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Australian Society of Exploration Geophysicists

PREVIEW

NEWS AND COMMENTARY

FEATURES

ASEG federal executive 2023–24

PRESIDENT: Eric Battig
T +61 408 993 851
E president@aseg.org.au

PRESIDENT ELECT (BRANCH LIAISON): Janelle Simpson
T +61 730 966 138
E president-elect@aseg.org.au

IMMEDIATE PAST-PRESIDENT (DIVERSITY COMMITTEE CHAIR): Emma Brand
T +64 272 983 922
E past-president@aseg.org.au

SECRETARY: Asmita Mahanta
T +61 467 745 968
E fedsec@aseg.org.au

TREASURER (FINANCE COMMITTEE CHAIR): Yvette Poudjomi Djomani
T + 61 2 6249 9224
E treasurer@aseg.org.au

Steve Hearn (Publications Committee Chair)
T +61 7 3376 5544
E publications@aseg.org.au

Mark Duffett (Technical Standards Committee liaison)
T +61 3 6165 4720
E mark.duffett@stategrowth.tas.gov.au

Ian James (Web Committee Chair)
T +61 488 497 117
E webmaster@aseg.org.au

Suzanne Haydon (Membership Committee Chair)
T +61 417 882 788
E membership@aseg.org.au

Mosayeb K. Zahedi (Communications Committee Chair)
T +61 421 874 597
E communications@aseg.org.au

Karen Aurisch (Education Committee Chair)
T +61 452 462 880
E education@aseg.org.au

Randall Taylor (International Affairs Committee Chair)
T +61 419 804 105
E international@aseg.org.au

Kate Brand (Professional Development Committee Chair)
T +61 432 642 200
E continuingeducation@aseg.org.au

The ASEG Secretariat

The Association Specialists Pty Ltd (TAS)
PO Box 576, Crows Nest, NSW 1585
T +61 2 9431 8622
F +61 2 9431 8677
E secretary@aseg.org.au

Standing committee chairs

FINANCE COMMITTEE CHAIR:
Yvette Poudjom Djomani
T +61 2 6249 9224
E treasurer@aseg.org.au

MEMBERSHIP COMMITTEE CHAIR:
Suzanne Haydon
T +61 417 882 788
E membership@aseg.org.au

BRANCH LIAISON:
Janelle Simpson
T +61 7 3096 6138
E branch-rep@aseg.org.au

CONFERENCE ADVISORY COMMITTEE CHAIR:
Michael Hatch
E cac@aseg.org.au

HONOURS AND AWARDS COMMITTEE CHAIR:
Marina Costelloe
E awards@aseg.org.au

PUBLICATIONS COMMITTEE CHAIR: Steve Hearn
T +61 7 3376 5544
E publications@aseg.org.au

TECHNICAL STANDARDS COMMITTEE CHAIR:
Tim Keeping
T +61 8 8226 2376
E technical-standards@aseg.org.au

HISTORY COMMITTEE CHAIR: Roger Henderson
T +61 406 204 809
E history@aseg.org.au

INTERNATIONAL AFFAIRS COMMITTEE CHAIR:
Randall Taylor
T +61 419 804 105
E international@aseg.org.au

PROFESSIONAL DEVELOPMENT COMMITTEE CHAIR:
Kate Brand
T +61 432 642 200
E continuingeducation@aseg.org.au

EDUCATION COMMITTEE CHAIR: Karen Aurisch
T +61 452 462 880
E education@aseg.org.au

WEB COMMITTEE CHAIR: Ian James
T +61 488 497 117
E webmaster@aseg.org.au

RESEARCH FOUNDATION CHAIR: Philip Harman
T +61 409 709 125
E research-foundation@aseg.org.au

COMMUNICATIONS COMMITTEE CHAIR:
Mosayeb K. Zahedi
T +61 421 874 597
E communications@aseg.org.au

Specialist groups

NEAR SURFACE GEOPHYSICS SPECIALIST GROUP CHAIR:
Vacant - enquires to fedsec@aseg.org.au
E nsgadmin@aseg.org.au

YOUNG PROFESSIONALS NETWORK CHAIR:
Jarrod Dunne
E ypadmin@aseg.org.au

ASEG branches

Australian Capital Territory

PRESIDENT: Wenping Jiang
E actpresident@aseg.org.au

SECRETARY: Mike Barlow
T +61 439 692 830
E actsecretary@aseg.org.au

New South Wales

PRESIDENT: James Austin (Jim)
E nswpresident@aseg.org.au

SECRETARY: Harikrishnan Nalinakumar
E nswsecretary@aseg.org.au

Queensland

PRESIDENT: Nick Josephs
E qldpresident@aseg.org.au

SECRETARY: Tim Dean
E qldsecretary@aseg.org.au

South Australia & Northern Territory

PRESIDENT: Paul Soeffky
E sa-ntpresident@aseg.org.au

SECRETARY: Vacant
E sa-ntsecretary@aseg.org.au

NT REPRESENTATIVE: Tania Dhu
T +61 422 091 025
E nt-rep@aseg.org.au

Tasmania

PRESIDENT: Tjaart de Wit
E taspresident@aseg.org.au

SECRETARY: Matt Cracknell
T +61 409 438 924
E tassecretary@aseg.org.au

Victoria

PRESIDENT: Thong Huynh
T +61 438 863 093
E vicpresident@aseg.org.au

SECRETARY: Vacant
E vicsecretary@aseg.org.au

Western Australia

PRESIDENT: Michel Nzikou
E wapresident@aseg.org.au

SECRETARY: Timothy Hill
E wasecretary@aseg.org.au

ASEG honorary editors

EXPLORATION GEOPHYSICS: **EDITOR IN CHIEF**
Mark Lackie
E eg-editor@aseg.org.au

PREVIEW: **EDITOR**
Lisa Worrall
T +61 409 128 666
E previeweditor@aseg.org.au

ADVERTISERS INDEX

ASEG CORPORATE PLUS MEMBERS

Velseis Pty Ltd
T +61 7 3376 5544 **E** info@velseis.com
W https://www.velseis.com/

TOTAL SEISMIC
T +61 (0)409 891 391 **E** info@totalseismic.com
W https://www.totalseismic.com/

ASEG CORPORATE MEMBERS

Santos Ltd
T +61 8 8116 5000
W https://www.santos.com

Southern Geoscience Consultants Pty Ltd
T +61 8 6254 5000 **E** geophysics@sgc.com.au
W http://sgc.com.au/

Transparent Earth Geophysics
T +61 (0) 409 887 459 Wayne Hewison
or +61 (0) 412 844 216 Andy Gabell
E info@transparentearth.com.au
W http://www.transparentearth.com.au

DUG Technology
T +61 8 9287 4100
E sales@dug.com support@dug.com
W https://dug.com/

Seismic Asia Pacific
Contact: Paul K Duncan
T +61 7 3719 3412 **E** paulk.d@seismic.com.au
W https://www.seismicapac.com/

HiSeis Pty Ltd
T +61 8 9470 9866 **E** admin@hiseis.com
W http://www.hiseis.com.au/

SKYTEM
T +61 8 9249 8715 **E** sjo@skytem.com
W https://skytem.com/

Planetary geophysics
T +61 7 4638 9001
E info@planetarygeophysics.com.au
W https://www.planetarygeophysics.com/

FRONT COVER

The way we were - a reminder of the careless days of exploration (and nuclear testing) in Australia. Photo by Doug Morrison of drilling near Halls Creek in Western Australia in 1982. An article by Pat Cunneen on the history of radiometric surveys over the Maralinga Nuclear Test Range in South Australia, and a call for a new survey, is in this issue.

Preview is freely available online at https://www.aseg.org.au/publications/PVCurrent and also https://www.tandfonline.com/toc/texp20/current

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CONTENTS

Editor
Lisa Worrall
E previeweditor@aseg.org.au

Assistant Editor
Thong Huynh
E Thong.H.Huynh@outlook.com

Associate Editors
Education: Marina Pervukhina
E continuingeducation@aseg.org.au

Government: David Denham
E denham1@iinet.net.au

Environmental geophysics: Mike Hatch
E michael.hatch@adelaide.edu.au

Minerals geophysics: Terry Harvey
E terry.v.harvey@glencore.com.au

Petroleum geophysics: Michael Micenko
E micenko@bigpond.com

Geophysical data management and analysis: Tim Keeping
E Tim.Keeping@sa.gov.au

ASEG Head Office & Secretariat
The Association Specialists Pty Ltd (TAS)
T (02) 9431 8622
E secretary@aseg.org.au
W www.aseg.org.au

Designer
Stripe Design
E info@stripedesign.com.au

Printer
CanPrint
T (02) 6295 4422
E canprint@canprint.com.au

Advertising
Lisa Worrall
T 0409 128 666
E Previeweditor@aseg.org.au

Publisher
E journals@tandf.com.au
W www.tandfonline.com

– Join us for the globally pre-eminent applied geophysical event –

ASEG 2024

AUSTRALIAN SOCIETY OF EXPLORATION GEOPHYSICISTS

1ST ASEG DISCOVER SYMPOSIUM

15–18 OCTOBER • Wrest Point Hotel, Hobart, Tasmania

KEY THEMES:

- Advances in Exploration and Sustainable Resources Recovery
- Case Histories
- Data Science
- Discovery Under Cover
- Supplier Showcase
- Technology & Innovation and more

SECURE YOUR SPOT!

Early Bird Registration and Call for Abstracts deadline

1 JULY 2024

PROGRAM AT A GLANCE

Tuesday 15 October	
1.00pm – 6.00pm	Registration
1.30pm	Workshops (included in the full registration fee)
6.00pm	Welcome Reception (included in the full registration fee)
Wednesday 16 October	
9.00am – 5.00pm	Workshops (included in the full registration fee)
5.00pm	Free night to enjoy Hobart's restaurants
Thursday 17 October	
9.00am – 5.00pm	Technical Presentations – Plenary and Breakout sessions
7.00pm	Conference Dinner - Those with a full registration can access the subsidised rate of $45 per person.
Friday 18 October	
9.00am – 4.00pm	Technical Presentations – Plenary and Breakout sessions
4.00pm	Farewell Refreshments

REGISTRATION FEES

Registration Type	Early Bird Rate (until 1 July)	Standard Rate (from 2 July)
Full Registration – Member	$900.00	$1,200.00
Full Registration – Non-Member	$1,200.00	$1,400.00
Full Registration – Student	$300.00	$400.00
Full Registration – Retired	$700.00	$700.00
Day Registration	$645.00	$735.00

For more information contact Lucy:
P: +61 3 6234 7844 | E: lucy@laevents.com.au

www.asegdiscover.com.au

Editor's desk

Sadly, it is true, David Denham is retiring after 25 years of contributing to *Preview*. I know that regular readers will feel bereft, and regular watchers of National Press Club lunches will miss the frisson attached to questions being asked by "David Denham, *Preview*". David's very last *Canberra observed* reflects on what has changed in the resources sector over the last 25 years. In addition, he takes a look at the Australian Government investment in the critical minerals industry, and muses about the situation facing Australian universities.

