. The course maintained popularity through the ups and downs of the exploration industry, and has been refined and expanded to a range of formats that remain on offer today. Courses continue to be run at remote exploration / mining sites as well as city venues.

In 2009 Dave and Leigh sought assistance to form a book based on the course content so as to expand and consolidate the reach of their methodology. The ASEG, through then President, the late Peter Elliot, immediately and enthusiastically offered substantial financial support. ASEG's Phil Schmidt and Mike Asten also championed the cause and carried the authors through the sometimes tortuous publication process. Their involvement resulted in the creation of two chapters on sedimentary basin exploration environments and a co-publishing arrangement with the SEG. David H. Moore, who led the integration of aeromagnetism (and other geophysical data) into Victoria's geological framework in the 1990s, volunteered a major editorial role that ensured the book would be appealing to geologists as well as geophysicists.

The book was released on CD in July 2013 and featured three main chapters based on worked, "real-life", exploration-interpretation examples.

The book in disk form achieved a wide readership and rejuvenated interest in Leigh and Dave's short courses. Once again, the stimulus was the stream of high-quality airborne data, both government surveys and historic, now open-file exploration company surveys. The current, multi-million km detailed "re-survey" of the Gawler Craton highlights the continued enthusiasm for high resolution aeromagnetic data and the need for astute, geological interpretation. The examples used in the course and in the book were kindly donated from the Aerodata "Multiclient" data bases. In the 1980s and early 1990s these very large scale, detailed (200 m line-spaced) data sets drove a step change in the mineral industry's approach to exploration, particularly for gold. Young explorers and mappers these days regard this as "old", "regional" data and expect to be using 100 m or 50 m data in their field programmes! Even so, 30 years later, the original multiclient data remains a high value backdrop to new company surveys.

New courses are now being offered by Leigh, Rick Valenta and Dave to suit a wide range of organisations and individual professional needs. Using in-house survey data in the training programmes is now common, and courses include field validation exercises wherever practicable.

Details of the courses can be found at

<https://www.daveisles.com/courses-overview>

and **most importantly** the book can be freely downloaded from

<https://www.aseg.org.au/publications/geological-interpretation-aeromagnetic-data>

Both of the authors welcome questions and feedback relating to the book. Leigh is now the main point of contact for new courses,

geointerp@skymesh.com.au

and Dave continues to promote the effective use of aeromag in any way he can.

disles@redgatevista.com.au

Australasian Exploration Geoscience Conference 2019: Workshops

The second Australasian Exploration Geoscience Conference (AEGC) will be held at the Crown Resort in Perth 2–5 September 2019. The AEGC is co-hosted by the Australian Institute of Geoscientists, the Australian Society of Exploration Geophysicists and the Petroleum Exploration Society of Australia. The AEGC is the largest exploration geoscience conference in the southern hemisphere and is expected to attract well over 1000 delegates from around the world. Themes cover the full spectrum of Australian geosciences from the mineral, petroleum and water resource industries, government and academia. Given its location in Perth, there will be additional, dedicated, streams for Western Australian sedimentary basins, discovery techniques, mineral mapping and remote sensing applications.

After a considered application and review process, thirty workshops are

being offered in a three day programme. Conference delegates will be able choose from an eclectic variety, as the offerings cater to a broad range of tastes:

- non-technical and soft skills (project management, presentation, mentoring and careers)
- petroleum focussed (sequence stratigraphy, chemostratigraphy, NWS basins and NWS reservoir drill cores)
- minerals focussed (drill optimisation, porphyry copper-gold, deposit and ore textures, petrophysics, magnetotellurics, estimating cover, exploration of drill core data and near surface geophysics)
- cross discipline (geo-statistics, uncertainty, digital disruption and machine learning in exploration)
- software orientated (GIS, python, modelling and inversion)

Workshops will primarily be run on the two days prior to the conference, Sunday 1 September and Monday 2 September, as either one or two day offerings.

A series of one day workshops will be held after the conference closes on Friday 6 September. All workshops held at the conference venue will be run with simultaneous breaks so that attendees can mingle and network over coffee or tea and lunch.

The Conference Organising Committee is looking forward to delivering a varied and interesting mix of workshops that foster discussion, aid in idea development and educate all attendees, while bringing together ideas and experiences from across petroleum and minerals geoscience.

Registrations are now open and you can find out more at <https://2019.aegc.com.au/workshops/>

Andrew Buffin
Workshop Co-Chair - Petroleum
Andrew.Buffin@resevalconsulting.com

Shane Mulè
Workshop Co-Chair - Minerals
Shane.Mule@csiro.au



AEGC2019

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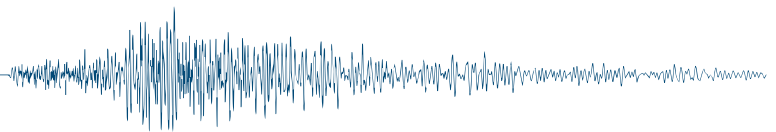


Australian Society of
Exploration Geophysicists



PESA
Petroleum Exploration
Society of Australia





SEISMIX2020

The 19th International Symposium on Deep Seismic Profiling of the Continents and their Margins

Curtin University in Perth invites you to participate in the 19th edition of the biennial International Symposium on Deep Seismic Profiling of the Continents and their Margins (SEISMIX 2020), which is now also extended to include the latest technological and scientific developments in the application of seismic methods. The symposium will be held in Fremantle, near Perth, Western Australia, from Sunday, March 1 to Friday, March 6 2020.

Symposium Program

The SEISMIX Symposium is unique in the way that it brings together geoscientists from around the world in a quest to investigate the interior of the Earth using the latest technologies, to unite active and passive source-imaging communities and those who study the Earth from the near surface to exploration scale and down to the continental scale. As usual, there will be a single session for oral presentations (no parallel sessions) and ample time

allocated for poster presentations. We also anticipate a number of keynote presenters (TBA).

The conference topics will include but are not strictly limited to:

- Novel seismic imaging and inversion methods
- Mineral exploration seismics, integration with other geological and geophysical data
- Active and passive seismic interferometry
- Active and passive seismics: together or not?
- Active continental margins and subduction zones
- Mid-ocean ridges and oceanic lithosphere
- Global processes—collisions and accretion
- Comprehensive geological interpretation
- Near-surface seismology—case histories
- New developments and advances in DAS applications

- Moho in 3D
- Special topic: ET (extra-terrestrial) resource potential
- Unconventional case histories—lessons learnt
- Big data issues: machine learning and artificial intelligence

Important Dates

- Early bird registrations and abstract submissions open: 02 09 19
- Abstract submissions close: 01 11 19
- Abstract acceptance notifications: 25 11 19
- Early bird registrations close: 14 12 19,
- Late registrations close: 03 01 20
- Symposium: 01 – 06 03 20
- Post-conference field trip: 07 – 14 03 20

Please visit the symposium web page (<http://www.seismix2020.org.au>) for more information.

Milovan Urošević
Curtin University
M.Urošević@curtin.edu.au

Near Surface Geoscience and Engineering conference 2019

The Geological Society of Malaysia (GSM) and the European Association of Geoscientists & Engineers (EAGE) are organising the second Asia Pacific Meeting on Near Surface Geoscience & Engineering (NSGE) in Kuala Lumpur from 22–26 April 2019. This conference follows the tremendous success of the first event in Yogyakarta, Indonesia, in 2018 and is supported by the Australian Society of Exploration Geophysicists, the Myanmar Geosciences Society, the Society of Exploration Geophysicists

Japan, the Chinese Geophysical Society, the Korean Society of Earth and Exploration Geophysicists, the Geological Survey of Papua New Guinea, the Australian Geomechanics Society and the Indonesian Association of Geophysicists.

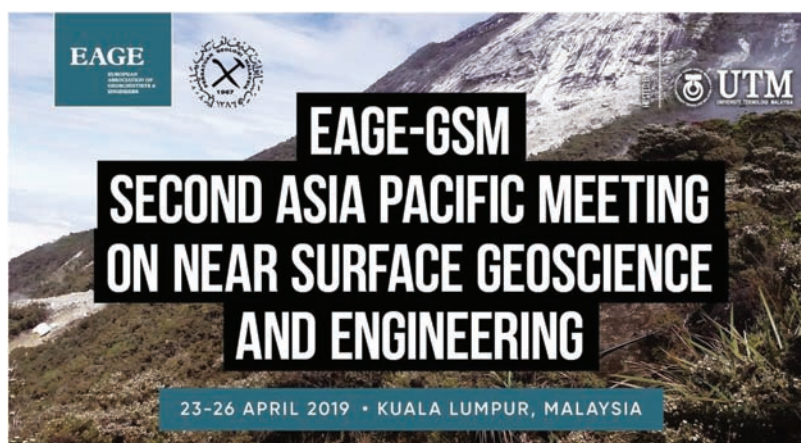
Confirmed keynote speakers are:

- Professor Kenneth Stokoe, The University of Texas, USA
- Professor M Atilla Ansal, Ozyegin University, Turkey

- Professor Joy Jacqueline Pereira, Universiti Kebangsaan, Malaysia
- Dr Oliver Kuras, British Geological Survey, UK

Find the NSGE on Facebook and LinkedIn: <https://www.facebook.com/EAGEglobal/photos/a.349106275193209/1753749774728845/?type=3&theater>

<https://www.linkedin.com/feed/update/urn:li:activity:6480254254039863296>



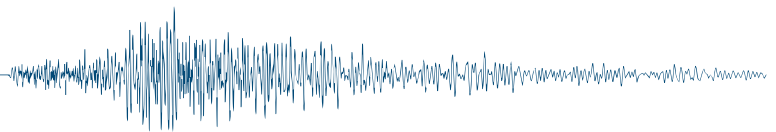
Update on geophysical survey progress from Geoscience Australia and the Geological Surveys of Western Australia, South Australia, Northern Territory, Queensland, New South Wales, Victoria and Tasmania (information current on 26 March 2019).

Further information on these surveys is available from Dr Yvette Poudjom Djomani at GA via email at Yvette.PoudjomDjomani@ga.gov.au or telephone on (02) 6249 9224.

Table 1. Airborne magnetic and radiometric surveys

Survey name	Client	Project management	Contractor	Start flying	Line km	Spacing AGL Dir	Area (km ²)	End flying	Final data to GA	Locality diagram (Preview)	GADDs release
Tasmanian Tiers	MRT	GA	TBA	TBA	Up to an estimated 66 000	200 m 60 m N-S or E-W	11 000	TBA	TBA	TBA	The National Collaborative Framework Agreement between GA and MRT is being updated
Tallaringa N (1A)	GSSA	GA	Thomson Aviation	26 Oct 2017	97 922	200 m 60 m E-W	17 320	26 Mar 2018	TBA	190: Oct 2017 p. 26	TBA
Tallaringa S (1B)	GSSA	GA	Thomson Aviation	26 Sep 2017	145 367	200 m 60 m E-W	26 010	12 May 2018	TBA	190: Oct 2017 p. 26	TBA
Coober Pedy (8A)	GSSA	GA	Thomson Aviation	18 Sep 2017	90 425	200 m 60 m N-S	16 140	21 Dec 2017	TBA	190: Oct 2017 p. 26	TBA
Billa Kalina (8B)	GSSA	GA	MAGSPEC Airborne Surveys	10 Oct 2017	90 353	200 m 60 m N-S	16 140	18 Dec 2017	27 Jul 2018	190: Oct 2017 p. 26	TBA
Childara (9A)	GSSA	GA	MAGSPEC Airborne Surveys	5 Nov 2017	134 801	200 m 60 m N-S	23 910	2 May 2018	30 Nov 2018	190: Oct 2017 p. 26	TBA
Lake Eyre (10)	GSSA	GA	MAGSPEC Airborne Surveys	2 Oct 2017	91 938	200 m 60 m E-W	16 180	22 Mar 2018	9 Oct 2018	190: Oct 2017 p. 26	TBA
Streaky Bay (5)	GSSA	GA	GPX Airborne Surveys	21 Jun 2018	90 630	200 m 60 m E-W	15 966	28 Sep 2018	TBA	194: Jun 2018 p. 19	TBA
Gairdner (6A)	GSSA	GA	GPX Airborne Surveys	31 Jul 2018	105 075	200 m 60 m N-S	18 307	23 Jan 19	TBA	194: Jun 2018 p. 19	TBA
Spencer (7)	GSSA	GA	MAGSPEC Airborne Surveys	11 Jun 2018	50 280	200 m 60 m E-W	8716	6 Aug 2018	TBA	194: Jun 2018 p. 19	TBA
Kingoonya (9B)	GSSA	GA	MAGSPEC Airborne Surveys	5 Aug 2018	150 565	200 m 60 m N-S	26 651	TBA	TBA	194: Jun 2018 p. 19	92% complete to 21 Feb 2019
Tanami	NTGS	GA	Thomson Aviation	14 Jul 2018	275 216	100/200 m 60 m N-S/E-W	48 267	2 Dec 2018	TBA	195: Aug 2018 p. 16	TBA

TBA, to be advised.


Table 2. Ground and airborne gravity surveys

Survey name	Client	Project management	Contractor	Start survey	Line km/ no. of stations	Line spacing/ station spacing	Area (km ²)	End survey	Final data to GA	Locality diagram (Preview)	GADDS release
Kidson Subbasin	GSWA	GA	CGG Aviation	14 Jul 2017	72 933	2500 m	155 000	3 May 2018	15 Oct 2018	The survey area covers the Anketell, Joanna Spring, Dummer, Paterson Range, Sahara, Percival, Helena, Rudall, Tabletop, Ural, Wilson, Runton, Morris and Ryan 1:250 k standard map sheet areas	TBA
Little Sandy Desert W and E Blocks	GSWA	GA	Sander Geophysics	W Block: 27 Apr 2018 E Block: 18 Jul 2018	52 090	2500 m	129 400	W Block: 3 Jun 2018 EBlock: 2 Sep 2018	TBA	195: Aug 2018 p. 17	TBA
Kimberley Basin	GSWA	GA	Sander Geophysics	04-Jun-18	61 960	2500 m	153 400	15-Jul-18	TBA	195: Aug 2018 p. 17	TBA
Warburton-Great Victoria Desert	GSWA	GA	Sander Geophysics	Warb: 14 Jul 2018 GVD: 27 Jul 2018	62 500	2500 m	153 300	Warb: 31 Jul 2018 GVD: 3 Oct 2018	TBA	195: Aug 2018 p. 17	TBA

TBA, to be advised

Table 3. AEM surveys

Survey name	Client	Project management	Contractor	Start flying	Line km	Spacing AGL Dir	Area (km ²)	End flying	Final data to GA	Locality diagram (Preview)	GADDS release
East Kimberley	GA	GA	SkyTEM Australia	26 May 2017	13 723	Variable	N/A	Nov 2017	24 Aug 2017	TBA	TBA
AusAEM (Year 1)	GA	GA	CGG	TBA	59 349	20 km with areas of infill	TBA	31 Jul 2018	2 Oct 2018	186: Feb 2017 p. 18	Released on GA website, 11 Dec 2018
Surat-Galilee Basins QLD	GA	GA	SkyTEM Australia	2 Jul 2017	4627	Variable	Traverses	23 Jul 2017	Nov 2017	188: Jun 2017 p. 21	TBA
Stuart Corridor, NT	GA	GA	SkyTEM Australia	6 Jul 2017	9832	Variable	Traverses	12 Aug 2017	Nov 2017	188: Jun 2017 p. 22	TBA

TBA, to be advised

Table 4. Magnetotelluric (MT) surveys

Location	State	Survey name	Total number of MT stations deployed	Spacing	Technique	Comments
Northern Australia	Qld/NT	Exploring for the Future – AusLAMP	320 stations deployed in 2017–18	50 km	Long period MT	The survey covers the area between Tennant Creek and Mount Isa. The 2018 eld season commenced in May 2018.
AusLAMP NSW	NSW	AusLAMP NSW	139 stations deployed in 2018 to date	50 km	Long period MT	Covering the state of NSW with long period MT stations at approximately 50 km spacing.
Olympic Domain	SA	Olympic Domain	320 total	Varied 1.5 to 10 km	AMT and BBMT	The survey area extends west of Lake Torrens and covers mineral prospects such as Carrapateena, Fremantle Doctor, Red Lake, Punt Hill, Emmie Blu- and Mount Gunson. The survey was completed to Jul 2018.

TBA, to be advised

Table 5. Seismic reflection surveys

Location	State	Survey name	Line km	Geophone interval	VP/SP interval	Record length	Technique	Comments
South East Lachlan	Vic/NSW	SE Lachlan	Approx 450	10 m	40 m	20 s	2D – Deep crustal seismic reection	The survey covers the South East Lachlan Orogen crossing the Victorian–New South Wales border. The data acquisition phase of the survey commenced on 5 Mar 2018 near Benalla in Victoria. The survey completed data acquisition south of Eden in NSW on 29 Apr 2018. Data will be released late 2019.
Kidson	WA	Kidson Subbasin	Approx 900	20 m	40 m	20 s	2D – Deep crustal seismic reection	Within the Kidson Sub-basin of the Canning Basin extending across the Paterson Orogen and onto the eastern margin of the Pilbara Craton. The survey completed acquisition on 8 Aug 2018.

Geological survey of Queensland: New geophysical data released for Queensland's north west mineral province

Data for the Cloncurry North airborne magnetic and radiometric survey were released on [QDEX Data](#) in February 2019. The survey consists of over 100 000 line km of data that was acquired at 100 m line spacing with a 50 m terrain clearance and provides new high-resolution coverage in the area to the north of Cloncurry.

The Cloncurry North survey borders the 2017 Cloncurry South survey and a merge of the two provides a seamless coverage over the approximately 20 000 km² area. Both new surveys show a marked improvement in data quality compared to the previous Mount Isa Mines Open Range survey acquired in the 1990s. The products of the Cloncurry North survey are currently being used within the GSQ to update the solid geology and structural interpretations of the northern Mary Kathleen domain.

The logistics report, DEM, magnetic and radiometric geodatabase as well as a collection of grid files (TMI, RTP, 1VD, K/Th/U/Dose) and Geotiff files are all available for download through [QDEX Data](#). A set of merged grids of the Cloncurry North and Cloncurry South datasets ([Figure 1](#)) is also available to download from [QDEX Data](#).

A contract for a new survey with similar specifications has been awarded to Thomson Aviation and flying is due to commence shortly, after a delay caused by the recent extreme weather conditions in North Queensland. The Central Isa magnetic and radiometric survey is located to the west of the Cloncurry North and Cloncurry South surveys extending towards Mount Isa ([Figure 2](#)). The survey will comprise of 85 000 line km of 100 m line spaced data with the resultant merge of all three surveys covering approximately 28 000 km².