This issue of *Preview* also features two articles by geophysicists at opposite ends of their careers, and in so doing illustrates the best of what *Preview* has to offer. Anthony Reid and his colleagues present a case study on the use of ambient noise tomography to image the supergene at the Alford East iron oxide copper-gold prospect in South Australia. And Pat Cunneen, after a long and illustrious career in geophysics, revisits radiometric surveys flown over the Maralinga nuclear test site over the last 70 years, and calls for a new survey to assist ongoing management and rehabilitation. As Pat points out, much of the historical survey data has been lost and his article has had to draw on salvaged slides and contour maps published in the grey literature. Thanks, Pat, for bringing this historical material to light and incidentally focusing attention on the need to archive historical slide collections – before they are lost forever!

In *Education matters* Marina Pervukhina interviews Boris Gurevich, John Curtin Distinguished Professor of Geophysics at Curtin University, about finding the balance between breadth and depth in education in the geosciences. Mike Hatch (*Environmental geophysics*) gets excited about mapping seagrass – who knew?! Terry Harvey (*Mineral geophysics*) thinks about exploring for lithium from first principles. Mick Micenko (*Seismic window*) muses on maintaining data quality in point source and receiver acquisition. Tim Keeping (*Data trends*) considers NetCDF as an alternative to ASEG GDF2, and Ian James (*Webwaves*) reviews the ASEG website project and the road ahead.

Lastly, a reminder that the ASEG has resumed control of advertising in *Preview* and hopes eventually to cover all publication costs from advertising. So, if you know of anyone in your part of the world whom you think would benefit from advertising in *Preview*, please urge them to get in touch with me!

Enjoy!

Lisa Worrall
Preview Editor
E previeweditor@aseg.org.au

Letters to the Editor

Hi Lisa and Steve

Congratulations on bringing *Preview* back home and the quality of the very first print run. As you know, I am keen on the print version because it gets read from cover to cover when I have it in print format.

I really like the expansion of the ASEG Research Foundation reports with the inclusion of some key figures from the student's research. I also like the inclusion of the expanded technical articles which allow you to get down to more detail.

Ted provided me with some background to the work required to get the new process up and running in parallel with the last few Taylor & Francis versions. That was a lot of work, and I am grateful for your efforts in making it happen.

Well done!

David Pratt, Manager Research & Development
Tensor Research Pty Ltd
E david.pratt@tensor-research.com.au

Lisa and Steve and the *Preview* Associate Editors and contributors - HUGE CONGRATULATIONS !!!

Our first self-published issue of *Preview* - February 2024 Issue 228 is an outstanding success with noticeable improvements in layout across the board!!

On-line publication was announced to Members on 14 February 2024, and I have just received my printed *Preview* 228 in the mail, 7 March, exactly three weeks from online publication - a truly outstanding achievement. Our Australian Members who request *Preview* in print form will be extremely happy.

The paper stock, printed colour quality, colour registration and text clarity of this *Preview* from CanPrint is outstanding - equal to or better than the T&F printed products. Photos and colour imagery and adverts show an improvement in clarity, colour density and brightness - great job CanPrint!

This is a top class printed publication that stands above the regular publications we see from other geoscience societies in Australia (and beyond).

Lisa, the success of our first self-published issue of *Preview* is very much a measure of your determination and extraordinary efforts to make this work in close partnership with Stripe and Canprint!

Huge appreciation and even Huge(r) congratulations from me … and I know from all of our ASEG colleagues that contribute and value our flagship magazine!

My best regards

Ted Tyne
E Ted.Tyne@bigpond.com

President's piece

Twelve months have now passed by since I wrote my first *President's piece*, and it has been an immense privilege to serve as President. While the year in many ways has passed in a blur, I am proud of, and humbled by, what our Society's volunteers have been able to achieve, both at the State and Federal levels.

Our State Branches have delivered many face-to-face and online talks, seminars, meetings and social events, providing opportunities to engage over the latest developments in science, establish new and strengthen existing networks. Of particular significance is that our branches provide forums to reach out and engage with students and early career professionals as the next generation geophysicists, and none of this would be possible without the dedication of our State Branch committee volunteers and the support of our State Branch sponsors.

The back end of 2023 was marked by three major events: MAG23, CAGE2023 and AEM2023. Each one was a resounding success in every measure, and I am certain we will continue to see MAG and CAGE headlining the ASEG's annual event calendar. And who can say no to a conference in a tropical paradise? Surely the international AEM workshop will return to our shores soon.

This year in October we will be presenting the ASEG's inaugural DISCOVER conference, hosted in Hobart. With DISCOVER we are launching an event that will showcase the ASEG as the premier society for applied exploration geophysics and are aiming for it to become the leading forum for sharing quality science and connecting with peers. The conference website has been launched and is open for early bird registrations and abstract submissions. You will also see regular communications with updates on the technical programme and social events.

2024 marked a very significant milestone for our Publications team, with *Preview* moving to self-production, allowing us to move to a more dynamic layout and to offer more interesting possibilities to advertisers. Hats off to our Editor Lisa Worrall and the Publications Committee for persevering with this mammoth effort. The Publications Committee is also continuing its efforts to strengthen our flagship scientific journal *Exploration Geophysics* and I encourage you to submit significant case histories and relevant research in geophysics.

By the time this edition of *Preview* reaches your inbox, we will have also undergone material changes in the digital space. Thanks to the Web Committee we have set up Google Workspace for Nonprofits and completed migration of ASEG communications to Google. Principally, this provides us with greater email security, but we also gain exposure to a host of other benefits that can help us with advertising, fundraising and organisational efficiency. The website refresh, which includes replacing our membership database is also near completion. This transition will provide a cleaner and simpler user experience and simplify the website login.

Internationally, we have taken deliberate steps to reinvigorate our relationships with the SEG and the EAGE, evidenced by our strong presence on the SEG Council, respective conferences, and efforts to renew respective MOUs.

Looming over all these good news stories is the state of declining geophysics education and expertise in Australia. This is an issue rooted in the image problem facing the broader resources industry and not one we can address on our own. We are able, however, to continue to play a significant role to improve the accessibility of our profession and I am heartened and encouraged by the efforts and initiatives coming from our Education, Professional Development and Young Professional Committees. We are increasing our presence at Career and Student Events, collaborating with other geoscience societies (*e.g.*, AusIMM and AIG) to develop materials targeting schools, and joining forces with universities to help frame future geophysics curriculum.

I hope this report has painted an exciting picture of the year that has passed. We need your help to continue to thrive and deliver Member value, and have a range of committees (**Committees | Australian Society of Exploration Geophysicists (aseg.org.au)**) on which you could serve. If any of these committees resonate with your interest(s) please reach out to the respective Chair directly. Any level of assistance will always be welcomed. We would also love to have more volunteers for the Hobart conference, so please contact me directly if this might interest you.

I look forward to seeing many of you in Hobart and, as always, please reach out (**president@aseg.org.au**) with any ideas of how we can improve the ASEG, general comments or feedback.

Eric Battig
ASEG President

E **president@aseg.org.au**

The ASEG in social media

social sow+shl

[adjective] ***Relating to society or its organisation***

[noun] ***Social media sites, applications or accounts***

Follow all our socials for the latest updates!

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 these monthly meetings. We hope you find these short updates valuable. If there is more that you would like to read about on a regular basis, please contact Asmita on fedsec@aseg.org.au. The FedEx had its last meeting on 14 February 2024. The summary updates on finance, membership, events, and communications are from this meeting.

Finances

The financial report presented to the February FedEx meeting was current as of 31 January 2023. The January 2024 operating income was $104 907, which was mainly derived from membership income of $100 726. The January 2024 operating expenses were $8992, which included the monthly TAS Management Fee of $7384. For the month of January 2024, the ASEG was running at a profit of $95 915, and the YTD profit was $95 915.

	January 2024	YTD
Total Income	$104 907	$104 907
Total Expense	$8 992	$8 992
Net Profit	$95 915	$95 915
Net Assets		$1 131 768

Membership

The annual membership renewal process is in progress. If you have not already done so, please renew your membership at your earliest convenience. As of 8 February 2024, there were 684 paid Members compared with 640 at the start of last month and 678 at this time last year. Our Corporate Plus Members are **Velseis** and **Total Seismic**. Our Corporate Members are **HiSeis**, **Transparent Earth Geophysics**, **Santos**, **Southern Geoscience Consultants, SkyTEM Australia, DUG Technology** and **Seismic Asia Pacific Pty Ltd**. We would like to ask our Corporate Members who are yet to renew their membership, to please consider renewal, as your support is appreciated. Welcome to all our new Members, and thanks to all our renewed Members, Corporate Plus and Corporate Members, and local sponsors of our local Branches for their continued support in 2024.

Events

Early bird registration is now open for the first ASEG DISCOVER symposium, which will be held at the Wrest Point Hotel, in Hobart, Tasmania, commencing on Tuesday 15 October and wrapping up on the afternoon of Friday 18 October 2024. The call for abstracts opened on 1 March, with a deadline of 1 July. This symposium is dedicated to applied geophysics in exploration, mining, energy and the near surface. It will cover themes including advances in exploration, to the application of geophysics in the mining value chain, and utilising data science and innovation. We are looking forward to seeing you all in Hobart!

Communications

There are many avenues for you to stay connected with ASEG including *Preview*, the ASEG Newsletter, the ASEG website, and various social media sites such as LinkedIn, Twitter and Facebook. There has been a steady increase in views on Facebook and LinkedIn, and a steady increase in followers on all social media sites. Please consider using social media to promote all ASEG events and publications.

Please contact me for more information about any of the above.

Asmita Mahanta
ASEG Secretary
E fedsec@aseg.org.au

Welcome to new Members

The ASEG extends a warm welcome to 15 new Members approved by the Federal Executive at its February and March meetings (see table).

First name	Last name	Organisation	State	Country	Membership type
Liam	Berryman	The University of Melbourne	Vic	Australia	Student
Charlotte	Buckingham	The University of Melbourne	Vic	Australia	Student
Nicholas	Chryssafis	The University of Melbourne	Vic	Australia	Student
Ben	Davidovic	Curtin University	WA	Australia	Student
Thomas	Davies	Southern Geoscience Consultants	WA	Australia	Active
Neil	Harbison	Queensland University of Technology	Qld	Australia	Student
Elnaz	Heidari	The University of Sydney	NSW	Australia	Student
Grace	Holtam	Queensland University of Technology	Qld	Australia	Student
Abhishek	Kumar	Curtin University	WA	Australia	Student
Theo	Le Gallais	Curtin Uni	WA	Australia	Student
Relly	Margiono	The University of Adelaide	SA	Australia	Student
Chrispin	Ngwata	Geological Survey Department of Malawi	Eastern Region	Malawi	Associate
Emma	Sands	Terrex Seismic	Qld	Australia	Associate
Hojatollah	Shirmardgouravan	The University of Sydney	NSW	Australia	Student
Robert Thinh	To	CGG	WA	Australia	Associate

Notice of the ASEG Annual General Meeting

The 2024 Annual General Meeting of the Australian Society of Exploration Geophysicists will take place on **Tuesday 30 April 2024 at the XXXX Alehouse, 20 Paten St, Milton, Brisbane** and via Zoom. The guest speaker will be Dr Tim Dean.

Be there to make a difference!

For more information, contact ASEG Secretariat at secretary@aseg.org.au, or by telephone on **+61 2 9431 8622**.

Call for nominations for members of the Federal Executive

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 Act". These are the President, President-Elect, Immediate Past President, Secretary and Treasurer. They shall be elected annually by the Members of the Society at the Annual General Meeting. These office bearers shall succeed the previous ones upon the conclusion of the Annual General Meeting. At the end of their term each officer will retire but may nominate and be eligible for re-election except for the President's position, which will be automatically filled by the outgoing President-Elect, and the Immediate Past President's position.

The Federal Executive shall comprise up to 12 members, and shall at least include the five elected members:

(i) a President (elected as a two-year term, one year as President, immediately followed by one year as Immediate Past President)

(ii) a President-Elect

(iii) the Immediate Past President

(iv) a Secretary

(v) a Treasurer

These officers will be elected by a ballot of Members.

In addition, the following offices are recognised:

- the Chair of the Publications Committee
- the Chair of the Membership Committee
- the Chair of the State Branch Committees (unless otherwise a member of the Federal Executive)
- Up to four others to be determined by the Federal Executive.

These officers will be appointed by the Federal Executive Committee.

Positions for which there are multiple nominations will be determined by an online ballot of Members, and the results declared at the Annual General Meeting.

Asmita Mahanta
ASEG Secretary
E fedsec@aseg.org.au

TUESDAY 30 APRIL 2024, BRISBANE

ASEG Honours and Awards: Nominate an ASEG Member for an award today!

I encourage you and your network to nominate someone you think is worthy of an ASEG award. The Honours and Awards Committee are here to help, so if you have any questions please don't hesitate to contact me. The Honours and Awards Committee are a great bunch of people, but we do not nominate people for awards, YOU do.

In 2024 the ASEG Awards ceremony will be held alongside the DISCOVER conference in Hobart 15-18 October 2024. The Awards Committee welcome all nominations for the following:

ASEG GOLD MEDAL - for exceptional and highly significant distinguished contributions to the science and practice of geophysics, resulting in wide recognition within the geoscientific community over many years. Dr Philip Schmidt, Dr Malcolm Cattach and Dr Bob Smith are recent recipients.

HONORARY MEMBERSHIP - for distinguished contributions by a Member to the profession of exploration geophysics and to the ASEG over many years. Dr Ted Tyne, Dr Andrew Mutton and Henk Van Paridon are recent recipients.

GRAHAME SANDS AWARD - for innovation in applied geophysics through a significant practical development in the field of instrumentation, data acquisition, interpretation or theory. Dr Lesley Wyborn, Dr Phil Schmidt and Dr Ross Brodie are recent recipients.

LINDSAY INGALL MEMORIAL AWARD - for the promotion of geophysics to the wider community. Doug Morrison, Dr Steve Mudge and Dr Mike Dentith are recent recipients.

EARLY ACHIEVEMENT AWARD - for significant contributions to the profession by a Member under 36 years of age, by way of publications in *Exploration Geophysics* or similar reputable journals, or by overall contributions to geophysics, ASEG Branch activities, committees, or events. Dr Janelle Simpson, Dr Stanislav Glubokovskikh and Regis Neroni are recent recipients.

ASEG SERVICE AWARDS - for distinguished service by a Member over many years to ASEG Branch activities, Federal or State committees, publications, conferences, or other Society activities. Dr Kate Brand, Danny Burns and Marina Costelloe are recent recipients. Tania Dhu, Fiona Duncan and Wendy Watkins are recent ASEG Distinguished Service Certificate recipients.

ASEG Members are eligible for all award categories. Non-members also are eligible for the Lindsay Ingall and Grahame Sands awards. Under exceptional circumstances, the other awards may be offered to a non-member of the ASEG who has given appropriate service to the ASEG or to the profession of geoscience, and who has been duly nominated by the Federal Executive.

Nomination procedure.

Any Member of the Society may submit nominations for an award. Nominations should be specific to a particular award and appropriate documentation is requested to support the nomination. The ASEG awards carry considerable prestige within the ASEG community and the geoscience profession, so please consider nominating someone who deserves the recognition. In the case of the Lindsay Ingall Memorial Award nominations should be supported by at least four geoscientists who are Members of an Australian geoscience body (*e.g.*, ASEG, GSA, AusIMM, AIG, PESA, or similar).

Nominations including digital copies of all relevant supporting documentation are to be emailed to: awards@aseg.org.au. All correspondence and nominations will be treated confidentially.

Further details of the award categories, lists of previous awardees and citations for recent awards, award criteria, nomination guidelines and nomination forms can be found on the ASEG website at: https://www.aseg.org.au/about-aseg/honours-awards

Further information can be obtained by emailing the Chair of the Honours and Awards Committee at awards@aseg.org.au.

Marina Costelloe
ASEG Honours and Awards Committee Chair
(on behalf of the Committee)
E awards@aseg.org.au

NOMINATIONS CLOSE 3 SEPTEMBER 2024

ASEG branch news

Australian Capital Territory

The ACT Branch is currently rustling up speakers for 2024. If you are visiting Canberra and would like to give a presentation to the Branch, then please get in touch with the President actpresident@aseg.org.au

And don't forget the about Geoscience Australia's Wednesday seminars in 2024 (https://www.ga.gov.au/news-events/events/public-talks). These seminars are a good source of geoscientific information that includes the use of geophysics.

Wenping Jiang

E actpresident@aseg.org.au

New South Wales

An invitation to attend NSW Branch meetings is extended to all interstate and international visitors who happen to be in town at the time. Meetings are generally held on the third Wednesday of each month from 17:30 at Club York. News, meeting notices, addresses and relevant contact details can be found at the NSW Branch website.

Harikrishnan Nalinakumar

E nswsecretary@aseg.org.au

Queensland

2024 started, as many Members probably wish it would continue, with a trip to a brewery. In this case, the XXXX Brewery over in Milton (only 2 km from the city centre). Despite being the venue for many previous ASEG Qld meetings, most Members had never toured the brewery itself, so a balmy Thursday evening found 15 of our Members (including a couple of interstate visitors for whom the lure of a trip to the home of the famous XXXX was too hard to resist) following a tour guide around the sacred halls.

The XXXX brewery was founded way back in 1878 by some of the first of many Victorians looking for a better life in the Sunshine State. The brewery has since gone from strength to strength and is now one of the leading brands in Australia (XXXX Gold is currently #3 in sales), and only in Australia (interestingly, XXXX is not available overseas). For those wondering why it is called XXXX, the story (apparently) is that the 'X' is an indication of the quality, and the four Xs were used to indicate that quality had risen beyond even the previous maximum standard of three Xs. After building up quite a thirst during the tour, it thankfully ended with a tasting session of some of the locally produced brews, ably poured by local President, and Harold Holt's former swimming partner, **Nick Josephs**.

The next event was the annual AGM and technical night on 7 March held at one of our familiar haunts, the Stock Exchange Hotel in central Brisbane. The night began in controversial fashion with the projector failing to display the presidential election results. This forced Members (including prodigal son **Shaun Strong**) to trust "honest Nick's" announcement that he had triumphed over "none of these candidates" by a vote of 5643 to 2. With the rowdy membership subdued by his stunning victory, Nick went on to announce that his other ~~cronies~~ cabinet members would continue unopposed in their posts (**Tim Dean** as Secretary and **Roger Cant** as Treasurer).

Controversy over (at least for another year), and the membership suitably fed and watered, we then enjoyed a presentation from QUT's Associate Professor of Geophysics, Dr **Craig O'Neill** who presented "Geophysics on the edge: Getting subsurface information on actively failing landslides (and living to tell about it!)" A stimulating summary of an area of geophysics that perhaps receives less attention than it should.

ASEG Qld Members enjoying a tour of the XXXX Brewery in Milton, Brisbane.

As always, we extend an invitation to anyone passing through to join us at a local event, particularly if you've got something interesting to share!

Tim Dean

E qldsecretary@aseg.org.au

ASEG Qld President, and inventor of the soft-close hinge, Nick Josephs gleefully announces his triumph in the latest local elections.

ASEG Qld Members enjoying the presentation from Craig O'Neill (yes, that is the typically flamboyantly dressed Shaun Strong in the foreground).

Craig O'Neill receiving bottle of red from Nick Josephs

South Australia and Northern Territory

On Tuesday 13 February, the SA-NT Branch proudly hosted Dr **Andrew Fitzpatrick** from IGO, who gave a fantastic talk titled "Modern use of electromagnetics in Nickel Exploration". This presentation was a great start to our year of technical talks.

On Thursday 7 March, the SA-NT Branch co-hosted the AusIMM Adelaide Student Chapter BBQ with committee member **Matt Zengerer** introducing the ASEG to the students on the night. The night was well attended both by students and ASEG Members with lots of networking happening.

Lastly, we couldn't host any of our fantastic events without the valued support of our sponsors. The SA-NT Branch is currently sponsored by **Beach Energy**, **Borehole Wireline**, **Vintage Energy**, the **Department for Energy and Mining**, **Zonge**, **Santos and Heathgate**.

Paul Soeffky

E sa-ntpresident@aseg.org.au

Tasmania

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 keep an eye on the seminar/webinar 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.

Tjaart de Wit

E taspresident@aseg.org.au

Victoria

It's "the gift that keeps on giving". Why couldn't it have been whisky or even generous servings of questionable recreational substances? I'm only kidding, I've been advised by my parole officer that I should consume less whisky ✌. Turning over power to the nominated President of the Victoria Branch for 2024 has not been smooth sailing. Far from that. Sometimes, the best kind of change is the one that happens without any fanfare, like the sort of change that happens suddenly and unfortunately, sometimes violently, like during a coup. Perhaps that's what is needed. An episode of blitzkrieg followed by some celebratory drinks. Thoughts?

Why on Earth am I still here? As the past-President of this awe-inspiring Branch, I did not want to leave it without an office-bearer. This has happened only once in our proud history, during 2008, when the Branch was, well…branchless ☺. It was also pretty dire the year before that when we only had an 'acting' President.

Alright then…so, nothing special ever happens at the Victorian Branch of the ASEG in the first three months of the year…any year, and for no real reason other than "we've all been so busy with our daily lives". I know. It's a lame excuse. Nevertheless, I expect to hand over power soon, real soon, at the next technical meeting night. I promise, this will be the very last time you'll hear from me. To all my fans, I mean valued ASEG Victorian Branch Members, remember - please, no tears.

Thong Huynh

E vicpresident@aseg.org.au

Western Australia

The ASEG-WA Branch held its first event of 2024, a Students and Young Professionals Networking Night, on 8 February. This networking event gathered students and young professionals at the Mayfair Lane Pub. The Branch President and committee members were also present.