GSQ geophysicists are currently in the planning stages of an extension to the well-received Cloncurry Magnetotelluric Survey. Site selection, landholder discussions and cultural heritage negotiations are currently

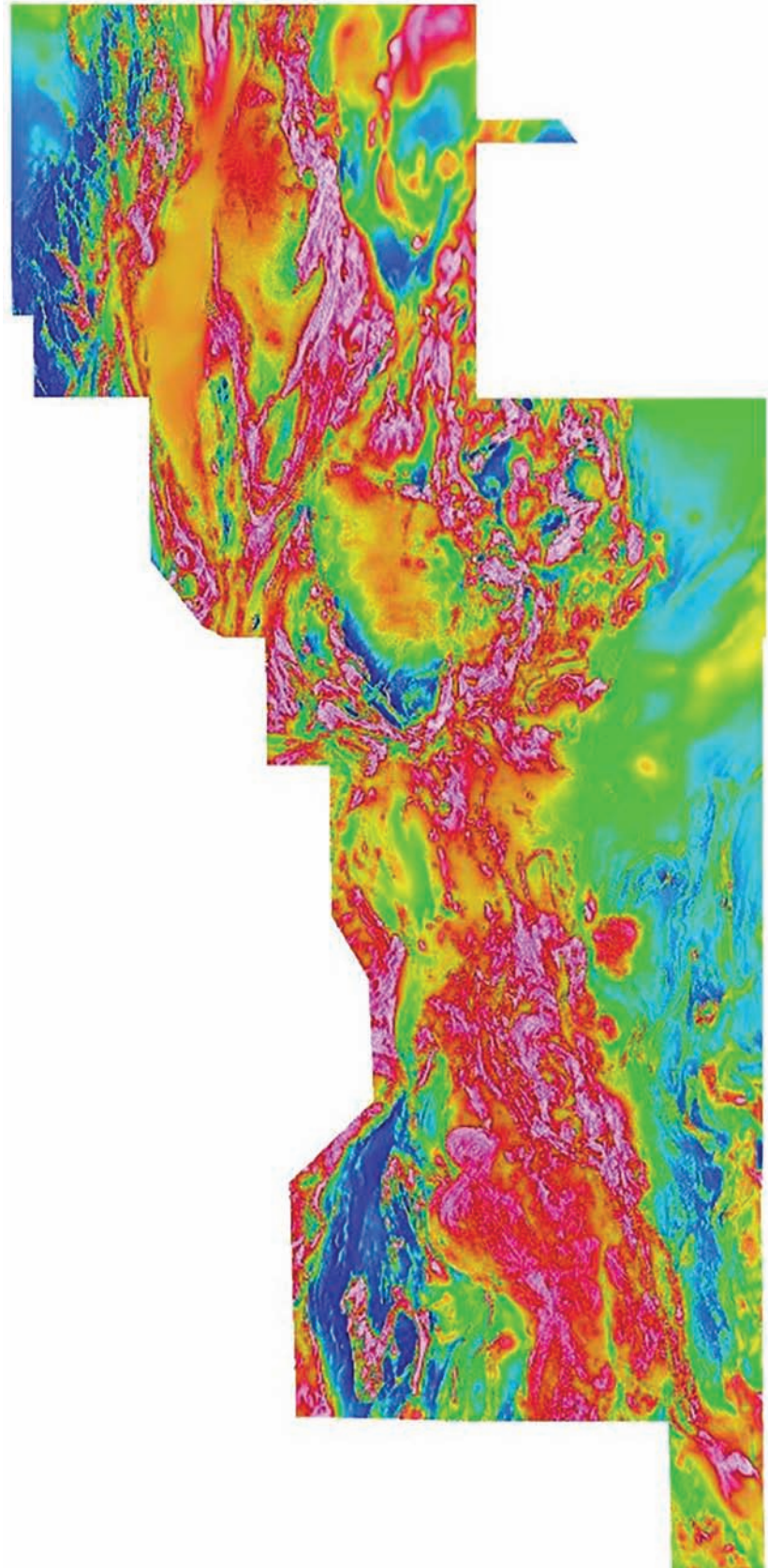


Figure 1. Reduced-to-pole magnetic grid overlain by partially transparent greyscale first vertical derivative of RTP of the merged Cloncurry North and Cloncurry South data sets.

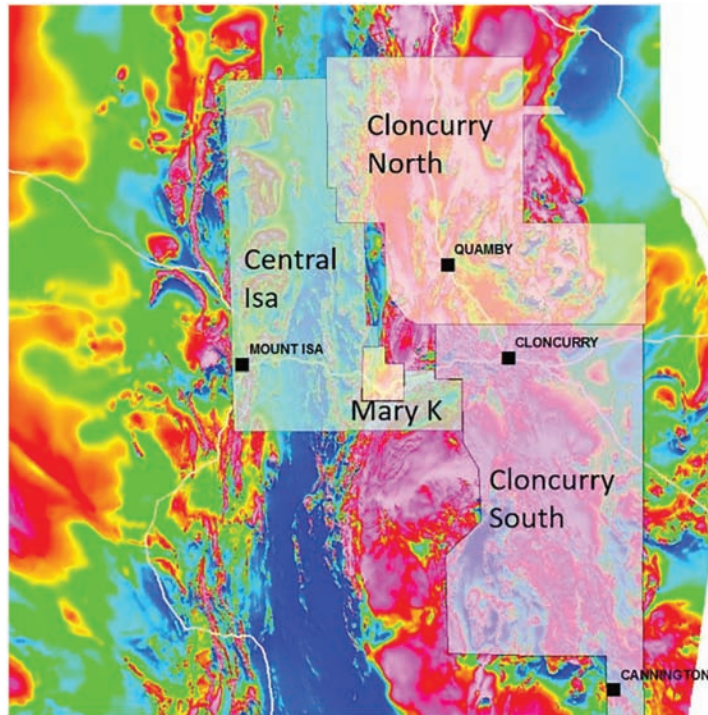


Figure 2. Locations of the two completed surveys and the planned Central Isa survey.

underway for the new survey that will be conducted with Geoscience Australia. Further information and location details will be confirmed in a future *Preview* article.

Matthew Greenwood
Geological Survey of Queensland
Matthew.Greenwood@dnrme.qld.gov.au

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Geological Survey of Victoria: Otway Basin Airborne Gravity Survey - data acquisition complete

The Geological Survey of Victoria (GSV) has completed the data acquisition phase of the Otway Basin Airborne Gravity Survey in south west Victoria (Figure 1). The survey is a key component of the Victorian Gas Program, which is a comprehensive program of scientific research and related activities to assess the potential for further discoveries of onshore conventional gas and offshore gas in Victoria.

CGG Aviation (Australia) Pty Ltd flew 32 000 line-km of Full Spectrum Falcon® gravity gradiometry and magnetic data at 500 m line spacing and 150–300 m terrain clearance between August 2018 and January 2019. The survey was flown using two fixed-wing aircraft (single engine onshore, twin-engine offshore)

and included flying a common repeat line and a test area, a block of 11 lines by 10 line-km, to verify that the two systems were collecting equivalent data.

The GSV is pleased to report no accidents or incidents associated with the survey, with extensive community consultation undertaken to facilitate flying near dairy farms, racehorse stables and protected marine mammal areas including whale nurseries.

During the data acquisition phase a total of 24 crew spent time in Warrnambool, and the survey contributed approximately \$430 000 to the local economy.

The survey has resulted in the largest airborne gravity dataset ever collected in Victoria and provides superior quality

gravity imagery in south west Victoria, compared with pre-existing data. Qualitative interpretations of the data will infill and complement seismic datasets in the Otway Basin, particularly over the three-nautical mile zone around the Otway coast where very little geological data has been acquired previously.

The survey data will be released to the public through the Earth Resources website (www.earthresources.vic.gov.au) in the first half of 2019. For more information on the Victorian Gas Program visit www.earthresources.vic.gov.au/earth-resources/victorian-gas-program or email vgp@ecodev.vic.gov.au.

Suzanne Haydon
Geological Survey of Victoria
Suzanne.Haydon@ecodev.vic.gov.au

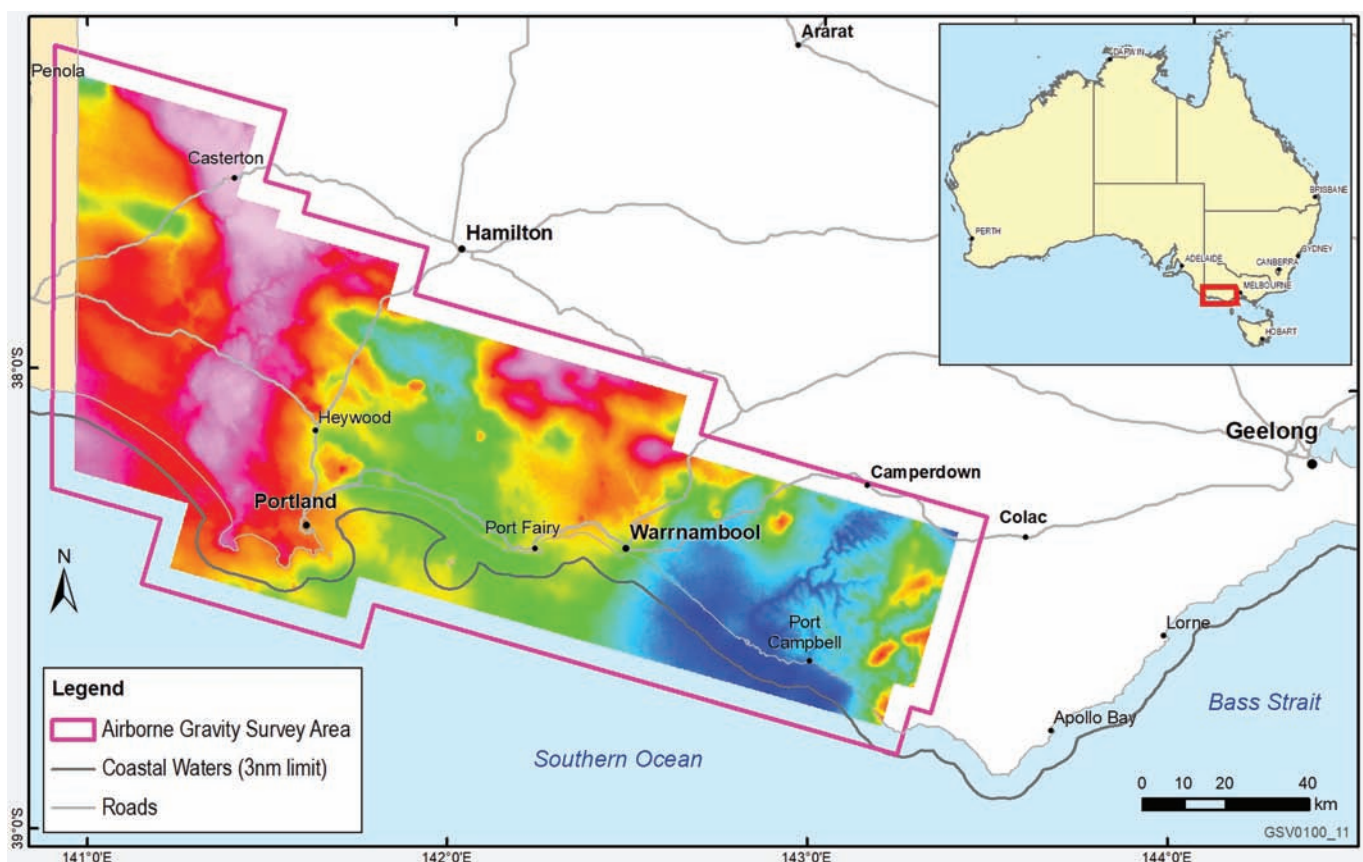
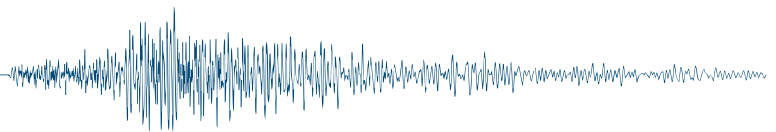


Figure 1. Map showing preliminary free air gravity data from the Otway Basin Airborne Gravity Survey (pink = high, blue = low).



Canberra observed



David Denham AM
Associate Editor for Government
denham1@inet.net.au

More exploration for both minerals and petroleum in 2018

Minerals

Investment in mineral exploration continues to increase, according to the Mineral and Petroleum Exploration data for the final quarter of 2018, released on 4 March 2019 by the Australian Bureau of Statistics (<http://www.abs.gov.au/Ausstats/abs@.nsf/glossary/8412.0>).

The trend-estimate for total mineral exploration expenditure for Australia increased 0.4% (\$2.2m) to \$554.4m in the December quarter 2018. This is 15% higher than the December quarter 2017 estimate. It is now at similar levels to what it was in the December quarter 2006, and although well below the peak of \$1163m in the June 2012 quarter (see Figure 1) the steady upward trend since the 2016 March quarter has been maintained.

Western Australia with a \$346m investment in the December 2018 quarter, continues to dominate with 60% of the Australian total. Gold is still the favoured commodity, with a record \$243 million invested. This is 42% of the total invested in the December quarter of \$583m. Gold is followed by copper at \$82m, iron ore at \$76m and coal at \$50m.

Without the investment in gold exploration, the minerals exploration sector could be in trouble.

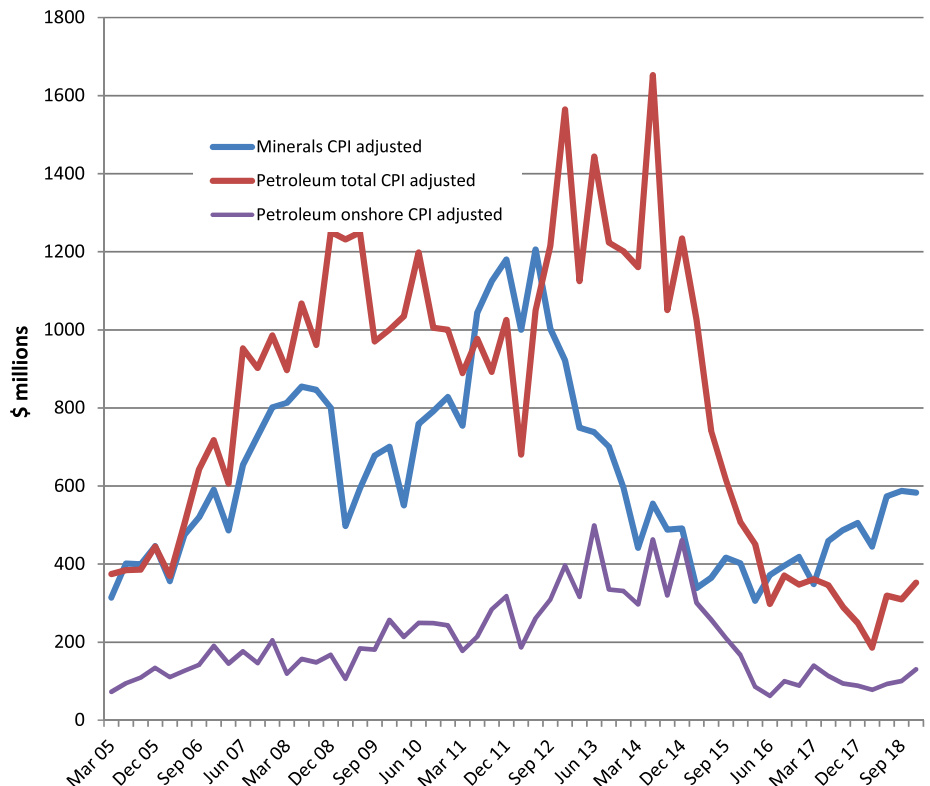


Figure 1. Quarterly investment in mineral and petroleum exploration from 2005 through 2018, adjusted AS in December 2018. The pale-yellow plot represents onshore exploration investment.

Petroleum

It looks as though the investment in petroleum exploration is starting to recover, with the trend estimate rising by 11.1% (\$35.6m) to \$356.4m in the December quarter 2018. Expenditure on production leases rose 31.3% (\$28.6m) and expenditure on all other areas rose 1.6% (\$3.6m). Figure 1 shows the actual expenditure for onshore and the total (\$352m) expenditure for both on and off shore activities. Both sectors are increasing, and the onshore component is now worth about 60% of the offshore amount. Western Australia still dominates with \$202m (57% of the total) spent in that state, followed by Queensland at \$64m.

Hopefully, the upward trends will continue, because we urgently need to find more petroleum in Australia.

Government encourages greenhouse gas storage

The Government announced, in February 2019, that it would like to hear from

companies interested in conducting exploration for greenhouse gas (GHG) storage in Australia's offshore areas (<https://www.industry.gov.au/news-media/greenhouse-gas-acreage-release-indications-of-interest-open>).

GHG acreage releases are held on an occasional basis, where there is enough industry demand. The last GHG acreage release in 2014 resulted in 3 GHG assessment permits being awarded to the Victorian Government in the Gippsland Basin. These are shown in Figure 2. VIC-GIP 001 was awarded to the Victorian Government in 2012. This permit is by far the largest and covers 4,400 km² off the Gippsland coast.

The Australian Government, along with state and territory governments, are investigating several GHG storage sites, shown in Table 1.

Government's main roles are to:

- provide companies the opportunity to apply for assessment permits, holding leases and injection licences,

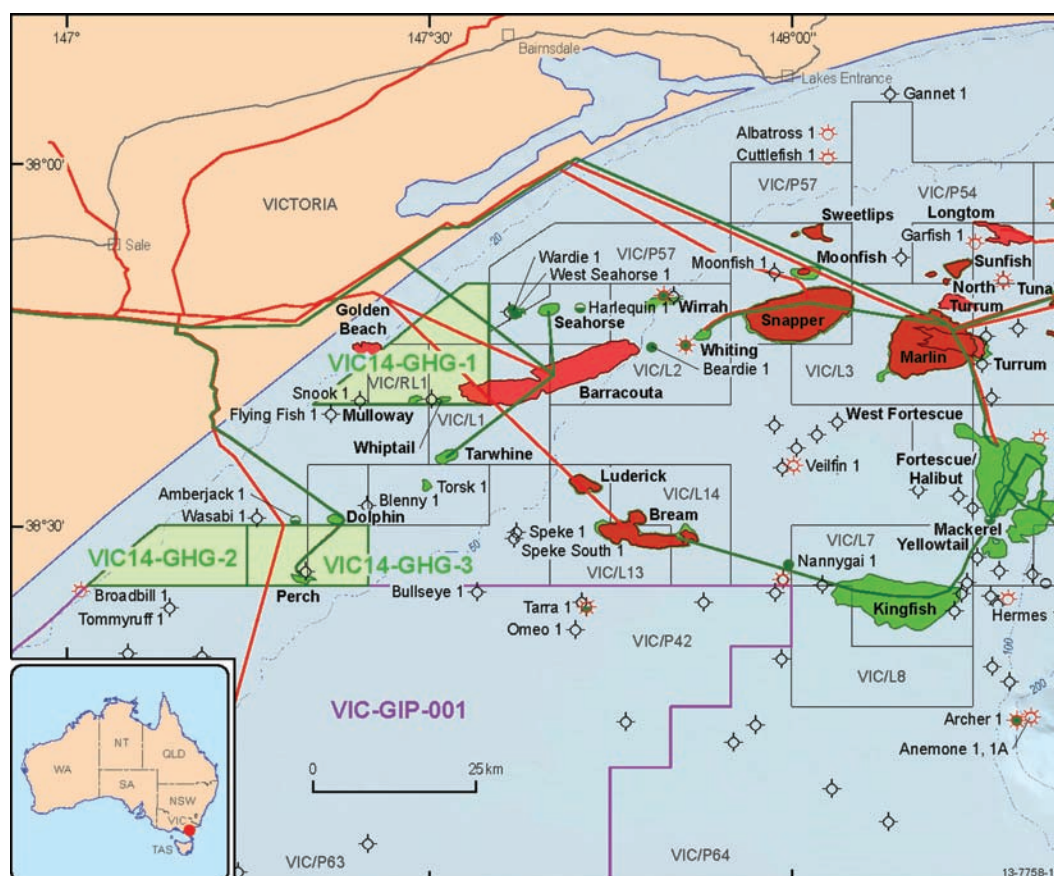


Figure 2. Areas in Gippsland Basin where permits have been awarded to explore for GHG storage sites. All four were awarded to the Victorian Government (see text).