On Thursday 28 February the ASEG-WA Branch hosted a technical night talk as part of its monthly technical talk series. The guest on this night was Professor **Mark Jessell** who is a Professor at the Centre for Exploration Targeting at The University of Western Australia. His scientific interests revolve around the tectonics and metallogenesis of the West African and Guyanese Cratons (WAXI & SAXI), microstructure studies (the Elle platform), and integration of geology and geophysics in 3D (the Loop project). Mark returned to Australia from France on a Western Australian Fellowship focused on improving the links between geological and geophysical data analysis in 3D via analysis of the geological and topological uncertainty. In 2013 he was awarded the Geological Society of Australia Hobbs Medal for major contributions in structural geology. He is a director of the Not-For-Profit Agate Project Ltd, which supports higher education in the Earth Sciences in Africa.

The ASEG WA Branch Students and Young Professionals Networking Night

In his talk, titled "New methods for constraining geology from geophysics", Mark presented some of the activities from the MinEx CRC/Loop Consortium/ DARE ITTC work on building 3D geological models using geophysical data. The talk briefly highlighted the following areas:

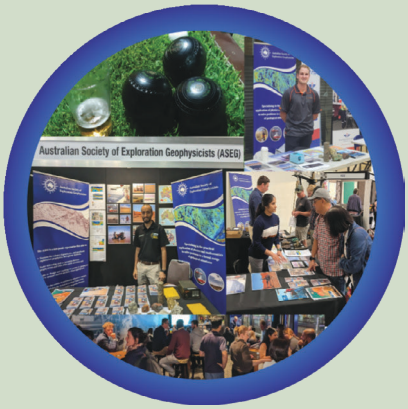
1. Integration of automatic implicit geological modelling in deterministic geophysical inversion (https://doi.org/10.5194/se-15-63-2024)
2. Some results from the Tomofast-x inversion platform, with its ability to use detailed petrophysical statistics as constraints on gravity/mag inversion

Professor Mark Jessell, who spoke to the WA Branch in February.

The WA Branch of the ASEG is now offering 2024 sponsorship and participation opportunities. The WA Branch is the largest State Branch of the ASEG, with more than 290 Members. We host regular technical meetings and social networking events and promote and support other geophysics-focussed initiatives including CAGE and the MAG symposia. We also foster student and early career professional participation in geophysics and showcase the geoscience profession to the greater community. The WA Branch organises educational booths at WA career exhibitions (*e.g.*, the Perth Careers Expo) and high school career-information sessions, and proudly supports student geoscience-outreach programmes, early career mentoring programmes and student and early career attendance at conferences and workshops via professional development bursaries.

The continued success of the ASEG WA Branch is dependent on the support from ASEG Members and the generosity of ASEG WA Branch sponsors and benefactors. On behalf of the ASEG WA Branch Committee, we invite you and/or your organisation to celebrate an integral part of the geoscience-community and sponsor the ASEG WA Branch in 2024!

Emad Hemyari
WA Branch Communications Officer
E emad.hemyari@gmail.com



SCAN ME

ASEG national calendar

ASEG Branches hold face-to face meetings and webinars. Registration for webinars is open to Members and non-members alike, and corporate partners and sponsors of state branches are acknowledged before each session. Recorded webinars are uploaded to the ASEG's website (https://www.aseg.org.au/aseg-videos), as well as to the ASEG's YouTube channel (https://bit.ly/2ZNglaZ). Please monitor the Events page on the ASEG website for the latest information about events.

Date	Branch	Event	Presenter	Time	Venue
15 Apr	Qld	Technical talk	Jan Francke	1630	Stock Exchange Hotel, 166 Charlotte St, Brisbane
17 Apr	NSW	Technical talk	TBA	1800	Level 2, Club York, 99 York St., Sydney
30 Apr	National	AGM	Dr Tim Dean	1700	XXXX Alehouse, 20 Paten St, Milton, Brisbane

Posthumous award: R.M.S. (Bob) White

The **Lindsay Ingall Memorial Award** recognises an Australian resident for the promotion of geophysics within the non-geophysical community, including geologists, geochemists, engineers, managers, politicians, the media or the general public. This award commemorates the life of ASEG founder, past President and Honorary Member, the late Lindsay Ingall for his capacity to cross geoscience boundaries, his ability to relate technically and effectively with other professionals, regardless of their own understanding of the principles of geophysics, and for his enduring commitment to assist geoscientists across Australia. It is awarded to an individual who has actively promoted geophysics to the wider community.

The award in 2024 is made to R. M. S. (Bob) White, a Sydney-based ASEG Member who is well known to mineral industry geophysicists and the broader geological and corporate community as a passionate advocate and promoter of geophysics and the resources industry. His nomination for this award has been strongly supported and endorsed by six senior company geologists. It is with great regret that we acknowledge that Bob passed away at his home in Terrey Hills on 24 August 2023.

Bob White was a talented geophysicist whose modest demeanour served to hide a brilliant analytical mind and a stimulating conversationalist on the philosophy of mineral exploration. In particular, he promoted an honest realistic understanding of the capability of common geophysical technologies to assist drill target definition for resource projects. His detailed knowledge of a wide range of geophysical methods was always communicated in straight-forward and clear language.

Bob completed his degree in exploration geophysics at Macquarie University then worked for many years as a company geophysicist (Cominco and Getty). In 1987, Bob started his consulting company Tooronga Resources, which supplied expert advice and support to many junior and mid-tier companies listed on the ASX, and he was acknowledged as an expert communicator in his field, as indicated in the six eloquent testimonials in support of this nomination supplied by the following senior geologists: Russell Meares OAM, John Horsburgh, Kim Stanton Cook, Tully Richards, Max Rangott and Damon Bird.

Bob had a strong appreciation of a range of geological settings that allowed for the reliable interpretation of important structural controls on mineralisation, at the project and at the prospect scale. This facilitated the useful assessment of potential new mineralisation and extensions to known mineralisation. His geological understanding covered a wide range of commodities including all metalliferous minerals exploration and even coal and gas.

Bob understood how changes to the physical properties of rocks were caused by chemical reactions associated with mineralising systems. This assisted him to identify patterns of alteration and structures in geophysical datasets. He was aware that many anomalous results are not detecting the economic commodity directly, but the associated more abundant gangue minerals such as pyrite or magnetite. He appreciated that drilling is the most reliable method for discovering new mineral deposits, and he focused on geophysics contributing usefully to the optimum design of drilling programmes.

Bob's capacity to communicate effectively to geologists, engineers, managers and accountants has resulted in an increase in the appreciation and implementation of the discipline of geophysics throughout Australia. His reasoned and realistic portrayal of the role and effectiveness of geophysics in many environments and applications did great credit to his profession and to the Australian Society of Exploration Geophysicists.

Bob gave various talks to geological symposia on the application of electrical geophysical methods and published technical papers on his practical experience and results. He was consistently interested in improving the quality of geophysical data acquisition and guided others in this important area of focus. He contributed to society-organised workshops that invited industry leaders to explain the role of geophysics for mineral exploration geologists.

Bob was an early adoptee of 3D inversion packages for resistivity and induced polarisation and realised this meant that geophysicists are no longer constrained by survey arrays designed to produce data to be plotted manually and interpreted by eye. He pointed out that 3D inversion processing means that there is no longer a need to place receiver and transmitter electrodes in a co-linear array. Accordingly, electrode arrays can now be designed to optimise target definition and data collection efficiency. He proposed that the double offset pole-dipole array offered a way to collect large amounts of data efficiently and has superior inversion sensitivity and depth of investigation to standard arrays.

Bob White was an enthusiastic and active Member of the ASEG, having first joined the Society in 1970, and was the ASEG FedEx Treasurer in 2001 and 2002, and an ASEG FedEx General Committee Member in 1999 and 2000. Bob's commercial approach led him to focus on the details of the ASEG's financial management and he brought a stronger sense of discipline and governance to the administration of the Society.

Bob White's innovative research conducted over the period 1974 to 2023 was accepted by the ASEG's History Committee as a significant milestone under the title "Geophysical Confirmation of Non-Linear Electrical Effects in Mineralised Rocks". The initial work tested base metal sulphide cores from Woodlawn and from Captains Flat, as well as an un-mineralised sandstone, with non-linear properties confirmed for those sulphidic materials. Fifty years later, the results of these studies are a current area of active research (in conjunction with Steve Collins, Keith Leslie and Andrew Sloot) to develop a new strategy for sulphide mineral exploration called the Heterodyne Method.

AEGC | Perth2025

Australasian Exploration Geoscience Conference

8 – 11 September 2025

SEPTEMBER 2025

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Geoscience Australia: News

Recent highlights of Geoscience Australia's geophysical programmes, as conducted under the Australian Government's Exploring for the Future (EFTF) project, and in collaboration with our State and Territory survey partners, are summarised below. Details of all current and recently completed programmes and survey locations can be found in **Figure 1** and the tables that follow this section.

Blackall airborne gravity gradiometry survey.

Geoscience Australia (GA), in collaboration with the Queensland Government's Geological Survey of Queensland (GSQ) will soon begin acquisition of up to ~16 000 line-km of Airborne Gravity Gradiometry (AGG) data over the Blackall region of the Adavale Basin, south-western Queensland. This survey is funded by both the Commonwealth and Queensland Governments as part of the Strategic Basins programme and will provide a new generation of data to improve the definition of gravimetric anomalies in the region. In addition, the AGG survey will provide better understanding of the cover sequence thickness and structural trends of the underlying basement geology.