Table 1. Greenhouse gas storage sites being investigated by Australian governments

Regions	Basins
South West Western Australia	South Perth (onshore) Vlaming sub-basin (offshore)
North West Western Australia	Browse (offshore) Canning (onshore)
Victoria	Gippsland (offshore) – Stage 1, Gippsland (offshore) – Stage 2
Southern and central Queensland	Surat and Bowen (onshore)
New South Wales	NSW (onshore) Darling (onshore)
Northern Australia	Petrel Sub-basin Bonaparte Basin (offshore)

- ensure the greenhouse gas is safely and securely stored,
- provide mechanisms to manage interactions between the green and petroleum industries, and
- regulate site closures and long-term liability treatments.

If you are interested in participating in this programme, then you should provide your contact details and a general location of the area that you may be interested in exploring to ghgacreage@industry.gov.au.

Offshore petroleum exploration update

Three new offshore exploration permits awarded

In February 2019 three new cash-bid exploration permits were awarded by the Australian Government. They are in offshore areas of Western Australia and Victoria, and are outcomes from the 2018 Offshore Petroleum Exploration Acreage Release auction (see <https://www.industry.gov.au/news-media/2018-offshore-petroleum-acreage-release-cash-bidding-results>).

[gov.au/news-media/2018-offshore-petroleum-acreage-release-cash-bidding-results](https://www.industry.gov.au/news-media/2018-offshore-petroleum-acreage-release-cash-bidding-results)).

Cash-bid permits authorise the holder to apply to undertake exploration activities in the permit area. They have usually been applied to small tenements, and the Government has announced that this will be the last cash-bid auction

for the foreseeable future. From now on, bids will be primarily assessed on the value of the committed programme of exploration activities proposed and will apply to all sizes of tenement.

The successful companies in this tranche of permits paid a total of \$11.1 million to secure the right to explore these areas for the next 6 years.

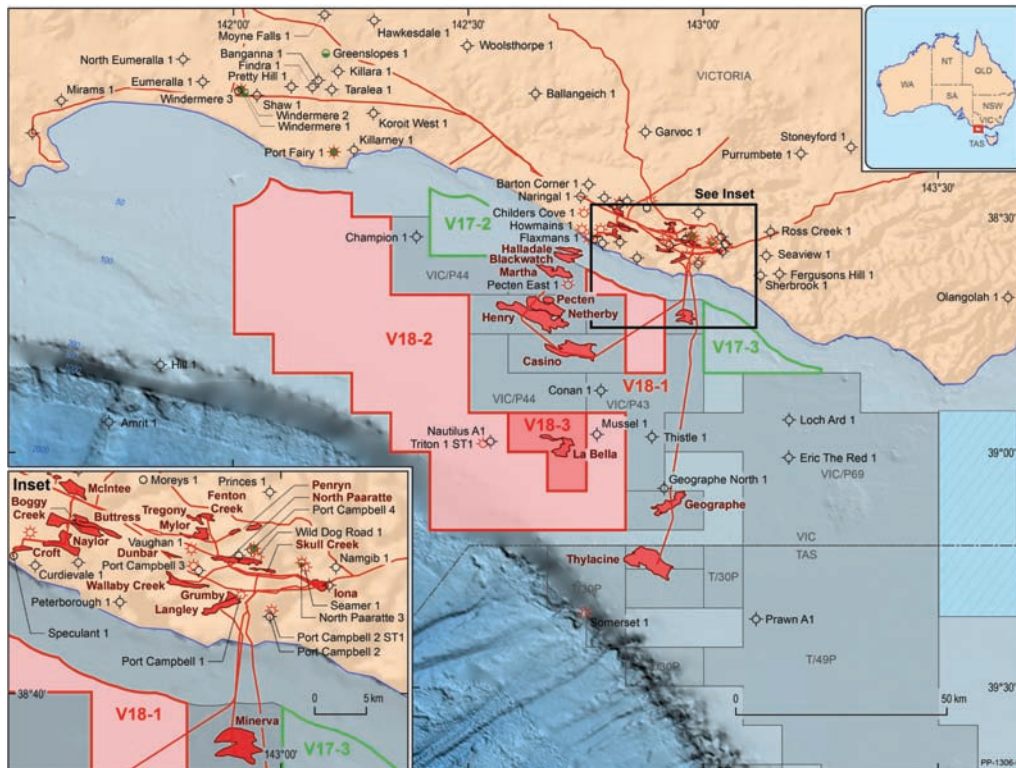


Figure 3. Location of release area V18-3 showing La Bella gas field. La Bella 1 intersected gas at about 2 km depth when it was drilled in 1993. There is no scale on the map but the area of V18-3 is approximately 270 km².

They were awarded as follows:

1. Exploration permit Vic/P73 in the V18-3 release area in the Otway Basin, 50 km south of Warrnambool, awarded to Lattice Energy with a successful cash bid of \$4 million. This area contains the La Bella gas field (See Figure 3).
2. Exploration permit WA-536-P in the W18-7 release area in the Northern Carnarvon Basin, 150 km west of Dampier, awarded to Woodside Energy and KUFPEC (as joint applicants). KUFPEC is an international petroleum resource company based in Kuwait. It operates in 13 countries and has a capital value of approximately US\$ 4000 billion. Two bids were made in the auction; the successful joint cash bid was \$5.1 million (see Figure 4).
3. Exploration permit WA-537-P in the W18-10 release area in the Northern Carnarvon Basin, 240 km west of Onslow, was awarded to Chevron Australia. One bid was made in the auction and the successful cash bid was \$2 million (Figure 5).

These three areas are all comparatively small, and are either in, or close to, areas that have been explored previously. The exploration activities planned by the successful bidders have

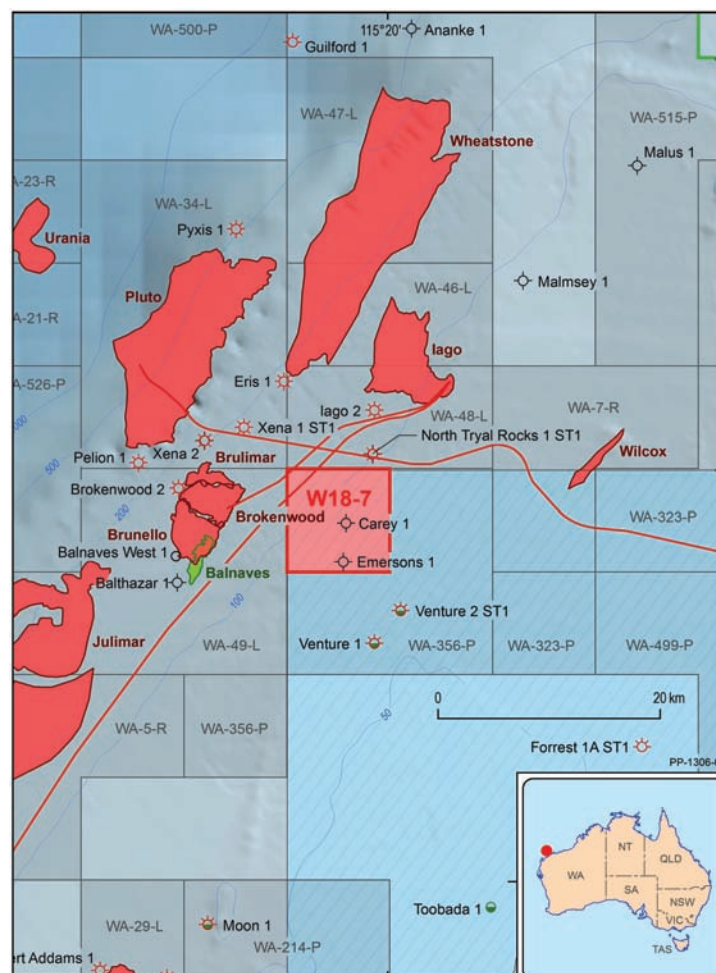
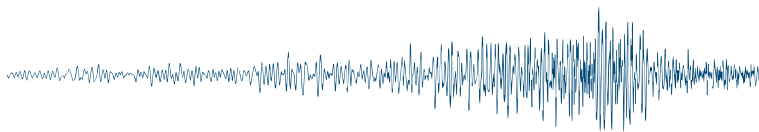
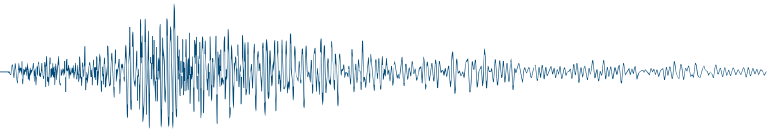


Figure 4. Location of release area W18-7, which occupies an area of about 90 km². The red lines indicate gas pipelines.



-



- better focus the sector's innovation, research and development on long-term, sectoral growth,
- develop and retain the world's best workforce and
- deliver better outcomes for stronger and more engaged communities.

These are all very nice words, but when you drill down into firm financial commitments there is not too much new money to be found.

There is a very welcome \$20m for a Co-operative Research Centre project to find and develop 'critical mineral resources' such as lithium, cobalt and titanium, and also a commitment to extend Geoscience Australia's 'Exploring for the Future' programme for four more years.

Beyond these items the words are non-committal. The key actions in the Statement are:

Investigating expanding the scope of Geoscience Australia's Exploring for the Future program and extending it for four years. This would extend its benefits into the southern half of the Australian continent and include targeted offshore areas to access new, deeper resources.

Working with industry, through the Australian Bureau of Statistics (ABS), to examine the feasibility of expanding the Survey of Mineral Exploration. Expanding this survey aims to improve the information collected about greenfield exploration to greater reflect current industry exploration activities.

Working with industry, state and territory governments and local communities to promote priority new greenfield basins and provinces. We will seek to align policies, provide information and investment services, and develop a shared vision for infrastructure.

Working cooperatively with the Northern Territory to bring forward the development of the Beetaloo Sub-basin as a potentially world-class new gas province and to assist in maximising the downstream value of the petroleum industry for the Northern Territory and the broader Australian economy.

Exploring longer-term options to enhance the offshore petroleum titles management framework in consultation with industry. Enhancements will aim to provide greater transparency on offshore gas reserves, accelerate offshore resources development and streamline administrative processes.

When I read words like 'Investigate expanding' or 'examine the feasibility of expanding' I start to worry about the commitment, particularly when the government has been cutting the budget of the Australian Bureau of Statistics.

The Australian Labor Party

The Australian Labor Party (ALP) also draws on the 2030 Task Force report, and provides for similar outcomes through a Future Mines and Jobs Plan (<https://www.jasonclare.com.au/media/portfolio-media-releases/4159-labor-to-kick-start-the-mines-and-mining-jobs-of-the-future>), which was also released in February 2019. Some parts of the plan state:

Labor will establish the Australian Future Mines Centre, to co-ordinate exploration work and lead the scientific research and development necessary to explore under deep cover. The Centre will be funded through a \$23 million Australian Research Council Special Research Initiative, with input from the Australian Academy of Sciences and the sector. We will also encourage industry co-funding as part of the Centre's work.

The Centre will also deliver on the need for an industry data strategy and explore options for innovation collaboration across the sector – key recommendations of the Resources 2030 Task Force Report.

The Plan will also help deliver the mining jobs of the future, with \$2 million to provide 100 scholarships to arrest the dramatic decline in mining engineering degree commencements. And consistent with Labor's commitment to equality for women of Australia, no less than 50 per cent of these places will be awarded to women.

Labor commits to a Resource White Paper process, to deliver the long-term vision across Government for the resource sector and to ensure we capitalise on all the opportunities it can bring.

Conclusion

It's good to have a bi-partisan approach with similar commitments and goals to boost exploration. The \$20 million commitment of new money from the Coalition and \$25 million from the ALP are very welcome, and let's hope that whoever is elected carries out their promises.

The Government announces details of a new National Interest Test

In the December 2018 issue of *Preview* I indicated that the Government was concerned that some of the research it funds through the Australian Research Council may not be in the national interest, even though all applications were being assessed against a "National Benefit" criterion.

On 27 November 2018, Dan Tehan MP, Minister for Education announced how the new National Interest Test (NIT) would apply to future ARC grant applications.

He stated that:

Applicants will be asked to explain 'the extent to which the research contributes

to Australia's national interest through its potential to have economic, commercial, environmental, social or cultural benefits to the Australian community'.

The previous "benefit and impact" application text will be replaced with a compulsory field for the applicant to make their case against the NIT. This statement will be 100 to 150 words long and in plain English. The NIT will apply to all future rounds. This approach creates "no additional burden" to researchers in preparing their applications but requires them to specifically address the NIT definition. ARC assessors will assess applications and provide recommendations to the

ARC CEO. The ARC CEO will assess the NIT of each application and provide advice to the Minister. The Minister can also use the NIT "in making their decision."

Although the NIT may result in "no additional burden" on the applicants, pity the CEO of the ARC having to read hundreds of NITs for every round of applications. And I would like to know what happens if an applicant can provide reasons the research is in the national interest in less than 100 words?

Is the Minister a control freak or is he trying to ensure that all research funds are spent wisely?

Education matters



Michael Asten
Associate Editor for Education
michael.asten@monash.edu

Next generations of earth scientists III: mentoring of early-career professionals in WA

The past two editions of *Preview* have included articles on earth-science education programmes in secondary schools of Western Australia (ESWA), and a programme linking science mentors with high-school students in the Australian Capital Territory. In this issue we feature an account of a mentoring programme operating at the next level up, which is, linking senior geoscientists

in a mentoring role with early-career professional geoscientists. This latest programme is a joint initiative of the West Australian branches of ASEG and PESA.

Heather Tompkins (ASEG WA President), with Ishtar Barranco (PESA Federal Secretary) and Carolina Pimentel (ASEG WA, Branch Committee), brings us the story.

A mentoring programme bridging the gap between generations working in the energy and resource industries

How can we leverage experience, assist with knowledge retention within our industry, and transition the next generation of geoscientists into future leaders? Our answer to this question is a mentoring programme, where success is measured not just by a focus on developing capability in a mentee, but by growth of a mutually beneficial partnership offering valuable new insights to both parties.

As Ishtar Barranco of PESA puts it, "Mentoring is a really personal and meaningful way that you can help someone, and give back to the industry".

The Australian Society of Exploration Geophysicists (ASEG) and Petroleum Exploration Society of Australia in Western Australia (PESA WA) have jointly established a mentoring programme. This programme kicked off in Perth during 2018 and comprised of 20 carefully matched pairs of individuals who worked together over the course of six months. The programme was initially designed to match very experienced professionals with less experienced or recent graduates; however, it was quickly expanded to also include individuals in the middle of their careers based on the expressions of interest that we received. Early and mid-career participants face different kinds of challenges, but both groups were looking for guidance and advice on their career pathways.

Carolina Pimentel is a member of the ASEG WA Branch Committee and she volunteered to design and coordinate

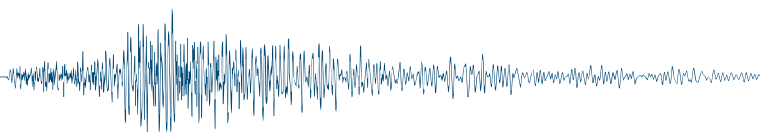
the 2018 mentoring programme, alongside Ishtar Barranco and Simon Molyneux of PESA. This team has facilitated workshops at set points along the mentorship journey. Carolina is the Data Management/GIS Specialist for CGG Services Multi Client and Venture department. Her background is engineering and previously she worked for more than 6 years with the CGG Subsurface Imaging Team. Carolina believes that the mentoring programme will help new generations to gain more confidence to pursue professional goals

in a controlled and safe mentoring environment.

The mentoring programme coordinators were keen to identify ways to help bridge the gap between generations working in the energy and resource industries. Ishtar reports that "We brought together very senior people, some of whom were actually retired but were willing to share their knowledge and experience, together with young people who were really thirsty for their insights. These people have worked all around the world and



Members of the WA mentoring programme organising committee: (left to right) Ishtar Barranco (PESA), Carolina Pimentel (ASEG) and Simon Molyneux (PESA).



can talk to the ways that the industry has changed and developed over decades. It's very inspiring for the younger generation to hear these perspectives".

Feedback on the mentoring programme from mentees highlighted the value in their gaining of advice, expanding networks, and developing personal skills to help in the workplace. A few very positive comments received were:

- "The programme provided me with the opportunity to expand my professional network and receive valuable career advice from industry professionals"
- "The programme helped me with my personal development – we focused on some of the 'softer' but really important skills like networking and communication"
- "Mentoring is a really personal and meaningful way that you can help someone, and give back to the industry,"

- "It's not just the mentees that reap the benefits. The industry is undergoing massive change as processes and systems are rapidly digitised. This creates the potential for experienced professionals to be left behind if they don't keep up with changing technology, and mentorship offers an opportunity to help bridge the gap".

The mentoring programme organisers believe that programmes like this one may help to address cyclicality in our industry and ensure that young people are supported, no matter what is happening in the external environment. One of the challenges in our industry is that it is very binary. In boom times the industry is extremely supportive of its young people. We find it easy to attract fantastic young talent, and spend a lot of money and time investing in training. But, when market conditions decline, it is harder for senior managers to support the next generation. This is one of the reasons we started the

programme – to help support and nurture talent through industry cycles.

Deemed a resounding success in 2018, the ASEG-PESA mentorship programme has returned for 2019, and joins with six other societies to provide a more diverse range of professional members and broader networking opportunities. With continual changes in the energy and resource industries, it's clear that mentorship programmes like this one will continue to be in high demand – serving to benefit both the experienced and the more junior members of our profession by leveraging professional and life experiences.

Heather Tompkins (ASEG WA, President)

Ishtar Barranco (PESA, Federal Secretary)

Carolina Pimentel (ASEG WA, Branch Committee member)

wa-mentoring@aseg.org.au

wa-mentoring@pesa.com.au

Honorary lecturer series continues in 2019

SEG/ASEG Honorary Lecturer Professor Boris Gurevich of Curtin University commenced his lecture tour during March 2019. He gave talks to each ASEG branch around Australia, and all the talks were live-streamed and recorded. Further details about how to access this programme of talks will appear in the next issue of *Preview*.

Professor Gurevich's Australian tour was proudly supported by CGG Geosoft (Platinum Sponsor), DUG (Gold Sponsor) and the ASEG. Also, these lectures would not be possible without Shell, a long-term sponsor of all SEG Distinguished and Honorary Lecture tours.



Professor Boris Gurevich presents his lecture "Seismic attenuation, dispersion, and anisotropy in porous rocks: Mechanisms and Models" to the WA Branch in March 2019.



Australian Society of
Exploration Geophysicists



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Environmental geophysics



Mike Hatch
Associate Editor for
Environmental geophysics
michael.hatch@adelaide.edu.au

Geoscientists without Borders mapping groundwater in Laos

Welcome readers to this issue's column on geophysics applied to the environment. This month I describe an interesting project that I am still working on with some colleagues from Flinders University.

Back in 2017 we were awarded a Geoscientists without Borders (GWB) grant from the SEG for a project in Laos. One of the interesting things about GWB grants is that they can't just be straight research, they have to (a) be on a project that is directly applicable and beneficial to a real-world problem,

and (b) must include local community involvement, local student involvement, and government involvement. All of which we did in spades – we wanted to introduce a number of geophysical techniques that could be applied to hydrogeological problems to professors and their students from local universities, as well as to government scientists involved in groundwater work.

We kick-started the project in March 2018 by giving a half day seminar to a number of students and government people about the application of geophysics to hydrogeological problems (they had some experience in this already). We then introduced them to a number of techniques, with which they did not have experience, that we wanted to test in the field. Nineteen ultimately spent time with us in the field collecting data, some only for a day or two, some for the entire ten day programme. Here is our story.

The Lao PDR is a landlocked country that depends mostly on rainfall and river irrigation for farming – and farming is the main occupation of most people in Laos. Groundwater supplies are not abundant, and are of mixed quality. Our project aim was to use geophysics to support investigations into the extent and quality of groundwater in Laos, and to attempt to expand known groundwater supplies into new areas for irrigation. Being close to the

equator, there are two seasons: a wet season and a dry season. The problem is that during the wet season there is plenty of water; during the dry only farmers within ~300 m of rivers are able to irrigate and to grow good crops. To complicate the groundwater story, there are sporadic salt deposits that reduce the quality of groundwater locally. Locating these salt deposits, and then staying away from them, is an important step towards ensuring good groundwater quality.

We collected data at 18 sites along a roughly 18 km line going E-W from west of Km52 Village to the Nam Ngung River (Figure 1). At six of these sites (the major study areas) we collected data using a number of techniques. These included (but were not limited to): ground resistivity (a 64 channel Iris system – Figure 2),

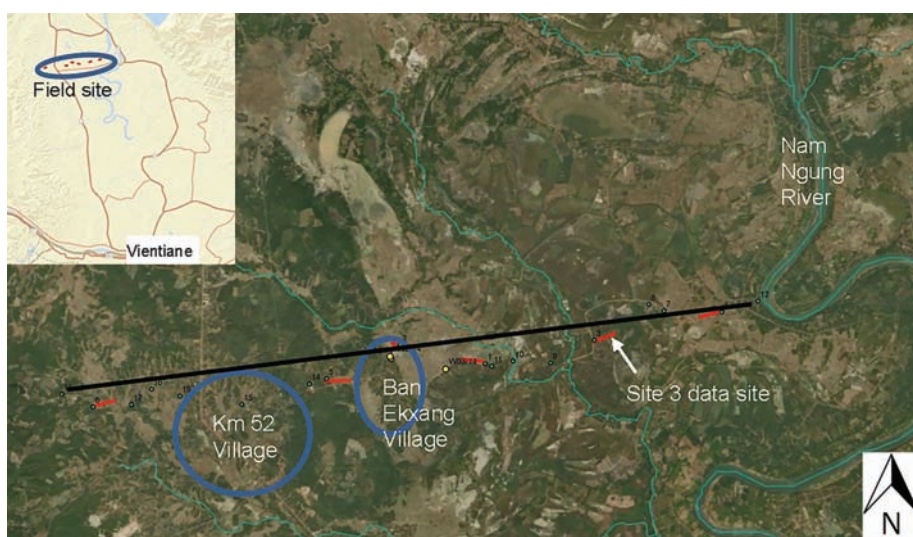


Figure 1. Overview of field area. Note that we collected data at various sites along an approximately 18 km transect (black line).



Figure 2. Setting up and running resistivity equipment on one of the survey sites.

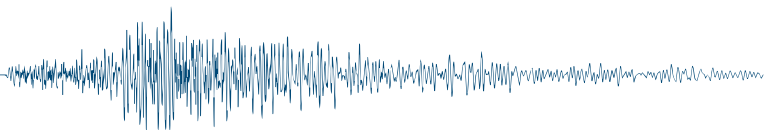


Figure 3. Collecting ground conductivity data at one of the survey sites.



Figure 4. Collecting shallow TEM data at one of the survey sites.

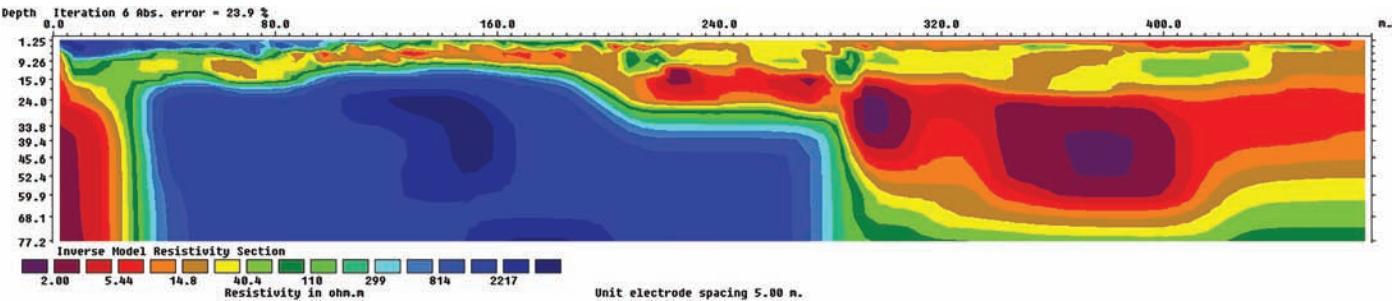


Figure 5. Resistivity data collected at Site 3. A resistive zone, possibly hard rock, is apparent on the left of the section and a conductive zone, possibly a salt deposit, is apparent on the right of the section.



Figure 6. Explaining our results to local government officials. This is the meeting where we found out that the locals have had problems with salty water in the creek near our Site 3 data line.

there would be no need to test drill other similar looking conductive units. More importantly, (b) it is obvious that this would not be a good place to drill for water as the water is likely to be of poor (very saline) quality.

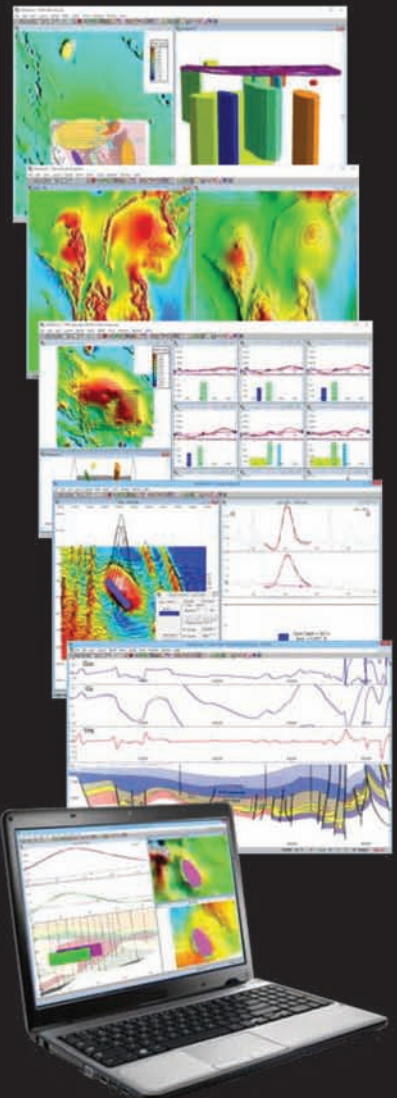
We thank the Society of Exploration Geophysicists (SEG), Geoscientists without Borders (GWB) programme

for the main funding of this project. We also thank the International Water Management Institute (IWMI) based in Vientiane for their support. In addition, we would like to thank all of the students, their professors, and all the government water management professionals who helped us collect the data. We could not have done this work without their help!

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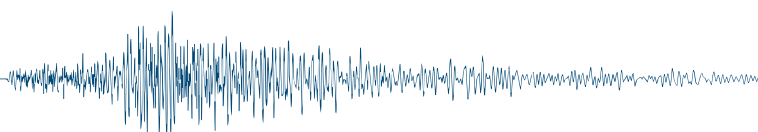


Tensor Research

support@tensor-research.com.au

www.tensor-research.com.au

Tel: +61 404 064 033



Minerals geophysics



Terry Harvey
Associate Editor
for Minerals geophysics
terry.v.harvey@glencore.com.au

Life without mining – A Brave New World

For the April issue of *Preview* I thought I'd postulate a futuristic scenario, activist style – a bit of hyperbole, a few unsubstantiated assertions, some alarmist comments, and possibly an accusation of opponents' malpractice and ill-intent. So, here goes.

The Australian continent is racing headlong towards India and mining is to blame. There can be no doubt – the onset of large scale mining, particularly iron ore, in northern Australia coincides with the first accurate measurements of this northward drift. No actual measurements of drift existed prior to this time. The same situation holds for the current unprecedented rate of global warming, so it must be true. Both are clearly modern phenomena. And it makes sense anyway. Mining has made Australia lighter, so it floats higher, and all that mass of iron ore shipped offshore to the north will attract Australia northwards by gravitational and magnetic forces.

So what are we going to do about it? We've got to get all that missing weight back again so Australia rides lower. Existing iron ore mines have to be filled in, and the mining industry is perfectly equipped to do this. We have the bulk transportation infrastructure in place –

it's just a matter of reversing the flow. And all those on-site crushers can now be used to pulverise whatever we import so that it will pack into the mines that much better. Even if it doesn't stop the drift, we've got to do something.

But we can go much further. Let's fill in all mines, then stop mining completely, and the government can declare Australia to be the first continent (except Antarctica) to be mining free. From this moral high ground we can lecture recalcitrant countries and trumpet our own Keep Australia Mine Free (KAMF) manifesto.

This will not happen without some economic pain, and the government will need a compensation policy. Mining companies will now be paid not to mine orebodies – Australia's version of an EU agricultural policy. Mineral exploration can continue, but any ore discovered stays in the ground. The demand for mineral exploration graduates will soar, both from mining companies seeking to generate new income, and from the state Mines Departments, which will be tasked with vetting the new discoveries to eliminate bogus claims.

"The Australian continent is racing headlong towards India and mining is to blame"

There will be other bonuses too. With the continent becoming drier, and without coal mining or gas and oil extraction, Australia will need to become totally reliant on renewable energy. In the absence of baseload power, given the typical 25–33% generation availability (i.e. 3/4 to 2/3 idle time) for solar and wind, we'll need to build a total renewable energy generation capacity at least quadruple the average demand. And, to weather extended periods of calm and cloudy days, we'll need a storage capacity of, say, 10–20 times Australia's total daily energy demand. That infrastructure will have quite a footprint. So there will be a renewable energy construction boom to take up the slack of displaced workers from the mining industry.

No fossil fuels means that all our transportation vehicles will have to be electric. This will translate to an enormous increase in our power needs, offset in part by a decrease in demand from now non-existent mining and a concomitant decrease in manufacturing. This will add further to the renewable energy construction boom.

The effects of the mining ban on various commodities will be hard to predict. Take Argyle diamonds, and opals, for instance. Will prices soar because loss of production means tighter supply, or will prices crash, like furs, because consumers will no longer want to be seen wearing a product of mining? The jewellery trade could be in for a real shakeup.

But, in reality, modern society cannot function without the products of mining. We could import all we need, but that would be rather hypocritical given our strident no-mining stance. And we probably couldn't afford it either. What we need is organic mining.

A bit of genetic tinkering and we could develop a suite of plants that do our mining for us. Silica from spinifex, lithium from salt lake plantings, iron from ferricrete-loving plants, etc. – the possibilities are unlimited. We could have massive commercial plantings – widespread agriculture is considered acceptable – with the bonus that much more carbon dioxide would be absorbed. Carbon credits from these organic mines could even be on-sold to add much needed finance. And in a government sponsored scheme, consumers could be encouraged to "Grow Your Own Device" in their own backyard with a series of boutique semi-conductor plantings – just pluck the leaves and deliver them to your local processing plant. I look forward to an advertising blurb proudly announcing the world's first totally organic lap-top, with hardwood highlights of course – choose from the fiery red of jarrah or the icy black of ironbark.

We could live in exciting times!

In the next *Preview* issue, back to real mineral geophysics.

Seismic window



Michael Micenko
Associate Editor for Petroleum
micenko@bigpond.com

Footprint removal

Most of us are familiar with an acquisition footprint in our seismic data. It is usually seen as a variation in amplitude, or striping, which runs parallel to the recording direction and is caused by changes in number, azimuth and offset of traces that contribute to the stacked trace. An example of acquisition striping is shown in [Figure 1](#).

It is relatively easy to remove this striping in most situations if we can somehow estimate the amplitude variations. One way to do this is to measure the variation in the data and apply a correction. In many cases the overburden consists of sediments that have relatively constant properties; such as shales. So, if amplitude variations are seen in this part of the sedimentary column, they can be assumed to be the acquisition footprint ([Figure 2](#)).

To remove the acquisition footprint, the estimated footprint is used to normalise the extracted amplitude at the target horizon. The result should be a stripe free amplitude map as seen in [Figure 3](#). Although the striping is not totally removed it is reduced enough to identify the edges of the amplitude anomaly.

If there is no constant property shale in the overburden then a good result can be obtained by calculating the average amplitude or RMS amplitude in a large window (say 500ms) above the target horizon and using that to normalise the target amplitudes.

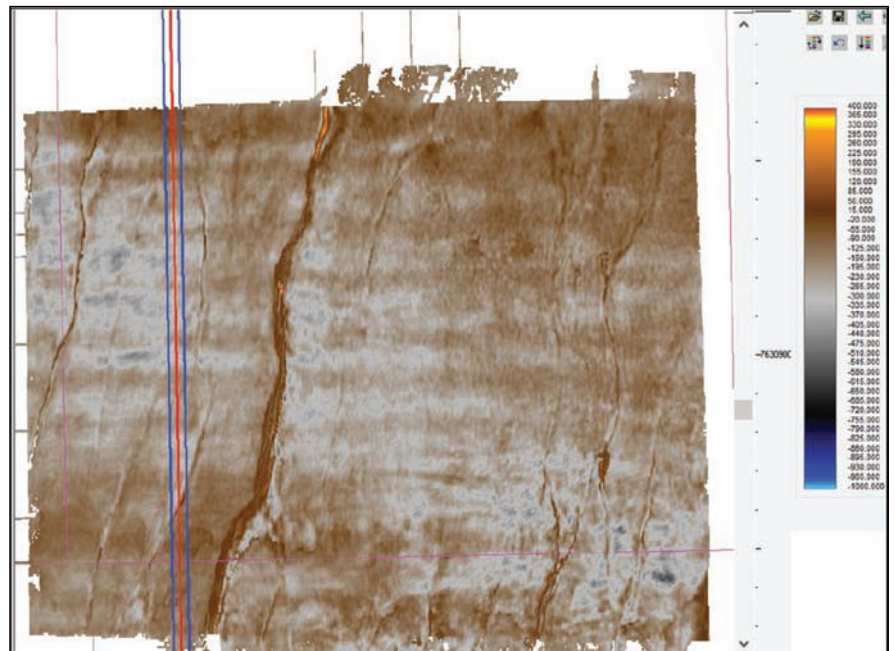


Figure 1. Horizon slice showing strong amplitude striping.

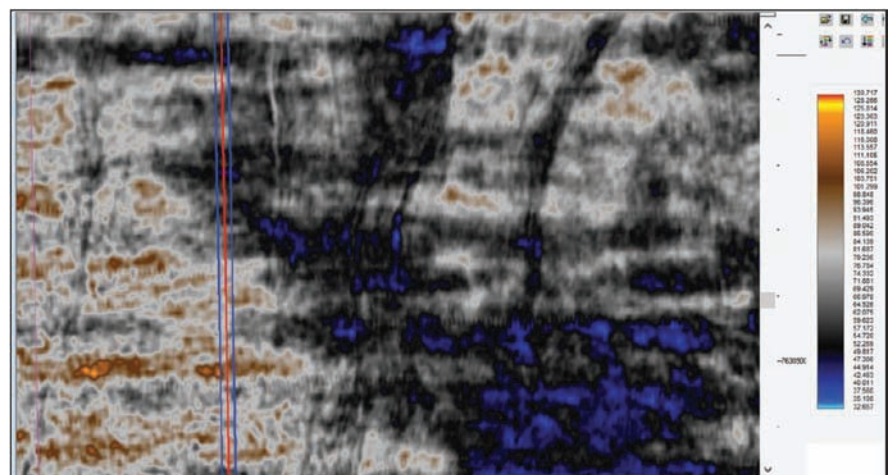


Figure 2. Estimate of striping average amplitude in a 400 ms window section above the target horizon.

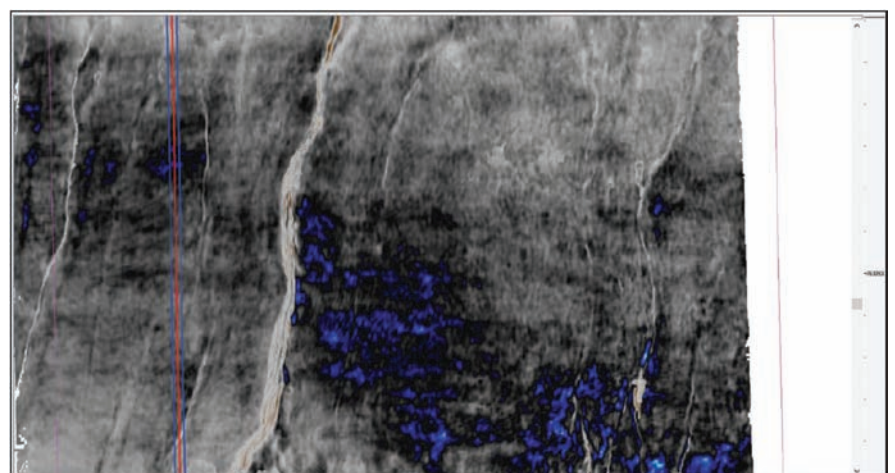
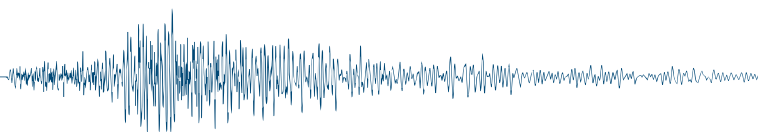


Figure 3. Normalised amplitude at the target horizon. The footprint has been reduced and the edge of the amplitude anomaly (blue) is more continuous.