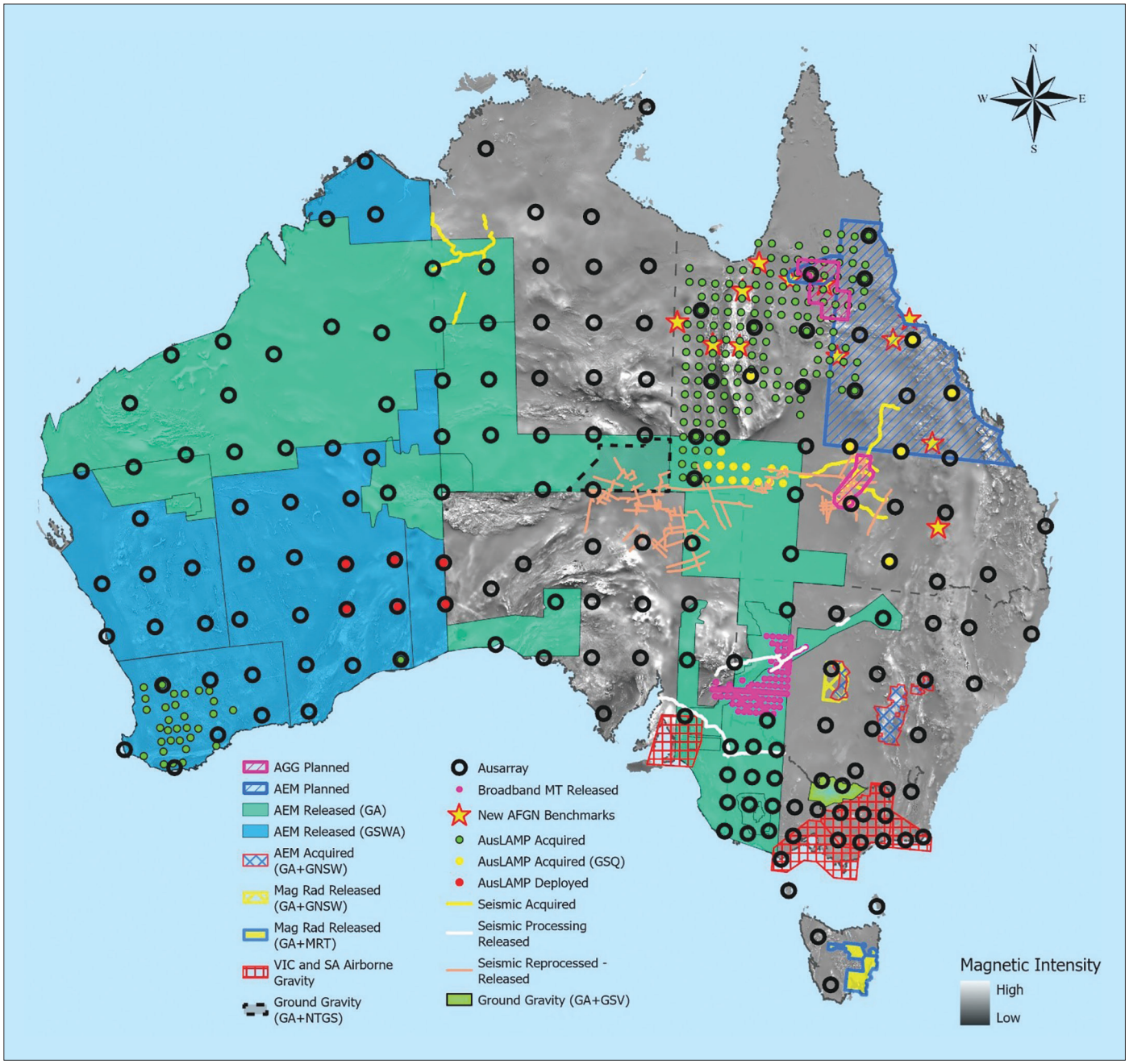


Figure 1. *2021-2024 geophysical surveys – in progress, released or for release by Geoscience Australia as part of EFTF, and in collaboration with State and Territory agencies. Projects that are partially or wholly funded by state government agencies are identified by the bracketed contributors. Background image of national magnetics compilation (first vertical derivative of the reduced to pole magnetics), Geoscience Australia, 2019 (see http://pid.geoscience.gov.au/dataset/ga/144725).*

Acquisition is slated to begin in the coming weeks and will take approximately seven weeks to complete. For further information on this survey please contact Roger Cant, Senior Geophysicist – Geological Survey of Queensland at Roger.Cant@resources.qld.gov.au

Georgetown airborne gravity gradiometry survey.

Geoscience Australia in collaboration with GSQ will soon begin acquisition of up to ~31 000 line-km of AGG data over the Georgetown region of northern Queensland. This survey is fully funded by the Government of Queensland via the New Economy Minerals Initiative (NEMI) and will provide a new generation of data to improve the definition of gravimetric anomalies in the region. In addition, the AGG survey will provide better understanding of the cover sequence thickness and structural trends of the underlying basement geology.

Acquisition is slated to begin in the second quarter of 2024. For further information on this survey please contact Roger Cant, Senior Geophysicist – Geological Survey of Queensland at Roger.Cant@resources.qld.gov.au

Northeast Queensland AusAEM survey (AusAEM Year 1 Extension)

Geoscience Australia, in collaboration with GSQ, will soon begin acquisition of up to ~18 000 line-km of Airborne ElectroMagnetic (AEM) data over northeastern Queensland at 20 km line spacing. These data will extend the existing 20 km spaced AusAEM Year 1 data eastward to the Queensland coast and is fully funded by the Government of Queensland via the NEMI. Information from this new AEM survey will complement, and be integrated with, other major national datasets (*e.g.*, crustal seismic, aeromagnetic, gravity, geology and geochemistry) for improved estimation of cover thickness, definition of basins and investigation of palaeovalleys.

Acquisition is slated to begin in the second quarter of 2024. For further information on this survey please contact Sasha Aivazpourporgou, Senior Geophysicist – Geological Survey of Queensland at Sasha.Aivazpourporgou@resources.qld.gov.au

Shepparton Numurkah ground gravity survey.

Geoscience Australia in collaboration with the Geological Survey of Victoria (GSV), are nearing completion of acquisition on the Shepparton Numurkah ground gravity survey in central north Victoria. This survey is fully funded by the Government of Victoria and is infilling the existing ground gravity network at approximately 500 m spacing along existing public roads and tracks. As part of this survey previous survey nodes and base stations have been included to assist merging of the new gravity stations with existing gravity data.

For further information on this survey please contact Suzanne Haydon, Geophysicist – Geological Survey of Victoria at Suzanne.Haydon@ecodev.vic.gov.au.

Forbes-Dubbo and Yathong airborne electromagnetic surveys (AEM) and Yathong airborne magnetic and radiometric (AMR) survey

Geoscience Australia, in collaboration with the New South Wales (NSW) Government's Geological Survey of NSW, recently completed the acquisition of over 15 000 line-km of airborne AEM data over four blocks within the Cobar-Yathong areas of NSW. This survey was fully funded by the Government of NSW. These data are currently undergoing final quality assurance and quality control checks prior to a release of the data by mid-2024.

Additionally, acquisition of the Yathong region Airborne Magnetic and Radiometric (AMR) survey is also complete. Acquisition was along east–west lines spaced 200 m apart and north–south lines spaced 2 km apart. These data are available at https://pid.geoscience.gov.au/dataset/ga/149105.

For more information about these surveys, please contact Astrid Carlton, Senior Geophysicist - Geological Survey of NSW, at astrid.carlton@regional.nsw.gov.au

NTGS Pedirka ground gravity survey

Geoscience Australia, in collaboration with the Northern Territory (NT) Government's Geological Survey (NTGS), has recently acquired ground gravity in the southeast corner of the NT adjacent to the Queensland and South Australian borders. This survey was fully funded by the NT Government and was helicopter assisted. Gravity data was acquired on a 4 x 4 km grid over an area of 61 370 km^2, with infill in selected areas at 2 km spacing. Approximately 13 000 gravity stations were acquired.

The data are currently undergoing quality assurance and quality control checks prior to final release, however, preliminary data is available via the Northern Territory's Resourcing the Territory website: https://resourcingtheterritory.nt.gov.au/news-and-events/news/2023/preliminary-gravity-data-available-from-ntgs-pedrika-basin-survey.

For more information about these surveys, please contact Tania Dhu, Senior Geophysicist – Northern Territory Geological Survey, at Tania.Dhu@nt.gov.au

Raw data released from northwest Northern Territory seismic survey

Geoscience Australia has recently released raw data from last year's northwest Northern Territory seismic survey designed to image the underexplored Birrindudu Basin and the highly prospective Tanami region (**Figure 2**).

A collaboration between GA and the NTGS, the survey was conducted from 5 August to 20 September 2023 and acquired approximately 900 line-km in the underexplored region between Timber Creek in the north and Tanami in the south.

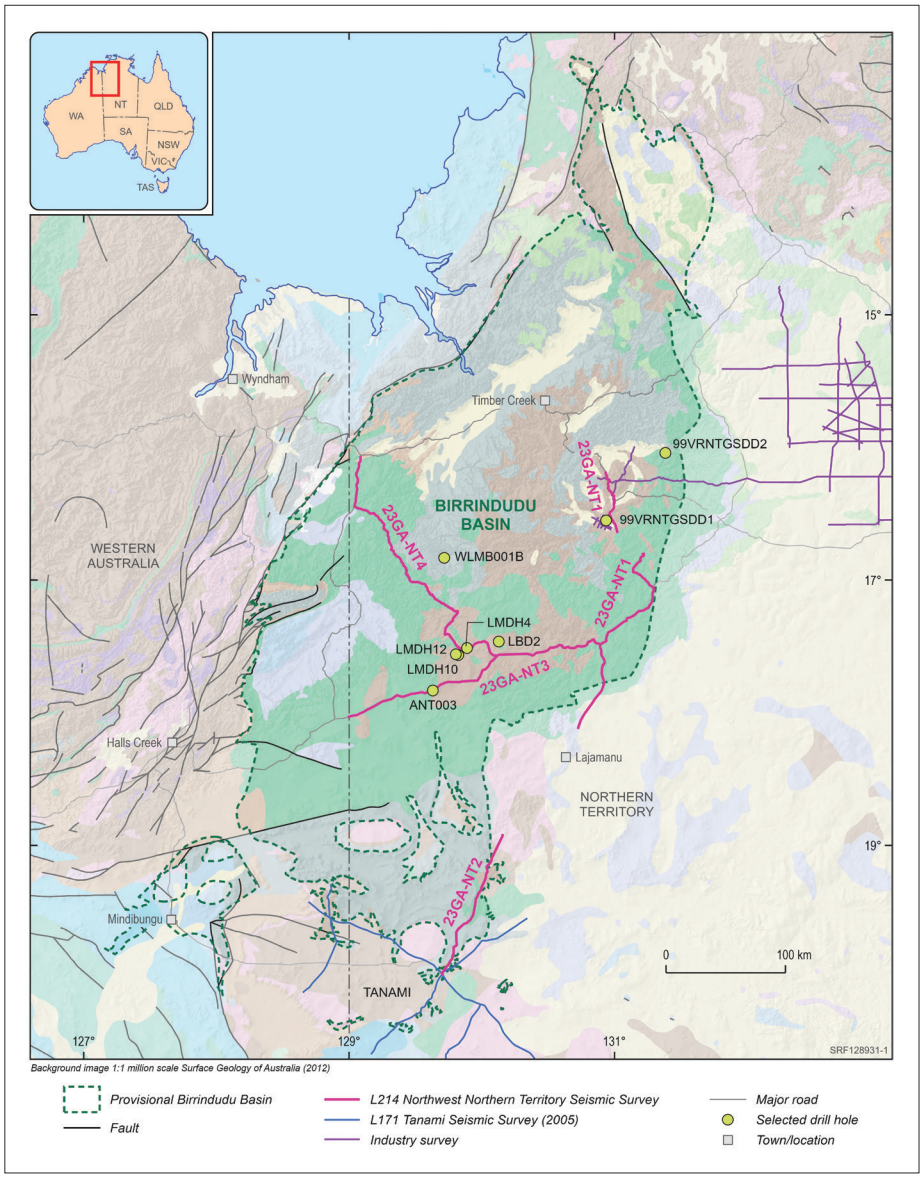


Figure 2. *Provisional outline of the Birrindudu Basin, showing existing drill holes sampled for analysis and the northwest Northern Territory seismic survey (L214). The seismic lines displayed represent the acquired seismic path. Some segments of the displayed lines were not acquired due to restrictions. No data is available in the upper crust under these restricted segments. However, the data in the mid and lower crust is available due to acquisition design and the signal spanning the restricted segments.*

The survey has tripled seismic coverage over the Birrindudu Basin and adjacent regions and builds on previous highly successful work in eastern and central Northern Territory, enabling new perspectives on the geology and resource potential of the region which is considered highly prospective for minerals, geoenergy, geological storage and groundwater resources.