Data trends



Tim Keeping
Associate Editor for geophysical data
management and analysis
technical-standards@aseg.org.au

Machine learning

The renaming of statistics to data science was easy to follow, but why a separate name for Machine Learning (ML)? Technology bloggers have described machine learning as programmes that use data to write themselves, accumulating rules-of-thumb “knowledge” in the form of statistical models to apply to data, especially visual data. Legend says after Google’s AlphaGo beat the world’s best Go players, a version stripped of its “knowledge”, but armed with machine learning hardware, supposedly learnt to play from scratch and could beat its “older brother” in under a week. Cue the spooky music.

Lucky for geophysicists and geostatisticians, the impending AI apocalypse is just what industry has been ordering for years. The industry has been at the front line of applied

pattern recognition in images and signals since the wonders of digital computers allowed “the first steps towards automated processing of gravity” in 1967 (Hansen *et al.*, 1967). Little surprise that ML is full of the same words and processes. Regularisation, matrices and error minimisation on super computers crunching kernels and optimisation. Rename the work function to objective function, and you are almost at a Doug Oldenburg ASEG talk.

“the impending AI apocalypse is just what industry has been ordering for years”

But what can it do for me – or for you? I looked at Google’s introductory Tensorflow lesson (Google, 2019), which resolves 60 000 pictures of clothing into 10 classes with 87% accuracy. It fell short of the psychologically classic 95% mark, but it could still help us get through the dry parts faster. I could train the software with radiometric line data, and then use it to identify odd readings in a survey. It could consume various layers within a multi layered storage format, such as the Multi Resolution Raster featured a few issues ago, and form “opinions” by predicting holes in data, or flag inferred contradictions when new data is added. ML supposedly promises all this without (much) programming.

Data science also promises to find yet unknown relationships, but a concern for users of said models will be the cumulative effect of the various confidence measurements of each data set used. If Tensorflow operates with 87% success on a 100% labelled data set (i.e. the answers can be

checked), what about surveys where only 95% or less of measurements are considered quality compliant. Is one fifth of the resulting map suspect? If so, which parts? Geostatistically a confidence measure on the input and output matters, as geological models are spun by methods that have more in common with computer science than geology. Each pixel and polygon could have an individual measurement for various survey aspects such as flight speed, height, and the various instrument related measures, which ML could probably be trained to generate.

This (sort of) ties into numbers, and the methods we think we can use. I am currently being extra wary of treating supposedly similar numbers with the same techniques. I am a user of the open source Python package Fatiando, whose author has just announced he has submitted a paper to *Geophysics* questioning the gravity anomaly as a harmonic function and the mathematical methods that entails. Go to Leonardo Uieda’s home page <https://www.leouieda.com/papers/use-the-disturbance.html> to read more.

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Webwaves



Dave Annetts
ASEG Webmaster
david.annetts@csiro.au

Password security

Why does the password “ji32k7au4a83” appear in a list (Hunt 2019a) of commonly-used passwords?

Account security, through password selection and data encryption, has been a common thread through the past few *Webwaves* columns, and this one is no exception. Readers may recall the discovery of the largest collection of breached data in history (*The Guardian* 2019). Comprising over 770 million email addresses in 87GB, Collection #1 was discovered by Hunt (2019a) and appears to comprise email addresses from different sources and different leaks rather than a single data breach. However, given that the collection contains 1 160 253 228 unique combinations of password and email address, readers may choose to check whether their email addresses appear on this (or other lists) by checking the website “Have I been pwned?” (Hunt 2019b).

Hunt’s site (2019b) has another particularly useful page. Entering a

password at Hunt (2019b) can show whether that password appears in any of the known data breaches. Annetts (2018) presented lists of the most common passwords found in leaked data. The most popular password since 2013 (“123456”) appears 23 174 662 times. Another common entry, “password”, appears 3 645 804 times. The password suggested by that article’s cartoon (XKCD 2019), “correcthorsebatterystaple”, appears 114 times. A quick series of tests using LastPass’ random password generator suggests Hunt’s (2019b) list is unlikely to contain randomly-generated passwords, at least up to 12 characters, so this may be a useful tool for generating secure passwords. Unfortunately, the very nature of such passwords is that they are invariably written down, or require installation of third-party software to save users remembering them (leading to automatic site login, leading to poor security practice, leading to ...).

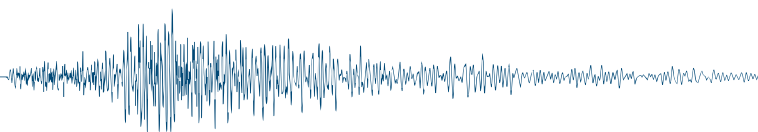
So what to do? XKCD’s suggestion (“correctbatterystablehorse”) is attractive since it is easily remembered. A test of another password suggestion (e.g. CERN 2018) adds weight. However, we must be careful. The password “ji32k7au4a83” appears on the list 114 times, despite being long and seemingly random. This password appears because it is a transliteration via Unicode of Mandarin to English. The original Mandarin is “mypassword” (Gizmodo 2019).

This column is my final column as ASEG Webmaster. After 20 columns since October 2015, it has been an interesting and enjoyable ride. Highlights include the redesign and launch of the website in August 2016, and the addition of videos and a considerable amount of content in the form of

equipment manuals and presentations from various workshops. Two photo competitions have been run, we have changed publishers, and introduced a Data Policy. Less visible, but no less important, has been the SA/NT Branch’s annual wine offer, and minutiae such as events and news. While I’ve been privileged to have been Webmaster since March 2015, it is important to note that there has been a web committee, and also web developers, without whom various tasks would not have been accomplished nearly as quickly. The credit for the success of the ASEG’s new website also belongs to them, and I thank Ian James, Karen Gilgallon, Chris Bishop and Paddy Rohr and his staff for their support. Reiterating, the past four years have been interesting and enjoyable, and I am confident that they will pale in comparison to what will happen next.

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Preview of *The Australian continent: a geophysical synthesis*

Brian L.N. Kennett,
Research School of Earth Sciences, Australian National
University, Canberra
Brian.Kennett@anu.edu.au

Richard Chopping,
Research School of Earth Sciences, Australian National
University, Canberra
Richard.Chopping@anu.edu.au

Richard S. Blewett
Geoscience Australia, Canberra
Richard.Blewett@ga.gov.au

The Australian Continent: A Geophysical Synthesis was launched online in August 2018, and in print at the AGCC in October 2018. Since then, the publication has garnered a lot of interest. Lectures on the material contained within the book are being conducted at ASEG branches around the country throughout 2019. Lectures have already been given in the ACT, Western Australia and Tasmania. Dates will be confirmed for later in the year for lectures in Queensland, NSW, Victoria and South Australia.

We produced this volume because we wanted to take a fresh look at a number of the available Australia-wide datasets, and to place many disparate datasets together on an even footing. We did not aim to provide all of the answers to questions about the underlying geology of Australia, but to expose readers to the wide range of datasets available in the hope that together we can begin to unravel Australia's complicated geological history and locate its buried resources.

We are deeply indebted to all of those who assisted in the provision of information and datasets, and hope that the compilation stimulates new thinking about Australia's remarkable geology.

The book is available for free download in PDF form from <http://press.anu.edu.au/publications/australian-continent>, and can, additionally, be ordered in print form from this location. To aid in comparisons, we have produced an electronic image gallery, which is available at <http://rses.anu.edu.au/AuSREM/Continental>. This gallery contains all the figures in the book, as well as some additional material.

The book is published under a Creative Commons Attribution 4.0 International (CC BY 4.0), www.creativecommons.org/licenses/by/4.0. We hope that this will encourage people to use the material available in the book, and the auxiliary links.

Preview readers are undoubtedly familiar with some of the geophysical datasets available. For those who are yet to download or obtain a copy of the book, we thought we would pique your interest by reproducing of the 2nd chapter of the book in the following pages. This chapter introduces the setting of Australia, including its broad tectonic and physical setting, and the surface, basement and sedimentary geology of the continent.

Continental setting of Australia

Australia, with an area of 7.69 million km², is the Earth's largest island and smallest continent. The continental landmass,

which measures about 3700 km from north to south and 4000 km from east to west, occupies a significant part of the Australian Plate, which is currently separating from the Indian Plate in a diffuse zone in the Indian Ocean. Since its separation from Antarctica at about 35 Ma, the Australian continent has been moving steadily northwards, currently at around 7 cm/year with respect to a hotspot frame of reference. Australia is the most rapidly moving continent on the globe, and has swept into the southern fringe of Asia with current collision active in Timor and Papua New Guinea (e.g., van Ufford and Cloos 2005).

Physiographic setting

Australia is an island continent with a landmass defined by a distinctive coastal outline, which has maintained its current shape for the last 6000 years. At the time of maximum glaciation, the Australian mainland, Tasmania and the island of New Guinea formed a single larger and differently shaped landmass that stretched from the equator to latitude 45°S. With the end of the last Ice Age, global temperatures increased, much of the continental ice melted and sea levels rose. This caused flooding of the land bridges between Tasmania and the Australian mainland 6000 years ago, and between Australia and New Guinea 8000 years ago. The rise in sea levels inundated about one-seventh of the larger ice age continent isolating Tasmania, the Australian mainland and New Guinea.

Much of the present topography of Australia is the result of prolonged erosion by wind and water, since there have been no major mountain building episodes in the last 200 Ma. Dating of the surface regolith indicates a weathering history stretching back over 300 Ma in some parts of the continent (Pillans 2008). The landscape has been strongly shaped by continent-wide glaciation; large ice caps developed in the Permian when Australia was very near the South Pole, and this glacial influence on the landscape persists to the present day. By the early Cretaceous, Australia was already so topographically flat, and of such low elevation, that a major rise in sea level divided the continent into three landmasses as a shallow sea spread over the land.

Today, the major physiographic features of the Australian continent comprise: (1) a major Western Plateau with localised ranges incorporating most of the Precambrian cratons, (2) the Eastern Uplands with the highest elevations concentrated along the Great Divide with dominantly Phanerozoic rocks and (3) an intervening zone of Interior Lowlands. The topography of the Australian continent is subdued. The highest point on the continent, Mount Kosciuszko, is only 2228 m above sea level, and the lowest point is Lake Eyre at 15 m below sea level. The average elevation is only 330 m, the lowest of any of the continents (Figure 1).

The Australian continent currently has passive margins on three sides and the fourth is the lower plate of a collision zone to the north. Thus, in the recent geological past, there have been no destructive convergent plate margins that are generally associated with mountain building, landscape rejuvenation and the formation of large reliable river systems. The largest rivers thus flow from the Eastern Uplands through the interior lowlands. Many of the rivers, particularly in the north are intermittent, with flow starting in the summer "wet" season, but

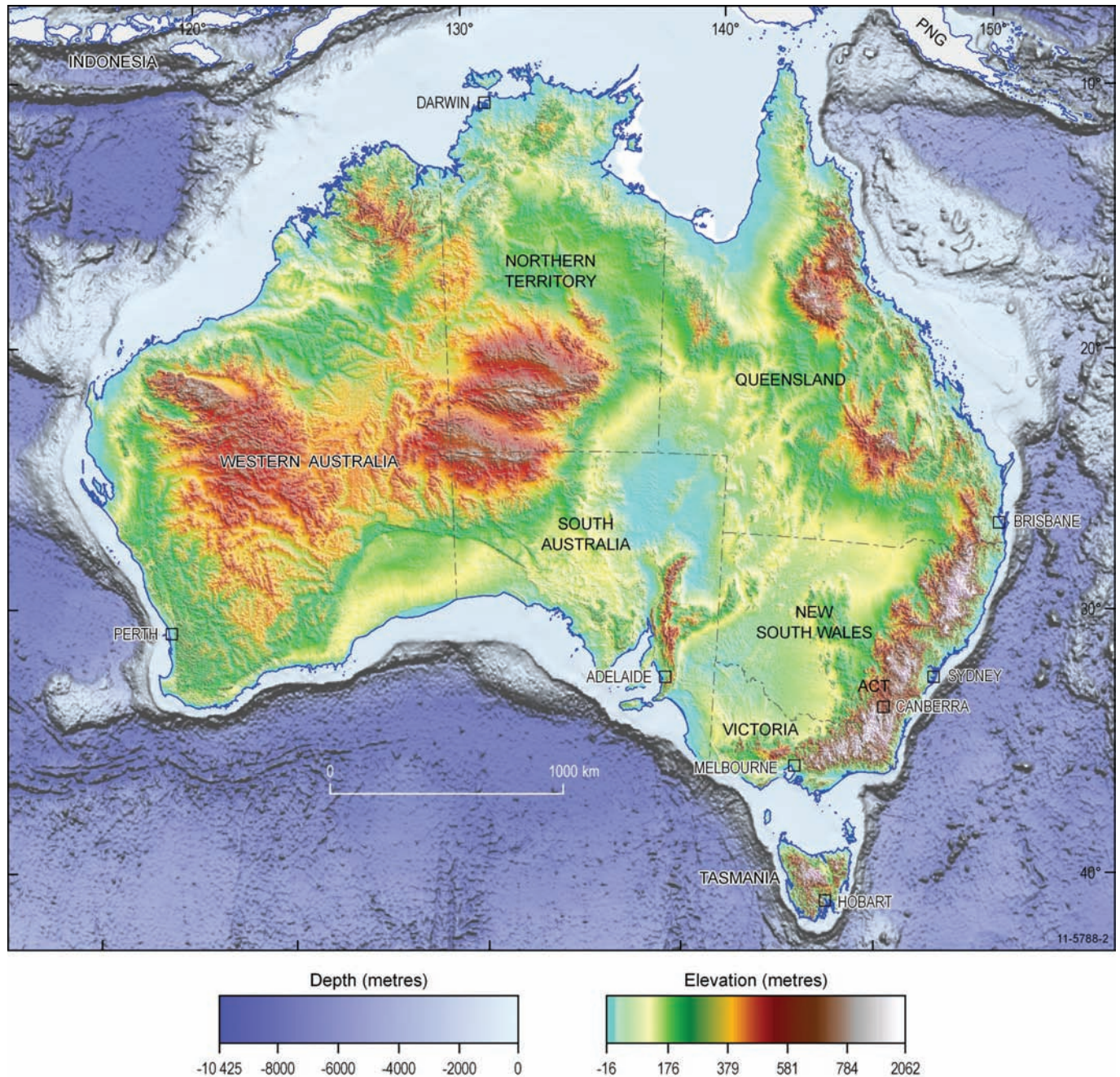


Figure 1. Topography of the Australian continent and bathymetry of the surrounding oceans. The state boundaries and state capitals are also indicated.

tapering off in the winter “dry”. After a particularly heavy wet, sufficient water can reach and fill the Lake Eyre basin that lies below sea level.

Although the glaciation in the Permo-Carboniferous had a broad impact on continental Australia, the last ice ages had only limited impact on the physiography. The Australian continent was already at fairly low latitudes in the Pleistocene, so that glaciation was confined to small areas in southeastern Australia, with little reworking of the older landscape.

The continental slope on all margins is deeply incised, with steep-sided canyons up to 2 km deep, reflecting either extinct drainage systems or the drowned valleys of current river systems (such as the Perth Canyon in West Australia). On the southern part of the eastern margin, the continental shelf is rather narrow, with a shelf break closer than 20 km from the

coast and the base of the abyssal plain sometimes reaching within 60 km of the coastline (Figure 1). The conjugate southern margins of Australia along the Great Australian Bight and the Antarctic coast, created by the opening of the Southern Ocean, show somewhat wider continental shelves.

The broad continental shelf off Queensland, left behind after the Coral Sea opened, forms a foundation for the Earth’s largest single living entity – the Great Barrier Reef – with 2900 reefs, 600 continental islands and 300 coral cays created in a mixed siliciclastic- carbonate depositional environment. The wide continental shelf between the coast of northern Australia and Indonesia, Timor and New Guinea represents the drowned remnants of the former single landmass. The extended continental shelf off Western Australia is host to most of Australia’s natural gas resources, and is marked by complex

Feature

embayments and salients left over from peri-Gondwanan fragments that broke away in the Mesozoic era and now form the basement in Southeast Asia. (Huston et al. 2012).

Tectonic setting

The Australian Plate is undergoing a complex set of interactions with its neighbours. To the south, an active spreading centre separates the Australian Plate from the Antarctic Plate. This margin developed with the break-up of Gondwana around 99 Ma, with full separation by 35 Ma. Following a major plate reorganisation in the Pacific Ocean at around 40 Ma, Australia acquired its present north–northeast trajectory. Australia has migrated more than 3000 km along this path at a rate of 6–7 cm/yr over the past 45 Myr, which, as previously indicated, makes it the fastest moving continent since the Eocene (Tregoning 2003).

Following break-up, Australia's initial drift was to the northwest. Ridge subduction in the northwest Pacific at around 52 Ma resulted in the termination of spreading in the Tasman Sea, and a change in the Australian Plate vector to its present-day northerly orientation. Sea floor spreading in the Southern Ocean accelerated at around 45 Ma, but it was not until 35 Ma that full separation of Australia and Antarctica occurred. Australia, as a separate continent, was released from the remnants of Gondwana and commenced a northward passage to meet Asia.

The eastern boundary of the Australian Plate with the Pacific Plate is marked by the Tonga–Kermadec Trench, north of New

Zealand, where the Pacific Plate is being subducted, giving rise to many of the Earth's deep earthquakes. In New Zealand itself, there is oblique subduction along the east coast of the North Island, with collision through the South Island moderated by the Alpine Fault. Beneath the Fiordland region of the South Island, the Australian Plate is subducting at the Puysegur Trench. This short subduction zone links to a largely strike-slip boundary that passes Macquarie Island and links to the boundaries of the Antarctic Plate (DeMets et al. 2010).

The Australian Plate is subducting beneath the Pacific Plate along its northeastern margin at the New Hebrides and Solomon Trenches. The northern boundary of the Australian Plate is complex. Continental Australia is colliding with the Pacific Plate through New Guinea. But to the west, the interaction is with the Eurasian Plate with collision in the Banda Arc region and subduction of the Australian Plate beneath Indonesia at the Java and Sumatra trenches (Figure 2).

Subduction in the Banda Arc region may well already have come to a halt with the arrival of thick buoyant Australian lithosphere that cannot readily descend to depth. The western boundary of the plate is a diffuse zone called the Capricorn Plate, which lies between the Australian Plate and the Indian Plate further to the northwest (DeMets et al. 2010).

The boundary forces acting upon the Australian Plate vary from tension in the south and southwest to compression in the east and north. The present stress state is largely controlled by compression originating from the three main collisional boundaries located in New Zealand, Indonesia

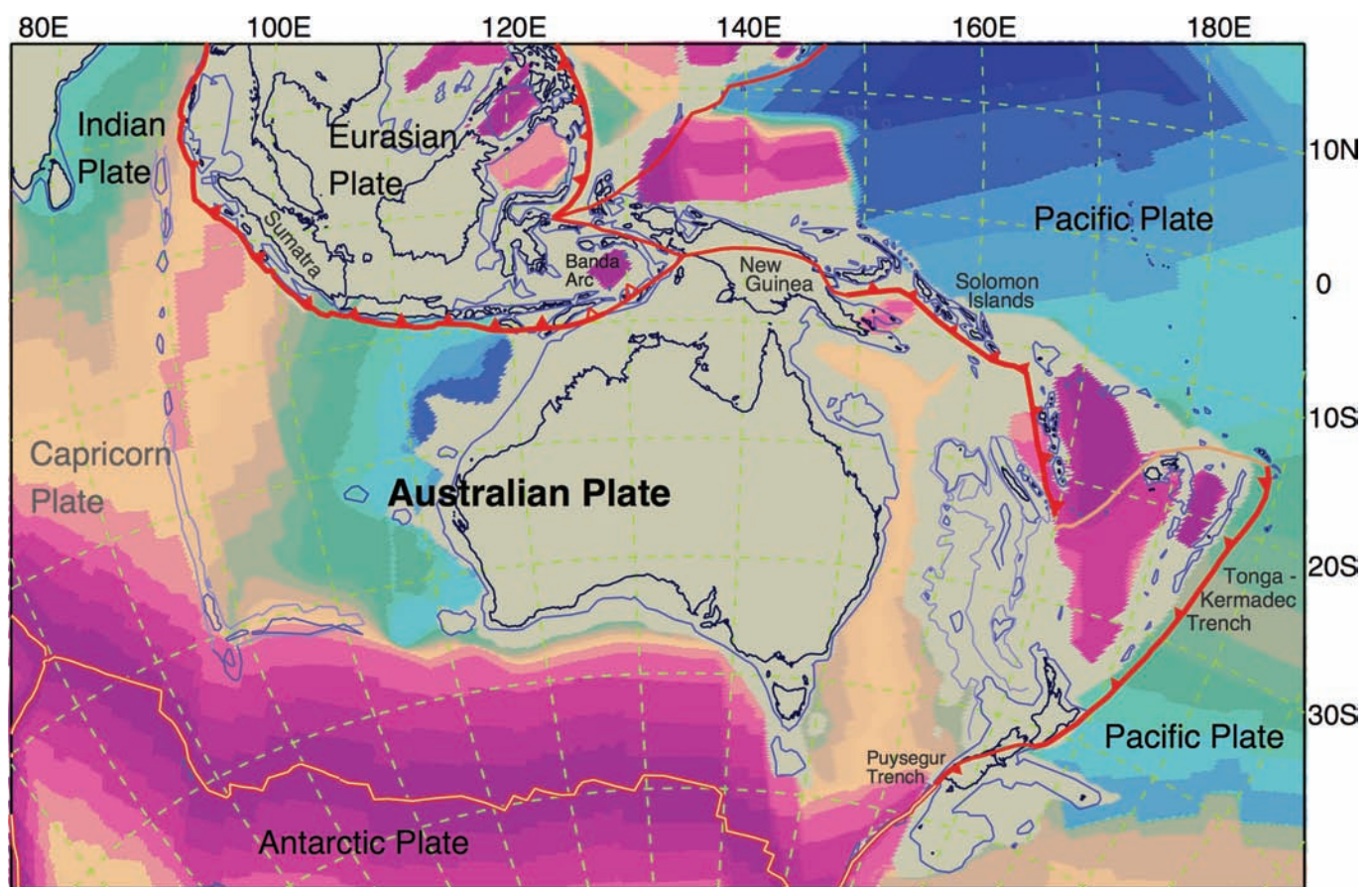


Figure 2. Tectonic setting of Australia, with major seabed features and plate boundaries, superimposed on the age of the sea floor (Müller et al. 2008). The mid-ocean ridges are indicated with a double line and the sense of subduction is indicated.

and New Guinea, and the Himalaya (transmitted through the Indian and Capricorn plates). South of latitude 30°S, the stress trajectories in the Australian continent are oriented east–west to northwest–southeast. North of 30°S, the stress trajectories are closer to the present day plate motion, with an orientation between east–northeast–west–southwest and northeast–southwest (see, e.g., Hillis and Müller 2003).

The complex pattern of stress in the continent is expressed in a relative high level of seismicity for what would normally be regarded as a “stable” intraplate continental region. The distribution of the larger events, which have reached nearly M_w 7 in recent years, is not uniformly distributed across Australia. Earthquakes are clustered into regions towards the edges of major structural blocks. The rate of occurrence of earthquakes is normally low, but is punctuated by periods of enhanced seismic activity associated with one or more large earthquakes. Since 1901, 18 earthquakes

with magnitude $M_w > 6$ have been recorded in Australia. The recurrence times for larger earthquakes, such as the 1988 Tennant Creek sequence with three M_w 6+ events in 12 hours, is more than 10 000 years, so that the brief snapshot of seismicity available will certainly be incomplete. Many neotectonic features have been recognised through careful mapping across the continent (Clark et al. 2011). In the Flinders Ranges in South Australia, there are clear indications of active faults thrusting Precambrian basement over Quaternary gravels (Quigley et al. 2010). The active intraplate deformation in Australia is likely to be guided by structures generated by past tectonic activity and thermal weakening of the lithosphere.

Geological setting

Rocks exposed at the surface in Australia span much of the Earth’s geological history (Figure 3). The Archean regions

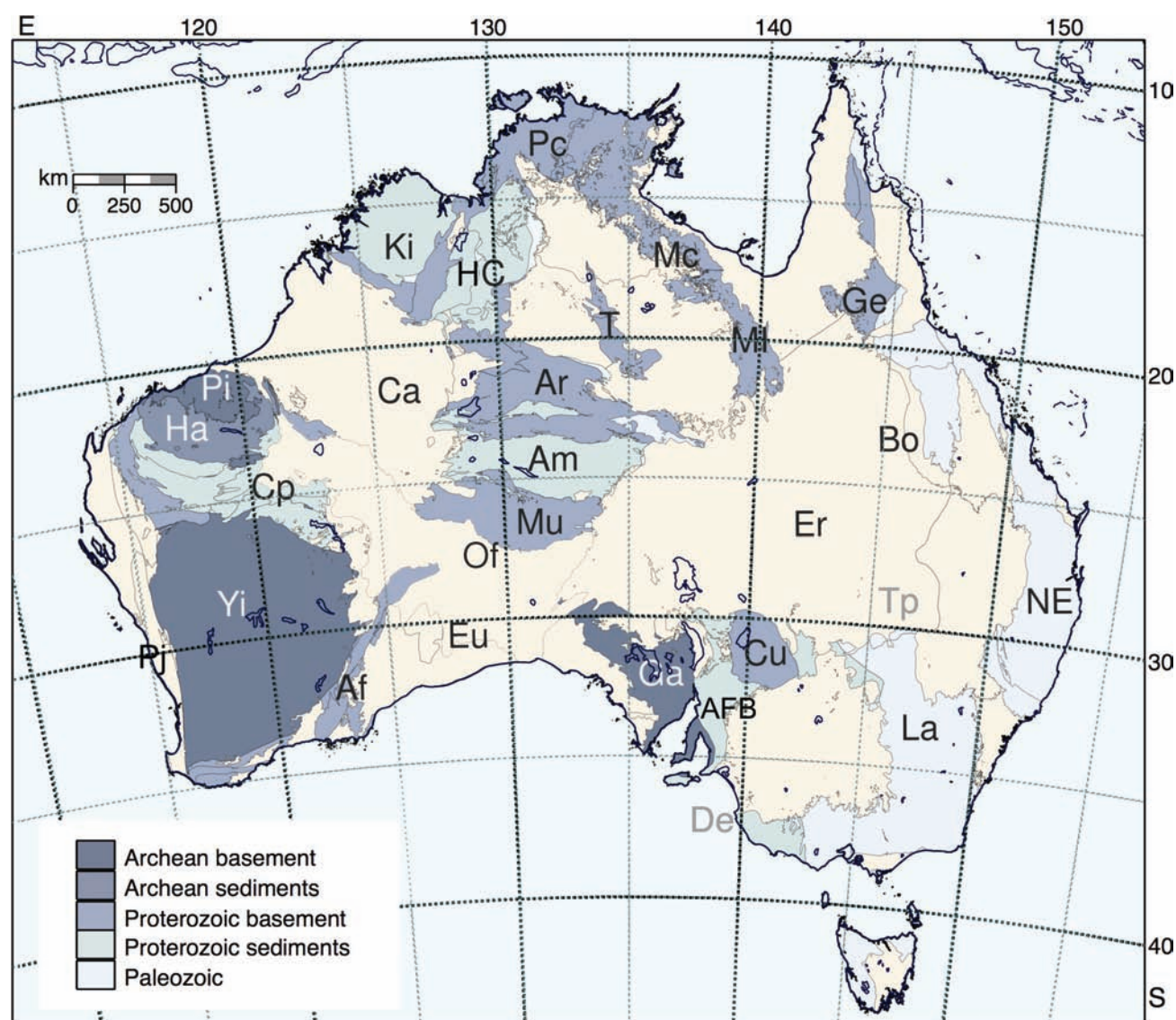
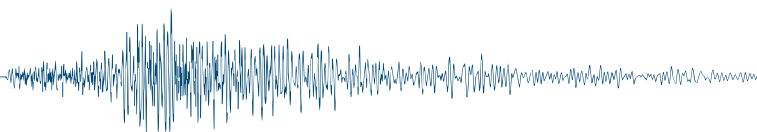


Figure 3. Key to marked features: AF, Albany–Fraser Orogen; AFB, Adelaide Fold Belt; Am, Amadeus Basin; Ar, Arunta Province; Bo, Bowen Basin; Ca, Canning Basin; Cp, Capricorn Orogen; Cu, Curnamona Craton; De, Delamarian Orogen; Er, Eromanga Basin; Eu, Eucla Basin; Ga, Gawler Craton; Ge, Georgetown Inlier; Ha, Hamersley Basin; HC, Halls Creek Belt; Ki, Kimberley Block; La, Lachlan Orogen; Mc, MacArthur Basin; MI, Mt Isa Province; Mu, Musgrave Province; NE, New England Orogen; Of, Officer Basin; Pc, Pine Creek Inlier; Pi, Pilbara Craton; Pj, Pinjarra Orogen; T, Tennant Creek Inlier; Tp, Thomson Orogen; Yi, Yilgarn Craton.



include rocks older than 3700 Ma in Western Australia and 3100 Ma in the Gawler Craton of South Australia. The oldest zircon crystals yet found on the Earth, dating back to 4400 Ma, occur in Proterozoic conglomerates within the Yilgarn Craton of Western Australia. In contrast, recent volcanic activity in both northeast and southeast Australia has left distinct volcanic edifices, with the latest eruptions in the southeast at about 4600 BCE.

Around 80% of Australia is covered by extensive Mesozoic and younger sedimentary rocks and regolith (beige areas in Figures 4 and 5). These cover rocks indicate the general tectonic stability of much of the continent from Mesozoic times to the Present.

The underlying Australian continental crust was accreted in three major supercontinent cycles, each building about one-third of the continental area from the Archean cratons in the west to the Phanerozoic provinces in the east (Huston et al. 2012). Disparate Archean crustal elements were assembled into three major cratonic zones in the Proterozoic.

The West Australian, the North Australian and the South Australian elements were formed by ~1830 Ma, and these cratonic elements were joined to the Rodinian supercontinent by 1300–1100 Ma. The configuration of these Archean materials is indicated in Figure 3, which shows a simplified map of solid geological provinces, along with the surrounding and linking Proterozoic belts.

Since the Proterozoic, there has been a set of deformation cycles in central Australia culminating in the Alice Springs Orogeny around 400 Ma. These events occurred away from plate boundaries and involved extension as well as compression, although their precise history remains difficult to unravel from the geologic record. Much evidence of deformation is left in the central Australian crust, which features significant Moho topography and an associated gravity signal.

The fold belt structures of the Phanerozoic Tasman Element comprise the eastern third of Australia, which was accreted onto the eastern margin of the Precambrian cratons in a number of stages (see, e.g., Collins and Vernon 1992; Rosenbaum 2018). The Delamarian Orogen at around 500 Ma formed part of a much larger belt of accretion along the eastern margin of Gondwana. This was followed by at least two further periods of accretion that added the Lachlan Orogen and the New England Orogen to the Australia–Antarctic land mass.

The break-up of Gondwana, through a series of rifting events from about 180 Ma, resulted in the formation of the passive margins around Australia, with the formation of the Coral and Tasman seas in the east, the Southern Ocean in the south and the Indian Ocean in the west (Huston et al. 2012). These rift events created the accommodation space for the late Paleozoic and Mesozoic sedimentary basins that host most of Australia's hydrocarbon resources.

There has been significant subsequent volcanism; in the Mesozoic, Australia was the continental margin of the subducting Pacific Plate and subsequently a set of chains of hotspot-related volcanism have developed through eastern Australia. The eastern margin of Australia has been influenced by sea floor spreading in the Tasman Sea from ~80 Ma and also by back-arc spreading in the Coral Sea.

The eastern seaboard, including Tasmania, is a patchwork of Paleozoic metamorphic, sedimentary and igneous rocks. These rocks are revealed, as highlands, due to the rift-flank uplift generated by opening of the Tasman and Coral seas which finished around 80 Ma.

The Flinders Ranges, a Y-shaped region of uplifted Neoproterozoic sedimentary rocks in South Australia, attest to the influence of regional compression across the Australian Plate. Across northern Australia, large areas of mostly Proterozoic metasedimentary rocks occur in the Kimberley, Pine Creek, Macarthur and Mt Isa areas. These basins were filled with vast sandsheets during a time when the Earth's land surface was devoid of the stabilising influence of life, and became the containers for major base metal and uranium mineral systems.

These simplified geological province boundaries provide a useful summary of the main features of the solid geology, as can be seen from Figure 6.

In subsequent sections [*of The Australian Continent: A Geophysical Synthesis*], these province outlines are used in combination with the major crustal boundaries dataset, illustrated in Figure 7, as an overlay on many of the geophysical images.

The two sets of boundaries provide a convenient reference frame for comparison of geophysical datasets. They also help to provide a tie between the distribution of geophysical properties and the different classes of geological environments.

Korsch and Doublier (2016) have developed a dataset of major crustal boundaries, based on the occurrence of crustal-scale breaks in the extensive continental coverage of seismic reflection profiles. Such features are often inferred to be relict sutures between different crustal blocks and hence mark changes in crustal properties. The boundaries have been extended away from the seismic profiles with the aid of geological information (e.g., outcrop mapping, drill hole sampling, geochronology, isotopes) and geophysical imagery (e.g., gravity, aeromagnetic, magnetotelluric).

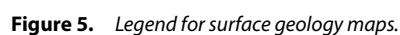
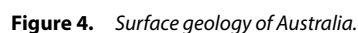
The dataset is built from rather heterogeneous materials and so the various boundary lines have different levels of confidence. In particular, in regions covered by thick sedimentary successions, the locations of some crustal boundaries are not at all well constrained. It is likely that some significant boundaries may be missed under cover in the Northern Territory, where little deep seismic reflection work has been undertaken.

Nevertheless, this crustal boundary dataset provides a useful reference frame for comparison of geophysical datasets.

Crustal age

The accessible rocks at the Earth's surface provide one facet of the nature of the continent, but the middle and lower crust remain hidden. Fortunately studies of isotopic tracers such as samarium-neodymium (Sm-Nd) provide a way to exploit felsic igneous rocks across the continent to map the development of the crust over time (Champion 2013).

This work has established a database of Sm-Nd isotopic data, and associated metadata, for >2650 samples of Australian rocks. Results have been compiled for a range of lithologies, including felsic and mafic igneous rocks, sedimentary rocks, as



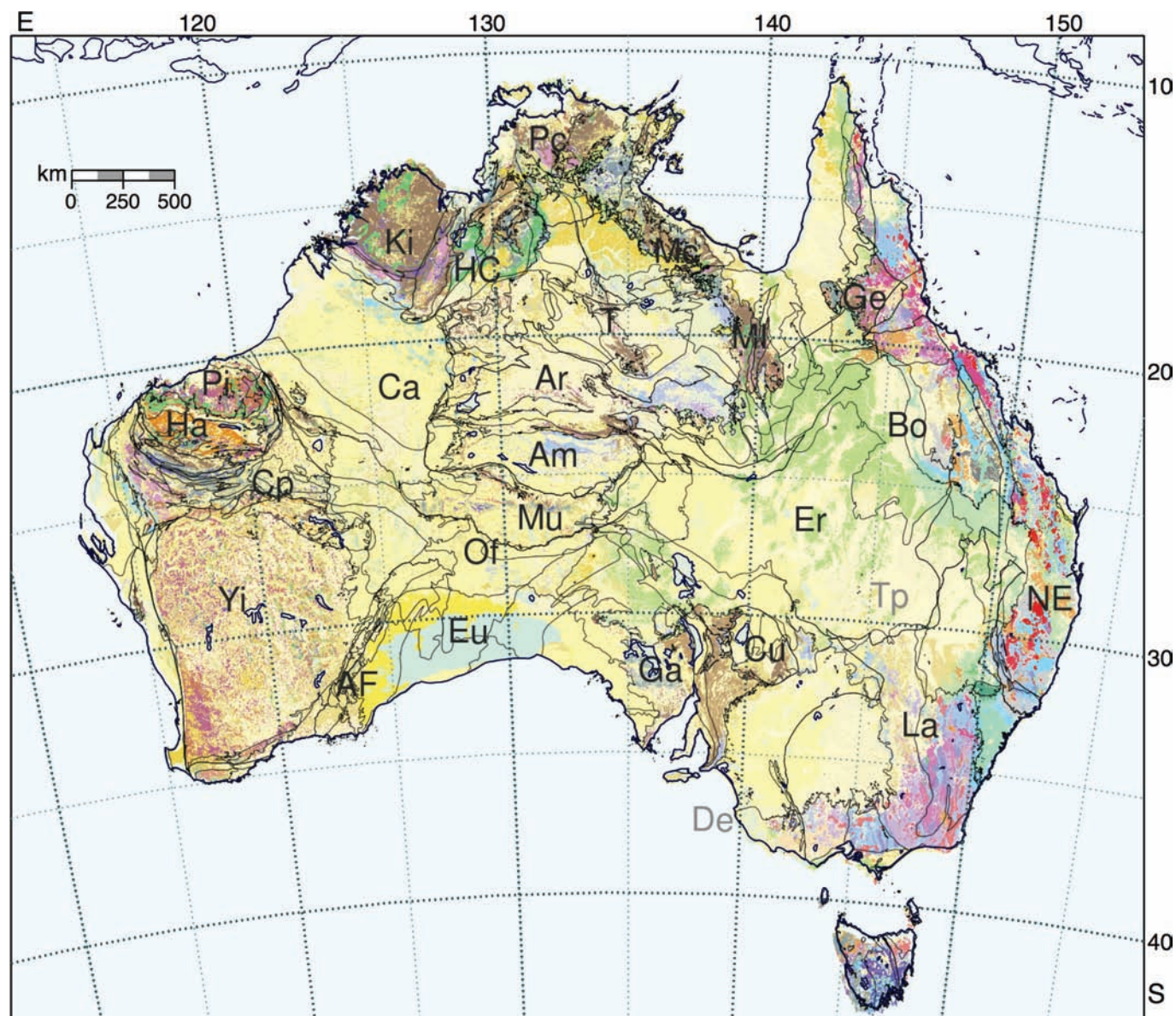


Figure 6. Surface geology of Australia with main geological provinces marked (following Figure 3).

well as some mineral data. For felsic samples there was a good agreement with estimated or known magmatic age.