Acquisition occurred at night, which minimised disruption to the community and produced better quality data due to reduced seismic noise from sources such as wind, traffic and daytime line deployment activities.

This seismic release complements the growing suite of data and information being delivered under the Exploring for the Future Officer–Musgrave–Birrindudu project and supports active exploration for critical minerals and energy resources for our transition to net zero by 2050.

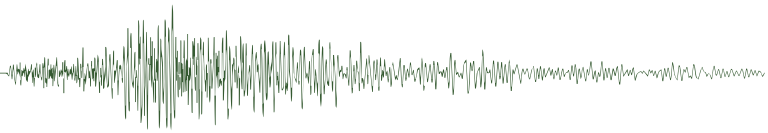
Raw data for this survey are available on request from clientservices@ga.gov.au - please quote eCat#149287. Processed data will be released later in 2024.

Adam Bailey
Geoscience Australia
E Adam.Bailey@ga.gov.au

Swimming lesson drop-off time = geology classroom?

Mikalya Sambrooks wants us all to be pro-active about educating and exciting Australian kids about geology and geophysics

›› See page 27



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 18 March 2024)

The survey details are provided for information only, and on the understanding that the Australian Government is not providing advice. Further information about these surveys is available from Adam Bailey Adam.Bailey@ga.gov.au (02) 6249 5813 or Donna Cathro Donna.Cathro@ga.gov.au (02) 6249 9298 at Geoscience Australia.

Table 1. Airborne magnetic and radiometric surveys

Survey name	Client	Project management	Contractor	Start flying	Line km	Line spacing Terrain clearance Line direction	Area (km²)	End flying	Final data to GA	Locality diagram *(Preview)*	GADDS release
Yathong	GSNSW	GA	MAGSPEC	May, 2023	65 504	200 m	11 399	Sept 2023	Oct 2023	See Figure 1 in previous section	Released by GSNSW and GA https://pid.geoscience.gov.au/dataset/ga/149105

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 (km²)	End survey	Final data to GA	Locality diagram *(Preview)*	GADDS release
Melbourne, Eastern Victoria, South Australia	AusScope GSV DEL WP	GA	Sander Geophysics	TBA	137 000	0.5–5 km	146 000	Expected Jun 2023	~ Oct 2023	See Figure 1 in previous section (GA news)	Late 2023
Kidson Sub-basin	GSWA	GA	Xcalibur Multiphysics	14 Jul 2017	72 933	2500 m	155 000	3 May 2018	15 Oct 2018	See Figure 1 in previous section (GA news)	Dec 2022 http://pid.geoscience.gov.au/dataset/ga/147481
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 E Block: 2 Sep 2018	Received by Jul 2019	195: Aug 2018 p. 17	Oct 2022 https://ecat.ga.gov.au/geonetwork/srv/eng/catalog.search#/metadata/147066
Kimberley Basin	GSWA	GA	Sander Geophysics	4 Jun 2018	61 960	2500 m	153 400	15 Jul 2018	Received by Jul 2019	195: Aug 2018 p. 17	Oct 2022 https://ecat.ga.gov.au/geonetwork/srv/eng/catalog.search#/metadata/147066
Warburton-Great Victoria Desert	GSWA	GA	Sander Geophysics	Warb: 14 Jul 2018 GVD: 22 Jul 2018	62 500	2500 m	153 300	Warb: 31 Jul 2018 GVD: 3 Oct 2018	Received by Jul 2019	195: Aug 2018 p. 17	Oct 2022 https://ecat.ga.gov.au/geonetwork/srv/eng/catalog.search#/metadata/147066
Pilbara	GSWA	GA	Sander Geophysics	23 Apr 2019	69 019	2500 m	170 041	18 Jun 2019	Final data received Aug 2019	See Figure 1 in previous section (GA news)	Nov 2022 https://ecat.ga.gov.au/geonetwork/srv/eng/catalog.search#/metadata/147265
SE Lachlan	GSNSW/ GSV	GA	Atlas Geophysics	May 2019	303.5 km with 762 stations	3 regional traverses	Traverses	Jun 2019	Jul 2019	See Figure 1 in previous section (GA news)	Set for incorporation into the national database in 2023

TBA, to be advised

Table 3. Airborne electromagnetic surveys

Survey name	Client	Project management	Contractor	Start flying	Line km	Spacing AGL Dir	Area (km²)	End flying	Final data to GA	Locality diagram *(Preview)*	GADDS release
Western Resources Corridor	GA/ GSWA	GA	Xcalibur Multiphysics	May 2022	~ 38 000	20 km	760 000	Oct 2022	Dec 2022	See Figure 1 in previous section (GA news)	Mar 2023 https://dx.doi.org/10.26186/147688
Musgraves	GA	GA	Xcalibur Multiphysics	Jun 2022	~ 22 000	1 – 5 km	~ 100 000	Aug 2022	Dec 2022	See Figure 1 in previous section (GA news)	Mar 2023 https://dx.doi.org/10.26186/147688
Upper Darling River	GA	GA	SkyTEM	Mar 2022	25 000	.25 – 5 km	14 509 line km	Jun 2022	Oct 2022	See Figure 1 in previous section (GA news)	Oct 2022 http://pid.geoscience.gov.au/dataset/ga/147267
Darling-Curnamona-Delamerian	GA	GA	SkyTEM	Jun 2022	14 500	1 – 10 km	25 000 line km	Oct 2022	Dec 2022	See Figure 1 in previous section (GA news)	Feb 2023 https://dx.doi.org/10.26186/147585

Table 4. Magnetotelluric (MT) surveys

Location	Client	State	Survey name	Total number of MT stations deployed	Spacing	Technique	Comments
Northern Australia	GA	Qld/NT/ WA	Exploring for the Future – AusLAMP	500 deployed 2016-23	50 km	Long period MT	The survey covers areas of NT, Qld and WA. Data acquired 2016-19 and related model released 2020. Data package: http://pid.geoscience.gov.au/dataset/ga/134997 Northern Australia model: http://pid.geoscience.gov.au/dataset/ga/145233 Data acquired 2020-23. Queensland model update and data release: https://dx.doi.org/10.26186/148633 Queensland time series data release: https://dx.doi.org/10.26186/148978
AusLAMP NSW	GSNSW/GA	NSW	AusLAMP NSW	~300 deployed 2016-21	50 km	Long period MT	Covering the state of NSW. Acquisition is essentially complete with fewer than 6 sites remaining to be acquired or reacquired. Phase 1 data release: http://dx.doi.org/10.11636/Record.2020.011 Phase 1 time series data release: https://dx.doi.org/10.26186/148544
Curnamona Province-Delamerian Orogen	GA/ GSNSW/ GSSA/ University of Adelaide	NSW/SA	Exploring for the Future - Curnamona Cube Extension	~100 deployed 2023	25-12.5 km	Audio and broadband MT	This survey extends the University of Adelaide-AuScope Curnamona Cube MT survey from the Curnamona Province into the Delamerian Orogen. Data was released in May 2023, https://doi.org/10.26186/147904. and related model published Aug 2023: https://dx.doi.org/10.26186/148623
AusLAMP Qld	GSQ/GA	Qld	AusLAMP Qld	19 deployed 2023	200+ km	Long period MT	Adding to the coverage in Queensland undertaken as a part of EFTF. Ultimate coverage planned at 50 km spacing.

Table 5. Seismic reflection surveys

Location	Client	State	Survey name	Line km	Geophone interval	VP/SP interval	Record length	Technique	Comments
Darling – Curnamona – Delamerian	GA	SA, NSW, VIC	Darling – Curnamona – Delamerian deep crustal reflection survey	~1275	10	10/40	20	2D deep/ crustal high resolution vibroseis seismic survey.	This survey will create an image of important crustal boundaries including the structure of the Delamerian margin, which runs through NSW, SA and Vic, separating older rocks of the Gawler Craton and Curnamona Province from younger rocks of the Lachlan Fold Belt (Tasmanides). Acquisition commenced in Jun 2022 and concluded in Aug. Data processing is complete and the raw and processed data are available for download at https://pid.geoscience.gov.au/dataset/ga/147423.
Central Australian basins	GA	Qld/ SA	Shallow legacy data	~2100	Varies	Varies	3-20 sec	2D shallow & deep legacy data, explosive, vibroseis	GA commissioned reprocessing of selected legacy 2D seismic data in Qld and SA, as part of Exploring for the Future, Australia's Future Energy Resources Project. The objective was to produce a modern industry standard 2D land seismic reflection dataset to assist in imaging the subsurface. Reprocessing of the legacy data is complete and the data package is available for download at https://pid.geoscience.gov.au/dataset/ga/148931.

(continued)

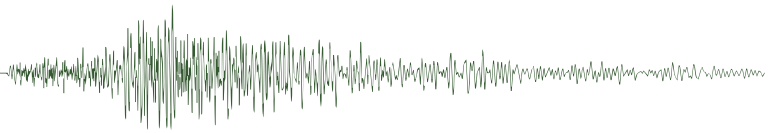


Table 5. Seismic reflection surveys *(continued)*

Location	Client	State	Survey name	Line km	Geophone interval	VP/SP interval	Record length	Technique	Comments
Adavale Basin	GA	Qld	Deep and shallow legacy data		2350	Varies	3-20 sec	2D shallow & deep legacy data, explosive, vibroseis	GA commissioned reprocessing of selected legacy 2D seismic data in the Adavale Basin, Queensland Australia, Data driven Discoveries Initiative. Reprocessing of the legacy data is complete and the data package will be released in the second half of 2023.
Adavale Basin	GA	Qld	Adavale 2D deep crustal seismic survey	1715	10	40	20 sec	2D Deep Crustal/high resolution vibroseis seismic survey	The Adavale deep crustal seismic survey can be combined with the recently released reprocessed seismic data to provide an important modern basin-scale seismic dataset for the Adavale Basin which will facilitate better understanding of the extent of salt bodies within the basin that may be able to store hydrogen, while also improving our understanding of the structural controls and potential for other resources in the basin. Processing of these data are underway, with the data expected for release Q2 2024
Northwest Northern Territory	GA/ NTGS	NT	Northwest Northern Territory deep crustal seismic survey	900	10	40	20 sec	2D deep crustal/high resolution vibroseis seismic survey	The Northwest Northern Territory (NWNT, L214) Seismic Survey was designed to correlate well-characterised areas of the basin with adjacent gravity lows to the west and to the complex geology of the Tanami Region to the south, in order to better characterise the regional crustal architecture and identify concealed sedimentary basins to better understand the energy, minerals and groundwater potential across the region. Processing of these data are underway, with the raw data package available at https://pid.geoscience.gov.au/dataset/ga/149287 For more information on the EFTF Officer–Musgrave–Birrindudu project please refer to https://www.eftf.ga.gov.au/officer-musgrave-birrindudu