The Sm-Nd data were standardised and used to calculate epsilon Nd (ϵ_{Nd}) and two-stage depleted mantle model ages ($T_{2\text{DM}}$). The map in Figure 8 has been constructed from around 1500 data points, with the exclusion of samples from S-type magmatism to avoid sediment contamination.

The estimated model ages range from ~4.0 Ga in the Yilgarn and Pilbara cratons of the West Australian Element to ca. 0.3 Ga in the New England Orogen of the Tasman Element in eastern Australia. Even though the granites may have somewhat variable properties with respect to retention of Nd signals, the model ages generally correlate well with the known geology of Australia and the major crustal elements.

There is a broad eastward trend in decreasing model ages across the Australian continent, mirroring the surface exposures. Younger domains through Central Australia separate the cratonic zones in West Australia and the Northern

and Southern Australian cratons. Archean model ages are most common in the Archean Pilbara and Yilgarn cratons of West Australia, but also occur in both the North and South Australian cratons. The majority of Australian model ages are Proterozoic in age. The youngest model ages are restricted to the Tasman Belt in the east, chiefly within the New England Orogen.

Within all the major elements of structure across the Australian continent there are indications of internal isotopic zonation, including regions with relatively sharp changes over narrow bands or distinct, but diffuse, gradients.

Many of the breaks and gradients in the distribution of model ages across the continent correspond to known crustal boundaries or changes in geology, which indicates that Sm-Nd whole rock signatures can be used to identify crustal changes. For example, the strong increase in younger isotopic signatures in the southern half of the Northern Territory suggests processes associated with an accretionary margin, similar to the patterns observed in the Tasman orogens.

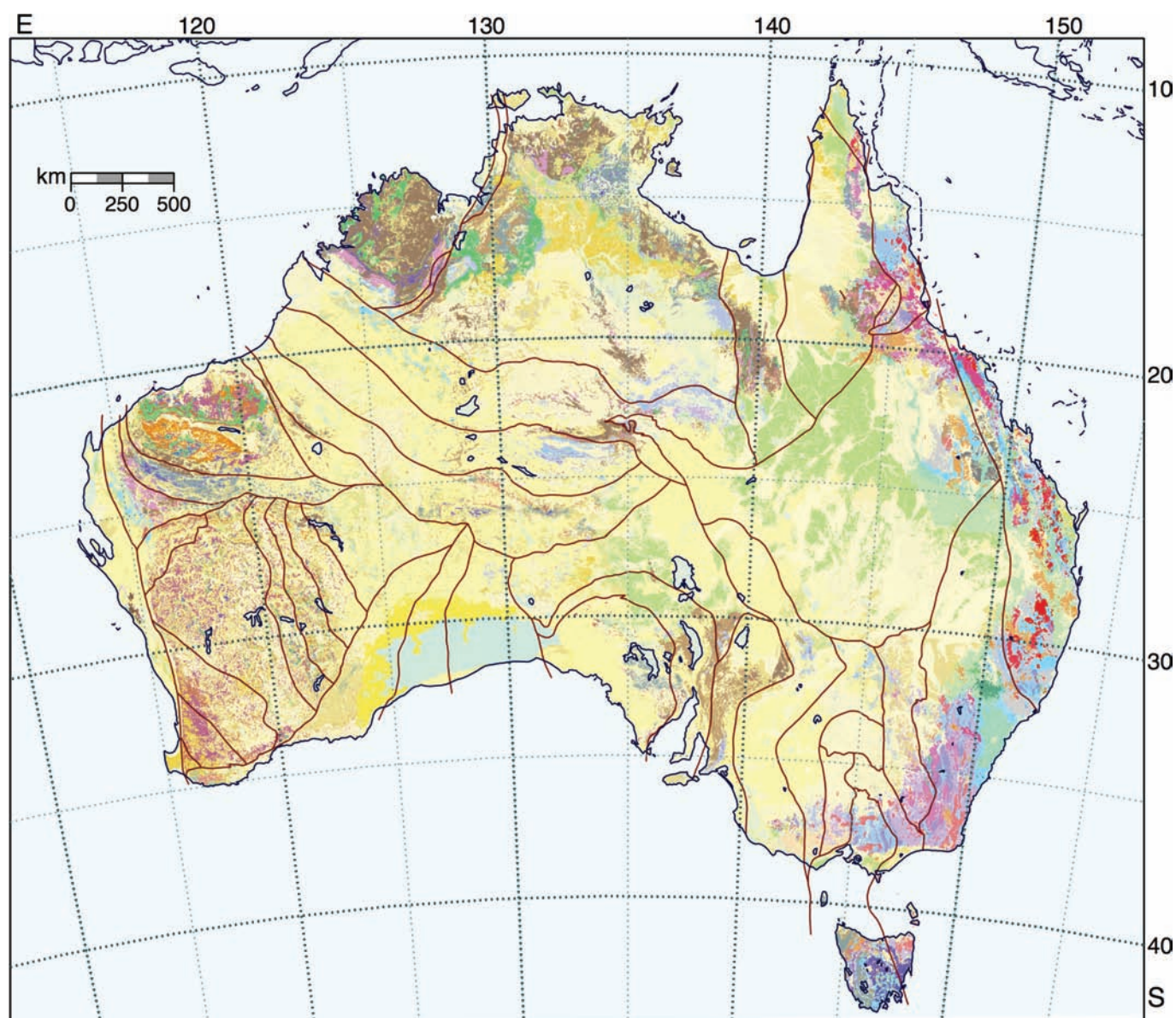


Figure 7. Major crustal boundaries from Korsch and Doublier (2016) superimposed on the surface geology of Australia.

Sedimentary basins

The combined thickness of Neoproterozoic and Phanerozoic basins across Australia, building on input from reflection seismology, gravity and magnetic surveys, is shown in Figure 9. Older Proterozoic sediments are included in the right hand panel of Figure 9, many of these are metasediments so that the distinction from basement is not always obvious.

Although a significant part of Australia is covered in sediments, the sequences on the continent are generally less than 7 km thick (Figure 9). Deeper basins (>15 km) occur offshore particularly in northwestern Australia. These deep sedimentary basins host most of Australia's oil and gas.

The onshore basins are also important, with major coal deposits in eastern Australia, mostly from the Permian, and gas accumulations in the Cooper Basin in southern Queensland. The majority of these basins are associated with gentle downwarps due to thermal sagging rather than localised rifting, and many

in the western part of the continent lie on relatively thick lithosphere.

A narrow band of deep sediments occurs in the Fitzroy Trough at the northern end of the Canning Basin, abutting the Precambrian Kimberley Block. This appears to be an area with periodic tectonic reactivation, and still displays moderate seismicity.

Concluding remarks

We hope that the preceding extract from *The Australian Continent: A Geophysical Synthesis* on the geology of Australia has stimulated the interest of *Preview* readers. We have compiled similar classes of figures and overviews for the continental-scale datasets such as radiometrics, gravity, magnetics and seismic velocity models (among other datasets) within the book and in the electronic image gallery. We look forward to presenting this material to ASEG Members in Queensland, New South Wales, Victoria and South Australia, once dates for presentations in those states have been finalised.

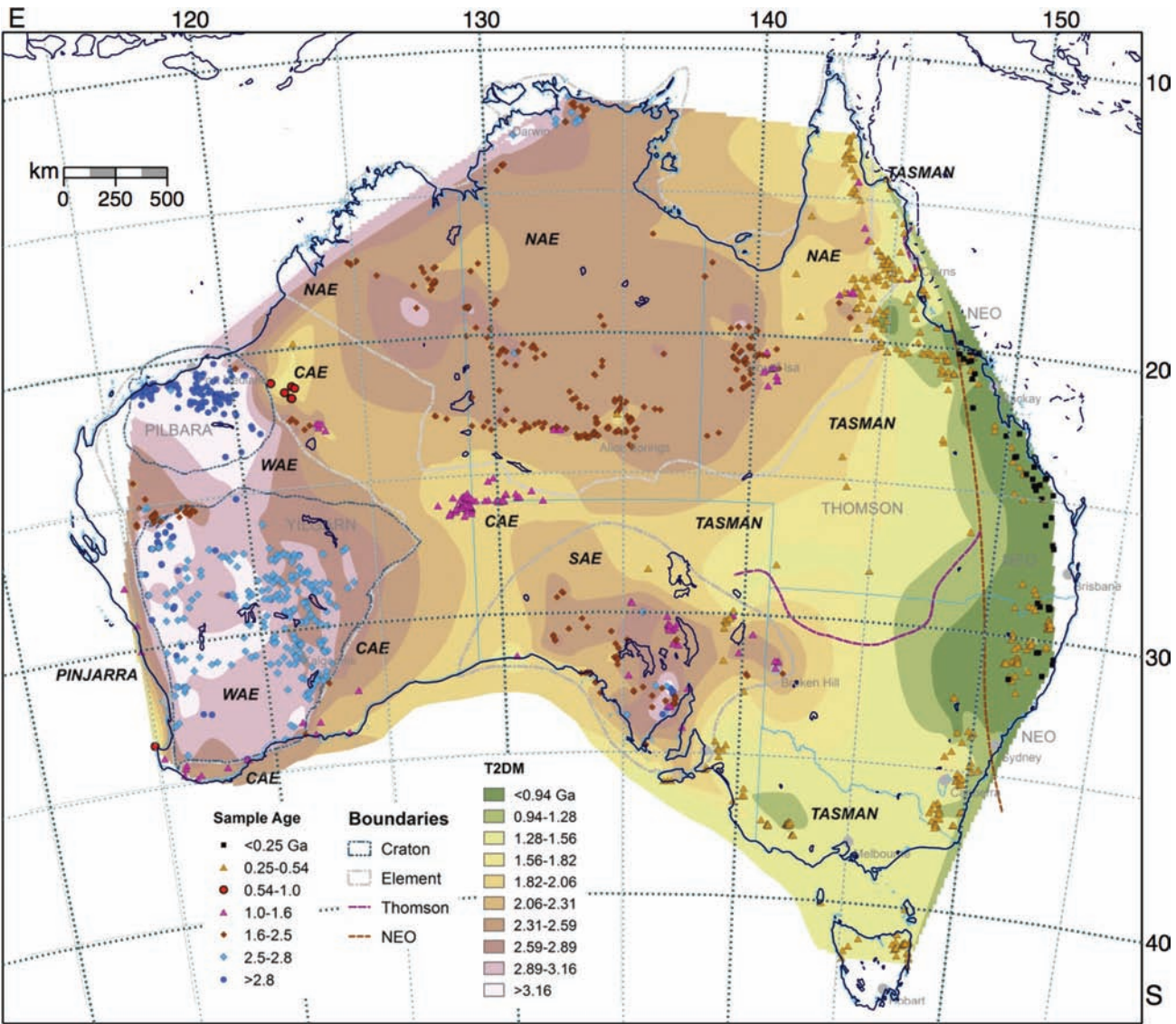


Figure 8. Distribution of crustal ages across Australia from Sm-Nd analysis of felsic igneous rocks (Champion 2013).

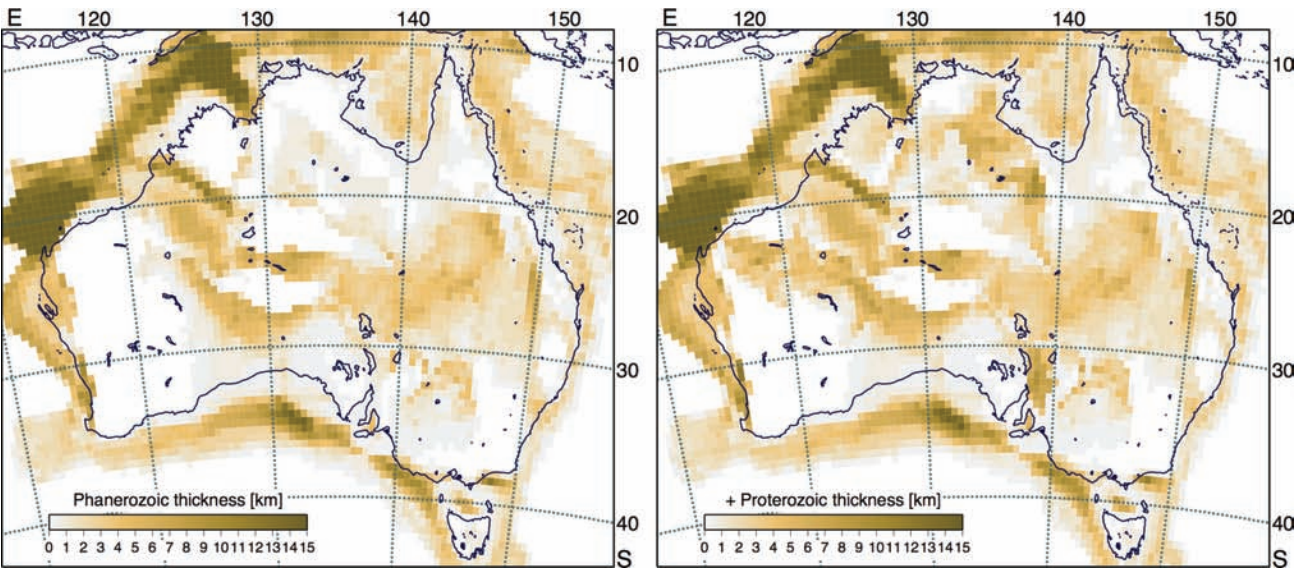


Figure 9. The distribution of sedimentary basin thickness across the continent based on the OZSeabase study (Frogtech 2005).

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Developing metadata standards for time series magnetotelluric data

Alison Kirkby
Geoscience Australia, Canberra, Australia
Alison.Kirkby@ga.gov.au

Magnetotellurics (MT) is a passive geophysical method that uses natural time variations of the Earth's magnetic and electric fields to measure the electrical resistivity of the sub-surface.

The electrical resistivity of rocks and minerals varies by many orders of magnitude, from very resistive crystalline igneous rocks, to very conductive saline-filled sedimentary rocks. As measured by the MT method, the resistivity obtained is a bulk property of a volume of earth material, and is associated with factors such as rock composition, porosity and permeability, as well as rock fluid composition and temperature.

The Earth's magnetic field varies continuously in both time and space. The MT method requires the electric field and variations of the magnetic field to be recorded at the same site over a period of time. The ratio of the electric field and variations in the magnetic field provides a measure of the electrical resistivity. Depth information is obtained by measuring the time variations over a range of frequencies. High frequencies only penetrate the Earth to shallow depths, while low frequencies penetrate deeper. Information can be obtained from a few hundred metres depth to hundreds of kilometres depth.

The MT technique has been used in Australia to image the electrical conductivity/resistivity structure of the subsurface at different scales for over 60 years. High-frequency Audio-MT data have been used to estimate cover thickness, and to assist

drill site targeting for a number of regional drilling projects. Regional-scale Broadband MT surveys have been undertaken along onshore deep reflection seismic transects, and over a number of potential mineral/energy provinces and greenfields areas across the country (Figure 1). These data are being used to map the crustal-scale electrical conductivity/resistivity structure, and to improve the understanding of basement architecture and resource potential in these regions. Recent high profile science publications have shown the relevance of the MT technique to exploration undercover.

Members of the MT community (Figure 2) have begun working towards defining agreed metadata parameters to be collected for time series Magnetotelluric (MT) data. This is the first step in defining a metadata standard, which will then enable development and standardisation of time series formats to be used amongst the Australian MT community. Following this, we will also build on this list to develop standards for processed MT data and derived resistivity models.

Table 1 lists the metadata parameters that we believe should be collected with time series MT data. The parameters are listed as compulsory or optional to facilitate compatibility with legacy data. We are seeking feedback from others in the MT community on the table, in particular, any additional parameters that are needed and any changes to those listed.

All the state and territory geological surveys support this initiative.

Please send any comments or suggestions to Alison.Kirkby@ga.gov.au.



Figure 1. MT survey site.



Figure 2. Members of the MT community.

Table 1. List of metadata parameters to be collected with time series MT data.