Table 6. Passive seismic surveys

Location	Client	State	Survey name	Total number of stations deployed	Spacing	Technique	Comments
Australia	GA	Various	AusArray	149 temporal seismic stations	~200 km spacing	Broad- band ~18 months of observations	The survey covers all of Australia to establish a continental-scale model of lithospheric structure and serve as a background framework for more dense (~50 km) movable seismic arrays. Deployment of this national array was completed in June 2023. Data will be acquired over 12-18 months.
Northern Australia	GA	Qld/NT	AusArray	247 broad-band seismic stations	50 km	Broad-band 1-2 years observations	The survey covers the area between Tanami, Tennant Creek, Uluru and the WA border. The first public data release of the transportable array was in 2020. See: http://www.ga.gov.au/eftf/minerals/nawa/ausarray Various applications of AusArray data are described in the following Exploring for the Future extended abstracts: • AusArray overview: http://pid.geoscience.gov.au/dataset/ga/135284 • Body wave tomography: http://pid.geoscience.gov.au/dataset/ga/134501 • Ambient noise tomography (including an updated, higher resolution model for the Tennant Creek to Mount Isa region): http://pid.geoscience.gov.au/dataset/ga/135130 • Northern Australia Moho: http://pid.geoscience.gov.au/dataset/ga/135179
Australia	GA	Various	AusArray, semi-permanent	12 high-sensitivity broad-band seismic stations	~1000 km	Broad-band 4 years observations	Semi-permanent seismic stations provide a back-bone for movable deployments and complement the Australian National Seismological Network (ANSN) operated by GA, ensuring continuity of seismic data for lithospheric imaging and quality control. Associated data can be accessed through http://www.iris.edu
AusARRAY Victoria Collaborative Project	GA/GSV	Vic	AusArray Victoria	21 temporary seismic stations	~100 km	Broad-band ~12-18 months of observations	Data acquired from the movable array sites will add to the scientific understanding of the Earth's lithosphere on the national and regional scale. Phase 1 of the deployment (~100 km) was undertaken in Mar 2023.

Table 7. Survey technical requirements

Survey type	Author	Contributors	GA Release
Magnetics, radiometrics and horizontal magnetic gradiometry	James Goodwin	Brian Minty, Ross Brodie, Mark Baigent, Yvette PoudjomDjomani, Matt Hutchens with acknowledgements to Peter Milligan, Laz Katona and Mike Barlow	Mar 2023 http://pid. geoscience.gov.au/dataset/ ga/147457

Geological Survey of Western Australia: Deep-crustal seismic survey 2023–24, data acquisition complete

Data acquisition for the Geological Survey of Western Australia's 2023–24 deep crustal seismic survey programme (*Preview* 226) was completed in February 2024.

The surveys were conducted by HiSeis Pty Ltd along three lines in the Southwest and Midwest of Western Australia (**Figure 1**) with the following survey configuration:

- Source: 3 x INOVA AHV-IV Vibroseis trucks @ 40 m vibration point spacing, 1 x 24 s sweep
- Receiver: 1600 x INOVA Quantum 5 Hz nodes @ 10 m spacing (nominal 200-fold), 20 s listen time.

Data processing is in progress for anticipated release of final data from line 23GSWA-SW1 in May 2024. A preliminary pre-stack time migration image of the data was released in March 2024. The SEGY file is available from GSWA's MAGIX and GeoVIEW.WA platforms by searching for MAGIX registration number 72447.

Data from the Midwest lines 23GSWA-MW1 and 23GSWA-MW2 should be available towards the end of July 2024.

Subscribe to the GSWA newsletter mailing list to receive advance notification of release dates.

David Howard
Geological Survey of Western Australia
E Geophysics@dmirs.wa.gov.au

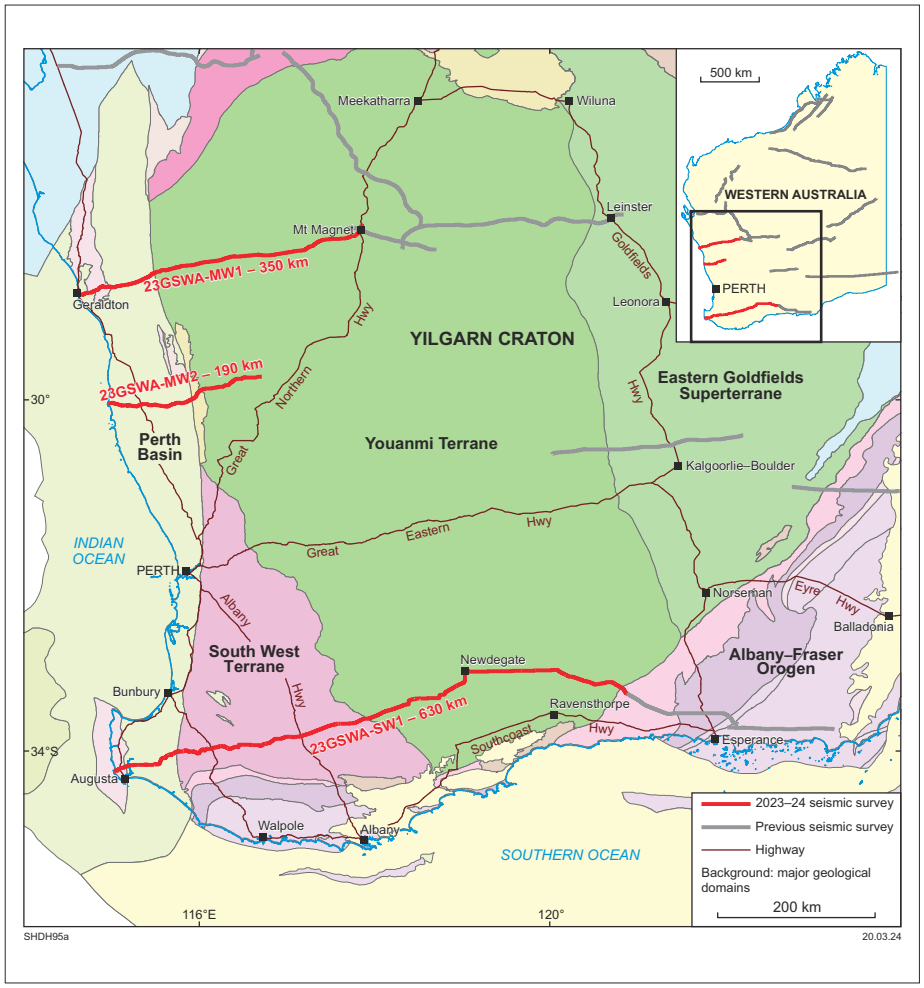
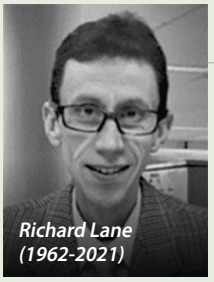


Figure 1. *Location map of GSWA deep crustal seismic surveys 2023–24.*


Richard Lane (1962-2021)

Richard Lane Scholarship 2024

An ASEG Scholarship has been established to support geophysics Honours and Masters students and to commemorate the life and work of ASEG Gold Medal recipient Richard Lane.

The scholarship is open to all BSc (Hons) and MSc geophysics students at an Australian University and consists of a grant of $5000 to the best ranked student for the current year. Ranking will be based on a 200 word discussion, overview of a geophysics project and on an academic transcript. For 2024 we acknowledge and thank Jayson Meyers and Resource Potentials Pty Ltd for the initial concept and ongoing donation.

All Honours (BSc) and Masters (MSc) students with focus predominantly in exploration geophysics are invited to apply.

The closing date is 10 May 2024 and the application details and form are at www.aseg.org.au/foundation/richard_lane

The scholarship is an annual event and donations to support the continuation of this scholarship are sought from institutions, companies and individuals. Information on donations via the ASEG Research Foundation can be found at www.aseg.org.au/foundation/donate Please mark donation specifically "Richard Lane Scholarship".

Mineral Resources Tasmania: Effects of infrastructure on geophysical exploration

In 2020 Mineral Resources Tasmania (MRT) commissioned Mitre Geophysics to investigate the impact of conductive infrastructure, particularly power lines, pipelines, railways and wind farms, on geophysical exploration. The resulting report, "Effects of Infrastructure on Geophysical Exploration" by Kate Hine and John Bishop has now been released by MRT as Geophysical Contractors Report (GPCR) 2021_03.

In addition to a review of the limited available literature, the report is based on data from several recent geophysical surveys and discussions with experts, together with the considerable personal experience of the authors. The cases presented include examples from NSW, Idaho, Denmark, Germany and western Tasmania, covering most techniques currently employed in mineral exploration.

The findings are summarised in **Table 1**. Among the most notable are that wind turbines and associated transmission cables significantly degrade airborne EM data for at least 150 m distance from the cables, sometimes up to 600 m, and effectively preclude high-resolution airborne surveys of all types. Surface EM and IP methods are also affected (see for example **Figure 1**), even if the infrastructure is not energised.

The report should be useful in formulating land use decisions, in the context of Australia's trajectory towards electricity generation technologies requiring many times greater extent than the current footprint, balancing this against the imperative to avoid degrading significant prospectivity. It may be downloaded from the MRT website: https://www.mrt.tas.gov.au/webdoc2/app/default/document_domrept_detail?id=123829

Mark Duffett
Mineral Resources Tasmania
E mark.duffett@stategrowth.tas.gov.au

Method	Pipeline/railway	Powerlines	Wind farm
Airborne EM	~200-600m wide, strong, EM response along the pipeline corridor, masking the response from basement conductors	Effect depends on the type of powerline. Possible effects up to 500m (even to 1000m) distant.	Survey not feasible due to flight path limitations and interference from buried cables.
Induced Polarisation	Data ok >300m away from pipe/rail	Effect is highly dependent on the type of powerline and ground conductance. Often possible unless SWER*.	Large (up to 400m wide) very strong IP anomalies are coinciding with buried cables, i.e., data quality too poor except where tower spacing is very broad.
Resistivity	Localised response	Localised response	Localised response near cables/towers
Aeromagnetics/ radiometrics	If present, response easily filtered from the data	Response easily filtered from data.	Wind towers preclude suitable flight path and generate strongly localised anomalies
Ground/drone magnetics	No known cases, probably a localised anomaly	No known cases, probably a localised anomaly	No known cases. Aeromag shows strong ~200m wide responses associated with towers—similar likely from drone and ground surveys.
Ground EM	No known cases	Generally speaking, no. Some local scale distribution lines are okay (unless SWER*), but regional transmission lines are not.	No known cases, but cable responses observed in airborne EM is likely also to be problematic in-ground EM.
Downhole EM			No known cases

* Single wire earth return

Table 1. *Effects of electrical infrastructure on geophysical exploration.*

Reference

Earner, N., 2020, 19 May 2020 Boda Drilling Update, Project Summary and Proposed Program, Alkane Resources Ltd ASX announcement.