Parameter	Units	Compulsory or optional	Explanation
Site name	Character string	Compulsory	Local name of site
Survey name	Character string	Compulsory	Name of survey to help with organisation of data
Survey location	Character string	Optional	Region in which survey is carried out
Data type	Character string	Optional	Long period/broadband/AMT
Acquired by	Character string	Compulsory	Name of agency/institution (s) acquiring the data. This field should allow for more than one name to be listed
AUSGRID number	Character string	System Generated	Position of site on national AusGRID grid
Latitude	Dec. degrees	Compulsory	Latitude of central box, from data recorder GPS if available or handheld GPS. This is the primary location information to be used in future processing
Longitude	Dec. degrees	Compulsory	Longitude of central box, from data recorder GPS if available or handheld GPS. This is the primary location information to be used in future processing
GPS projection system	Character	Compulsory	Projection, datum and coordinate system of data recorder GPS
Location method	Character	Optional	Method of measurement of primary location information e.g. data recorder or handheld GPS
Latitude (alt)	Dec. degrees	Optional	Latitude of central box, from an alternative method (e.g. handheld GPS device). This may be useful for QA purposes
Longitude (alt)	Dec. degrees	Optional	Longitude of central box, from an alternative method (e.g. handheld GPS device). This may be useful for QA purposes
GPS projection system (alt)	Character	Optional	Projection, datum and coordinate system info of alternative location data
Location method (alt)	Character	Optional	Method of measurement of alternative location information
Altitude	Metres	Optional	Elevation above sea level of central box
Operator	Character string	Optional	Name of individual (s) who deployed the site
Local start time	YYYY:MM:DD:HH:MM:SS.SS	Compulsory	Local start date and time (YYYY:MM:DD:HH:MM:SS) of recording
Local time zone	Integer	Compulsory	Time zone of recording; number of hours to add to UTC time
UTC start time	YYYY:MM:DD:HH:MM:SS.SS	Compulsory	UTC start date and time (YYYY:MM:DD:HH:MM:SS) of recording
Julian day	Integer	Optional	Julian day of start of recording
Data recorder type/model	Character string	Compulsory	Data recorder type/model
Magnetometer type/model	Character string	Compulsory	Magnetometer type/model
Electrode type/model	Character string	Compulsory	Electrode type/model
Power source type/model	Character string	Compulsory	Power source type/model
Data confidential	True/false	Optional	Flag indicating if data is confidential
Data confidential until	Character string	Optional	Blank or date data to be released from confidentiality
North reference		Compulsory	Magnetic or True North
Declination	Degrees	Optional	Magnetic declination (can be determined from Lat/Long/ date if not recorded)
Drift calculation start time – time	YYYY:MM:DD:HH:MM:SS.SS	Optional	Drift calculation start time local or UTC time via watch etc
Drift calculation end time – time	YYYY:MM:DD:HH:MM:SS.SS	Optional	Drift calculation end time local or UTC time via watch etc
Drift calculation time method	YYYY:MM:DD:HH:MM:SS.SS	Optional	Method of measuring drift start and end time (instrument vs watch etc)
Data recorder drift	Seconds	Optional	Old orange boxes required a check with PC clock to see by how much the data recorder local clock drifted

(Continued)

Feature

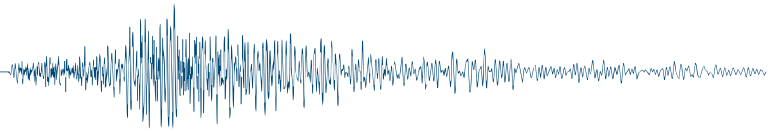


Table 1. Continued.

Parameter	Units	Compulsory or optional	Explanation
Bx sampling rate	Hz	Compulsory	Sample rate for magnetic field (X direction as defined by Bx azimuth)
Bx channel gain	Float	Compulsory	Magnetic field instrument gain (X direction as defined by Bx azimuth) equal to 1 if no gain
Bx azimuth	Degrees	Compulsory	Magnetic Y field measurement azimuth clockwise from magnetic or true north depending on north reference above
Bx coil number	Integer	Optional	Bx Coil Number
By sampling rate	Hz	Compulsory	Sample rate for magnetic field (Y direction as defined by By azimuth)
By channel gain		Compulsory	Magnetic field instrument gain (Y direction as defined by By azimuth)
By azimuth	Degrees	Compulsory	Magnetic X field measurement azimuth clockwise from magnetic or true north depending on north reference above
By coil number	Integer	Optional	By coil number
Bz sampling rate	Hz	Compulsory	Sample rate for magnetic field (vertical direction)
Bz channel gain		Compulsory	Magnetic field instrument gain (vertical direction)
Bz coil number	Integer	Optional	Vertical coil number
Mag sensor number	Character string	Optional	Identifying number on magnetic sensor instrument if not using coils
Bx (from data recorder)	nT	Optional	X magnetic field reading from box for QA purposes
By (from data recorder)	nT	Optional	Y magnetic field reading from box for QA purposes
Bz (from data recorder)	nT	Optional	Vertical magnetic field reading from box for QA purposes
Ex sample rate	Hz	Compulsory	Ex sample rate
Ex dipole Length	Metres	Compulsory	Length of X electrode dipole
Ex azimuth	Degrees	Compulsory	Azimuth (clockwise from north reference) of X electric field
Ex channel interface box gain		Compulsory	Ex field gain applied at the data recorder (value of 1 if no gain)
Ex channel pre amplification gain		Compulsory	Ex field gain applied as pre-amplification before the data recorder (value of 1 if no gain)
Ex resistance	kohm	Optional	Resistance across Ex dipole
Ex positive Length	Metres	Optional	Length of Ex from positive x direction (defined by Ex azimuth) to instrument. In a standard deployment with Ex oriented North-South this would be the length from the central box to the north electrode however this allows for deployments with Ex oriented in different directions
Ex positive electrode longitude	Dec. degrees	Optional	Longitude of Ex positive electrode
Ex positive electrode latitude	Dec. degrees	Optional	Latitude of Ex positive electrode
Ex positive electrode number	Character string	Optional	Identifying number on Ex (positive) electrode
Ex positive resistance to ground	kohm	Optional	Resistance to ground on Ex (positive) electrode
Ex negative length	Metres	Optional	Length of Ex from negative x direction (Ex azimuth + 180 degrees) to instrument. In a standard deployment with Ex oriented North-South this would be the length from the central box to the south electrode
Ex negative electrode longitude	Dec. degrees	Optional	Longitude of Ex negative electrode
Ex negative electrode latitude	Dec. degrees	Optional	Latitude of Ex negative electrode
Ex negative electrode number	Character string	Optional	Identifying number on Ex (negative) electrode
Ex negative resistance to ground	kohm	Optional	Resistance to ground on Ex (negative) electrode

(Continued)

Table 1. Continued.

Parameter	Units	Compulsory or optional	Explanation
Ex AC	MilliVolts	Optional	AC variation in X electric field
Ex DC	MilliVolts	Optional	DC level of X electric field
Ey sample rate	Hz	Compulsory	Ey sample rate
Ey dipole Length	Metres	Compulsory	Length of Y electrode dipole
Ey azimuth	Degrees	Compulsory	Azimuth (clockwise from north reference) of Y electric field
Ey channel interface box gain		Compulsory	Ey Field Gain applied at the data recorder (value of 1 if no gain)
Ey channel pre amplification gain		Compulsory	Ey Field Gain applied as pre-amplification before the data recorder (value of 1 if no gain)
Ey resistance	kohm	Optional	Resistance across Ey electrode dipole
Ey positive length	Metres	Optional	Length of Ey from positive y direction (defined by Ey azimuth) to instrument. In a standard deployment with Ey oriented East-West this would be the length from the central box to the east electrode
Ey positive electrode longitude	Dec. degrees	Optional	Longitude of Ey positive electrode
Ey positive electrode latitude	Dec. degrees	Optional	Latitude of Ey positive electrode
Ey positive electrode number	Character string	Optional	Identifying number on Ey (positive) electrode
Ey positive resistance to ground	kohm	Optional	Resistance to ground on Ey (positive) electrode
Ey negative Length	Metres	Optional	Length of Ey from negative Y direction (Ey azimuth + 180 degrees) to instrument. In a standard deployment with Ey oriented East-West this would be the length from the central box to the west electrode
Ey negative electrode longitude	Dec. degrees	Optional	Longitude of Ey negative electrode
Ey negative electrode latitude	Dec. degrees	Optional	Latitude of Ey negative electrode
Ey Negative electrode number	Character string	Optional	Identifying number on Ey (negative) electrode
Ey Negative resistance to ground	kohm	Optional	Resistance to ground on Ey (negative) electrode
Ey AC	milliVolts	Optional	AC variation in Y electric field
Ey DC	milliVolts	Optional	DC level of Y electric field
Ground / centre electrode number	Character string	Optional	Identifying number on ground electrode
Battery voltage no load	Volts	Optional	Voltage measured using a multimeter before battery is connected
Battery voltage under load	Volts	Optional	Voltage measured using a multimeter once the instrument is set up and is under load, with solar panel connected if being used.
Battery voltage data recorder	Volts	Optional	Battery voltage from data recorder
Case No	Character string	Optional	Identifying number on instrument case
Data recorder number	Character string	Optional	Identifying number on data recorder
Interface box number	Character string	Optional	Identifying number on interface box (electric field connection)
Data storage device number	Character string	Optional	Identifying number on data storage device – e.g. hard drive, memory card etc.
Deployment comments	Character string	Optional	Comments relevant to deployment that might have bearing on later processing
Number of photos – deployment	Integer	Optional	0 or number of photos
Photo identification	Character string	Optional	For each photo, photo ID separated by semicolon
Local start time	YYYY:MM:DD:HH:MM:SS.SS	Compulsory	Local finish date and time (YYYY:MM:DD:HH:MM:SS) of recording
Ex resistance; finish	kohm	Optional	Resistance across Ex electrode dipole on pickup

(Continued)

Feature

Table 1. Continued.

Parameter	Units	Compulsory or optional	Explanation
Ex AC; finish	MilliVolts	Optional	AC variation in X electric field on pickup
Ex DC; finish	MilliVolts	Optional	DC level of X electric field on pickup
Ey resistance; finish	kohm	Optional	Resistance across Ey electrode dipole on pickup
Ey AC; finish	MilliVolts	Optional	AC variation in Y electric field on pickup
Ey DC; finish	MilliVolts	Optional	DC level of Y electric field on pickup
Data recorder operational status	Character	Optional	Recording/not recording
Pickup battery voltage	Volts	Optional	Battery voltage on pickup (under load)
Magnetic Cable Status	Character String	Optional	Status of magnetic cable (i.e. intact/damaged/pulled/chewed through)
Ex Cable Status	Character String	Optional	Status of Ex cable/s (i.e. intact/damaged/pulled/chewed through)
Ey Cable Status	Character String	Optional	Status of Ey cable/s (i.e. intact/damaged/pulled/chewed through)
Pickup Comments	Character String	Optional	Comments as relevant to pickup that might have bearing on later processing including any warnings on instruments on pickup
Number of photos – pick up	Integer	Optional	Pickup of Photos taken – 0 or number of photos
Photo Identification	Character String	Optional	Identification number/character string on photos separated by semicolon
Site Quality Status	Character String	Optional	Site OK for further use or needs repeating

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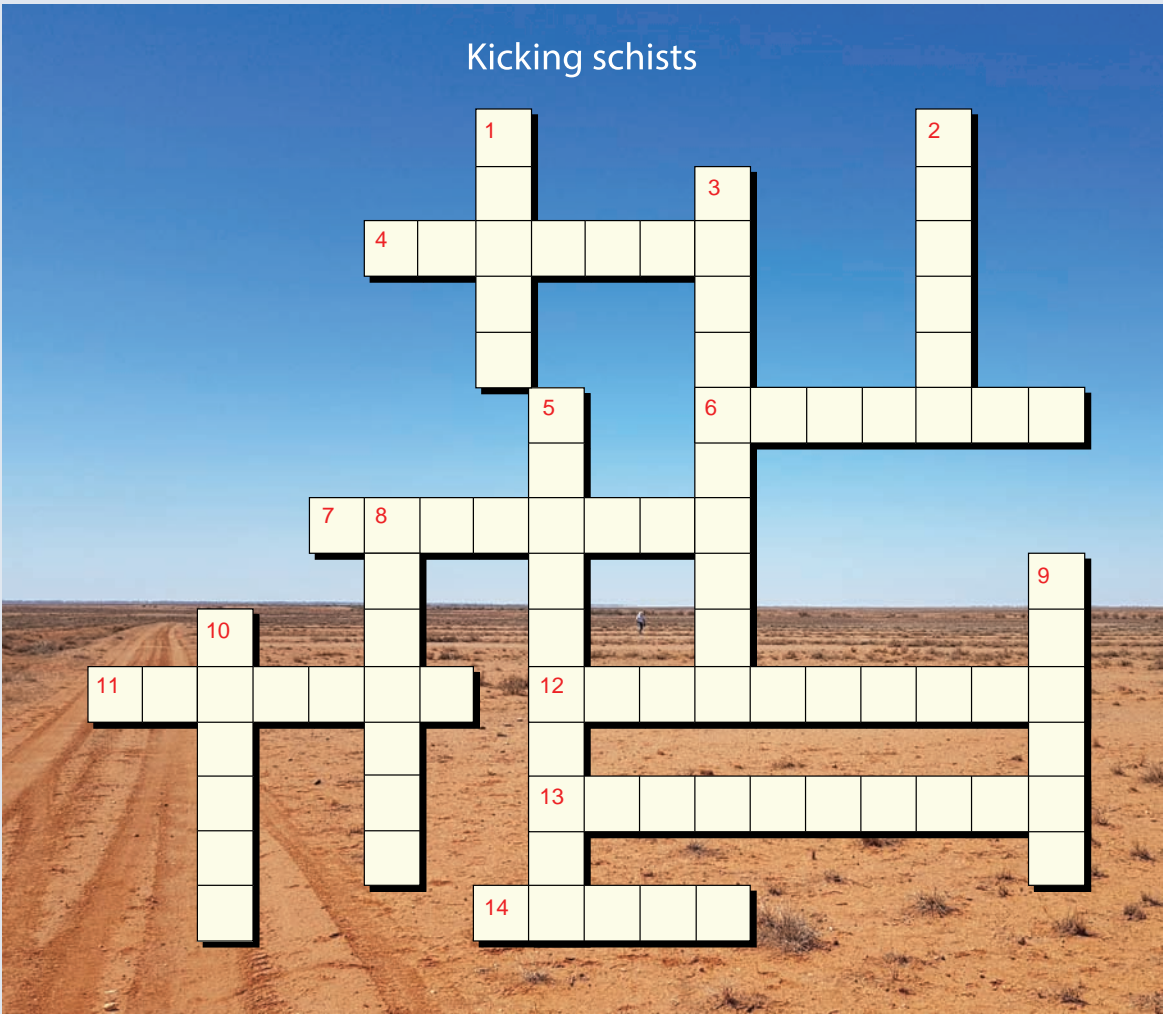


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Geophysical Software Research and Services

Kerryn Parfrey BSc, MGeoscience
Manager Geophysical Software

Mob +61 404 064 033 (Melbourne)
PO Box 5189, Greenwich NSW 2065
kerryn.parfrey@tensor-research.com.au
www.tensor-research.com.au

Preview crossword #1

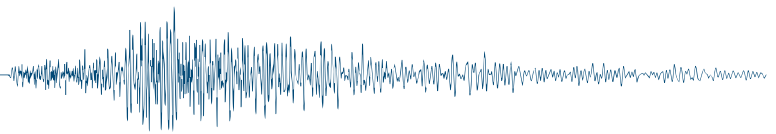


Across	Down
<p>4. A type of fold characterised by very long straight limbs and very narrow angular hinges.</p> <p>6. A major period of mountain building.</p> <p>7. The largest Galilean moon.</p> <p>11. Topographic and structural depression formed by the collapse of a magma chamber roof into its underlying magma body.</p> <p>12. A relative sea-level fall.</p> <p>13. A poorly sorted pyroclastic flow deposit whose name is derived from the Latin words for 'fire' and 'rain'.</p> <p>14. The amount of horizontal displacement between two sides of a dip-slip fault.</p>	<p>1. Unconsolidated aeolian sediment composed largely of silt-sized particles.</p> <p>2. Fool's gold.</p> <p>3. Instrument used to measure the speed of flow in a fluid.</p> <p>5. A brecciated igneous rock containing abundant xenoliths derived from the mantle that may contain various quantities of a precious but extremely hard, high-pressure mineral.</p> <p>8. Copper carbonate mineral named for its deep blue colour.</p> <p>9. A single super-continent that existed during the late-Paleozoic before fragmentation in the late-Triassic.</p> <p>10. General term applied to a body of intrusive igneous rock irrespective of shape, size or composition.</p>

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23–26	EAGE-GSM 2nd Asia Pacific Meeting on Near Surface Geoscience & Engineering https://events.eage.org/en/2019/eage-gsm-nsge-2019/	Kuala Lumpur	Malaysia
May	2019		
6–9	Offshore Technology Conference http://2019.otcnet.org/welcome	Houston	USA
13–17	GeoConvention 2019 https://www.geoconvention.com/	Calgary	Canada
14–15	Seismic 2019 https://www.spe-aberdeen.org/events/seismic2019/	Aberdeen	UK
19–22	GEM 2019 Xi'an https://seg.org/Events/Events-Calendar/GEM-2019-Xian	Xi'an	China
June	2019		
3–6	81st EAGE Conference & Exhibition 2019 https://events.eage.org/2019/EAGE%20annual%202019	London	UK
11–13	AGU/SEG Airborne Geophysics Workshop	Golden	USA
16–20	8th International Geosciences Student Conference	Uppsala	Sweden
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18–23	Goldschmidt 2019 https://goldschmidt.info/2019/	Barcelona	Spain
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15–20	SEG International Exposition and 89th Annual Meeting https://seg.org/Annual-Meeting-2019	San Antonio	USA
22–25	2019 GSA Annual Meeting https://www.geosociety.org/GSA/Events/Annual_Meeting/GSA/Events/gsa2019.aspx	Phoenix	USA
October	2019		
6–9	SAGA 16th Biennial South African Geophysical Association Conference and Exhibition http://sagaconference.co.za/	Durban	South Africa
21–24	Fifth International Conference on Engineering Geophysics (ICEG) https://seg.org/Events/ICEG-2019	Al Ain	UAE
29–30	Asia Petroleum Geoscience Conference & Exhibition (APGCE 2019) www.apgce.com	Kuala Lumpur	Malaysia
29–31	OTC Brazil http://www.otcnet.org/Brazil	Rio de Janeiro	Brazil
March	2020		
1–6	International Symposium on Deep Seismic Profiling of the Continents and their Margins (SEISMIX 2020) http://www.seismix2020.org.au	Fremantle	Australia
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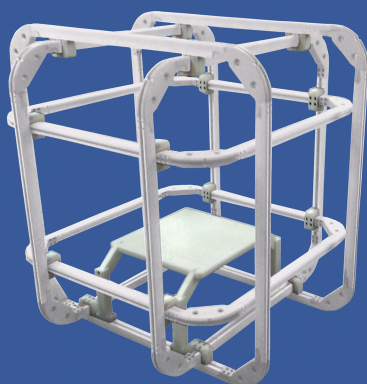
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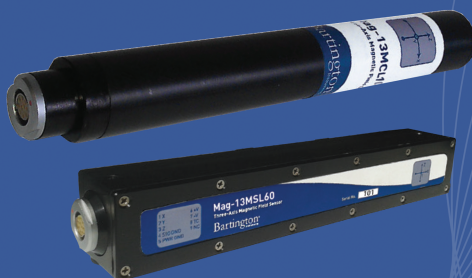
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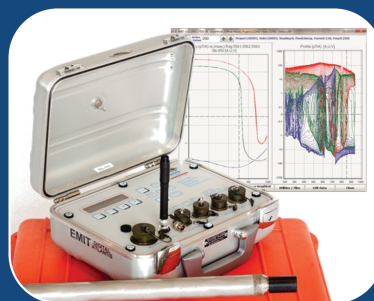
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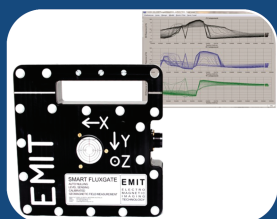
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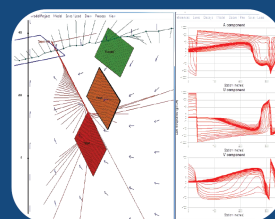
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