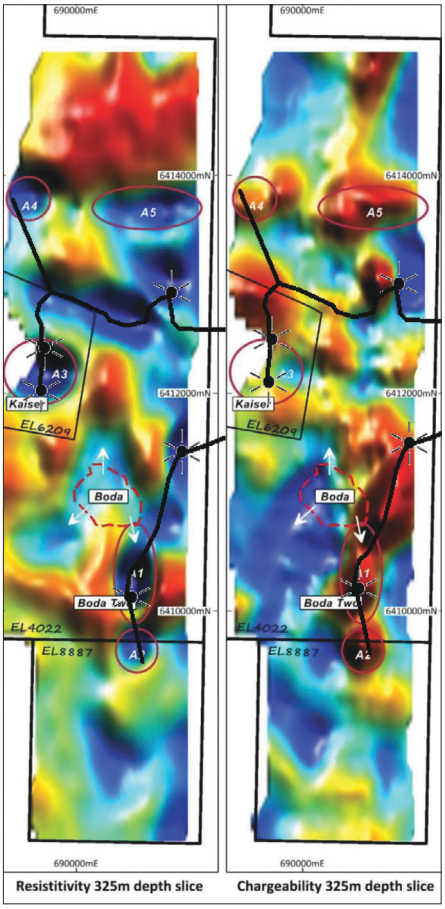


Figure 1. *Resistivity and chargeability (at 335 m) depth slices from a post-wind farm IP survey, with buried cables and wind towers superimposed. There is a strong spatial association of cables with chargeability responses and, to a lesser extent, resistivity anomalies. Modified after Earner 2020.*

Geological Survey of South Australia: Legacy ground gravity, to relevel or not to relevel - an informal spiel

An ongoing task for geophysicists at the Geological Survey of South Australia (GSSA) is to maintain a database containing gravity observations acquired in SA. For a variety of reasons, we are obliged to house the data as we receive it. So, for example, if explorer A asks for the public domain 2004 gravity survey conducted by contractor B for company C, we hand it over as it is. Or, as is more common now, explorer A downloads the data directly off SARIG. The gravity data as we receive it is digitally paperclipped to the PDF containing the history of a tenement.

So, what happens if (say) during a survey a gravity operator or processer writes down a base station value incorrectly and this carries over to the gravity reduction and the Bouguer Gravity looks fine? It means that when explorer A downloads the survey from SARIG, they are downloading data that has some issue with it. And from a strict Government auditor's perspective that's okay. The data is evidence that money was spent on a tenement. We don't modify someone else's data. In a very bureaucratic and government-paperwork sense: all is as it should be.

But there's a problem. We'd much rather distribute data that will help explorers make the correct exploration decisions. When it comes down to it, our job is to boost the economy of the State, and we're more likely to succeed in doing that if the data that people are using to make economic decisions are correct.

The problem becomes apparent when the geophysicists at the GSSA undertake another one of their duties: creating a seamless image of the Bouguer gravity of South Australia. We can load down all the gravity data from our database and work our way through Katona (2017)'s Supervised Variable Density Gridding methodology. We're working through this process again now, and are starting to revisit some of the older surveys to produce a "more correct" image.

We create a statewide image and we see that some areas of gravity stand out like plateaus, and the sides of the plateaus coincide with the boundary of the survey. Coincidence? Generally, no. But we need to be careful. For example, does a newer survey need relevelling or do the older surveys around it need attention?

I'm not going to present any of the actual data in this short news piece, and I request the reader's imagination for the following. Imagine these scenarios:

- A gravity survey where the observed gravity values are noticeably different to neighbouring values,
- A gravity survey where the elevation data are noticeably different to DEM/SRTM/surrounding values,
- A gravity survey where both observed gravity and elevations are noticeably different to surrounding values,
- A discrete portion of a survey is noticeably different from the rest of the survey,
- A big red or blue dot on a gravity map, and
- Gravity surveys conducted along a road/s.

Often the first time an issue is noticed is when looking at the Bouguer Gravity of a group of surveys, such as a state grid. The Bouguer Gravity is calculated using the observed gravity and the elevation (and the latitude) of the measurement point. These are the quantities that I'll analyse in the first instance to quantify any adjustment.

If the issue is with the observed gravity, it becomes necessary to also revisit other factors such as the time of the measurement and the base station used to level the survey. I've not yet found issues with measurement times, but I've identified two instances of base station issues in historical surveys.

One survey we noticed had observed gravity values approximately 10 mGal higher than surrounding points. The base station used is recorded in the report and has the value of A mGal. Searching for the same base station in the database resulted in another value, B mGal. The difference A minus B is 10 mGal. After subtracting 10 mGal from the observed gravity and re-gridding the survey with its neighbours, we observed that the survey blends in seamlessly.

Occam's razor states that the simplest solution is probably the correct one, so I would suggest that a typo was made, and fixing the typo fixed the survey. This illustrates the value of a survey reports containing the base station information. However, we're looking at older surveys here, where survey reports are rarely available.

Even without a survey report, additional research can yield satisfactory results. In a second survey we had to examine the data, determine which point was the base station (it's usually the first point) and compare its value with other mentions of the base station in other reports/surveys. For this second survey, a value of 7.096 mGal was subtracted from all the observed gravity values. This difference was the difference between the base station value in the data, and the value of a gravity station at the same spatial coordinates on SARIG. We've no idea why they are different – maybe it was a typo again – but as the survey stood out by approximately 7 mGal this was another simple "evidence-based" adjustment. Again, the relevelled survey now blends in with the rest of the state.

Relevelling surveys is therefore easy enough, but we need to consider how we manage the data on our database and what our customers receive when they request data.

Without going into a discussion on the pros and cons of handling the data in different ways, here is the resolution on which we have landed. Raw gravity data files – that is gravity data as we receive from companies in the first place – are attached to open file envelopes (documents containing the entire history of a mineral tenement) and are therefore available to stakeholders unedited and untouched. Our database contains both the unlevelled and the relevelled data. There is an entry for the unlevelled data and a separate entry for the relevelled data. If the unlevelled data is public domain, we can set it without an Export Quality tick, meaning the survey doesn't find its way to the spatial layers on SARIG. The relevelled data has the Export Quality ticked on, meaning the data becomes a visible part of the point dataset on SARIG.

In essence, the data is available twice. The original company data attached to the envelope, and a relevelled dataset incorporated into the statewide point dataset. Does this make it confusing for people using the data? Possibly. If anyone has questions about the data that they are looking at remember, if it is paperclipped to a pdf then we definitely haven't modified it.

So, what about those other scenarios? Where both the elevation and gravity are out? In the instance where this happened, we have no report and have resorted to comparing nearby points and elevation models. I'm loath to relevel a gravity survey without robust justification, but in this one case I've looked at empirical evidence (*i.e.*, nearby points) and calculated average differences and used that to relevel the survey. When the Bouguer Gravity is calculated and gridded we get an improved dataset, but it's not perfect. There are still busts. In this case we'll probably just mute the survey, that is, switch it to "grid flag = no", so the data is available but doesn't get included in the state grid.

Here's another one. This one is from 1991. The gravity is out by about 8 mGals and the elevation is out by approximately 1 m but when we dig up the original file we find that it doesn't include observed gravity values. There are Bouguer Gravity values calculated for crustal density models at 2.20, 2.40, and 2.67 grams/cc. So now we need to back calculate the observed gravity – which we can do in an optimisation exercise with the three Bouguer gravities and numerous assumptions about which equations were used – and then reload and check, a process I'm informally dubbing back-un-relevelling. This is a work in progress.

Regarding discrete red and blue dots, these either occur as a single discrete point of anomalous gravity, or they occur where two traverses cross and don't match at the crossover. If we had the funding, I'd take our CG5s and DGPS gear out and visit all these points. For the moment, I've discreetly muted some of those points and have crossed my fingers that I haven't just hidden the world's largest super deposit hosting every possible commodity ever. If you'd like to look at these points, I recommend downloading the current state grid because it will be replaced with a new version soon.

Regarding roads, gravity surveys along roads are great. You can plot them up and model a fault or whatever and that's fine. In 1D they're OK. When we view them top down on a 2D map it is generally difficult to see gravity and we just see a line of disturbance correlating to the position of a road. Again, we don't delete them from the database – they'll still be attached to pdfs – just when we're making the state grid we'll (generally) leave them out, or grid them at a lower resolution so they "blend in".

And that's about it. The 2024 SA gravity release and report are well underway.

Ngaityalya
(Kaurna, thank you)

Philip Heath
Geological Survey of South Australia
E Philip.Heath@sa.gov.au

References

Katona, L.F. 2017. Gridding of South Australian Ground Gravity Data, using the Supervised Variable Density Method. Report Book 2017/00012. Department of the Premier and Cabinet, South Australia, Adelaide.

SARIG: https://map.sarig.sa.gov.au/

Geological Survey of Victoria: News

Structural modelling of the Portland Trough

The Geological Survey of Victoria (GSV) has completed structural modelling of the Portland Trough in the southwest Otway Basin, using a combination of geophysical data and geological modelling methods (Boyd *et al*. 2024). The Portland Trough is a subsurface structural depression, and the new study suggests the trough may be significantly deeper than previously determined. A new structural feature, the "Deep Portland Trough", has implications for energy recovery, hydrogen and gas storage, and geothermal energy potential in the area.

Download the report (**Figure 1**) and associated data from Resources Victoria's Earth Resources Publications website.

Central-western Victoria regional fault data package

The GSV has released a new compilation of fault interpretation data for central and western Victoria (**Figure 2**). This is the first update to regional scale Victorian fault interpretations in 25 years. Positions of major crustal-scale structures have been re-interpreted, constrained by recent seismic reflection and enhanced potential field geophysical data. The new interpretation highlights potentially prospective regions not previously recognised (Skladzien and Cayley 2023).

The report and data package can be accessed via the Earth Resources Publications website. The fault data can also be viewed and downloaded via Resources Victoria's free online mapping program – GeoVic - by adding the following layer from the Data Layers Menu: *Geophysics>Interpretations>Geophysics 250K>Regional geological faults of Central and Western Victoria.*

Suzanne Haydon, Phillip Skladzien, Matt Boyd
Geological Survey of Victoria

E Suzanne.Haydon@deeca.vic.gov.au

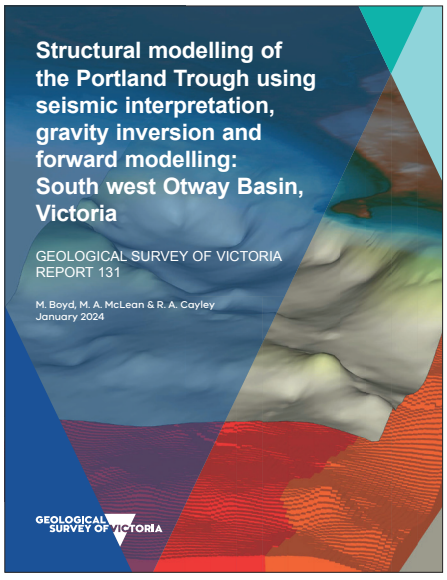


Figure 1. *The report cover highlights the Portland Trough in a 3-D perspective view of the basement, above the discretised model (shown in red/orange).*

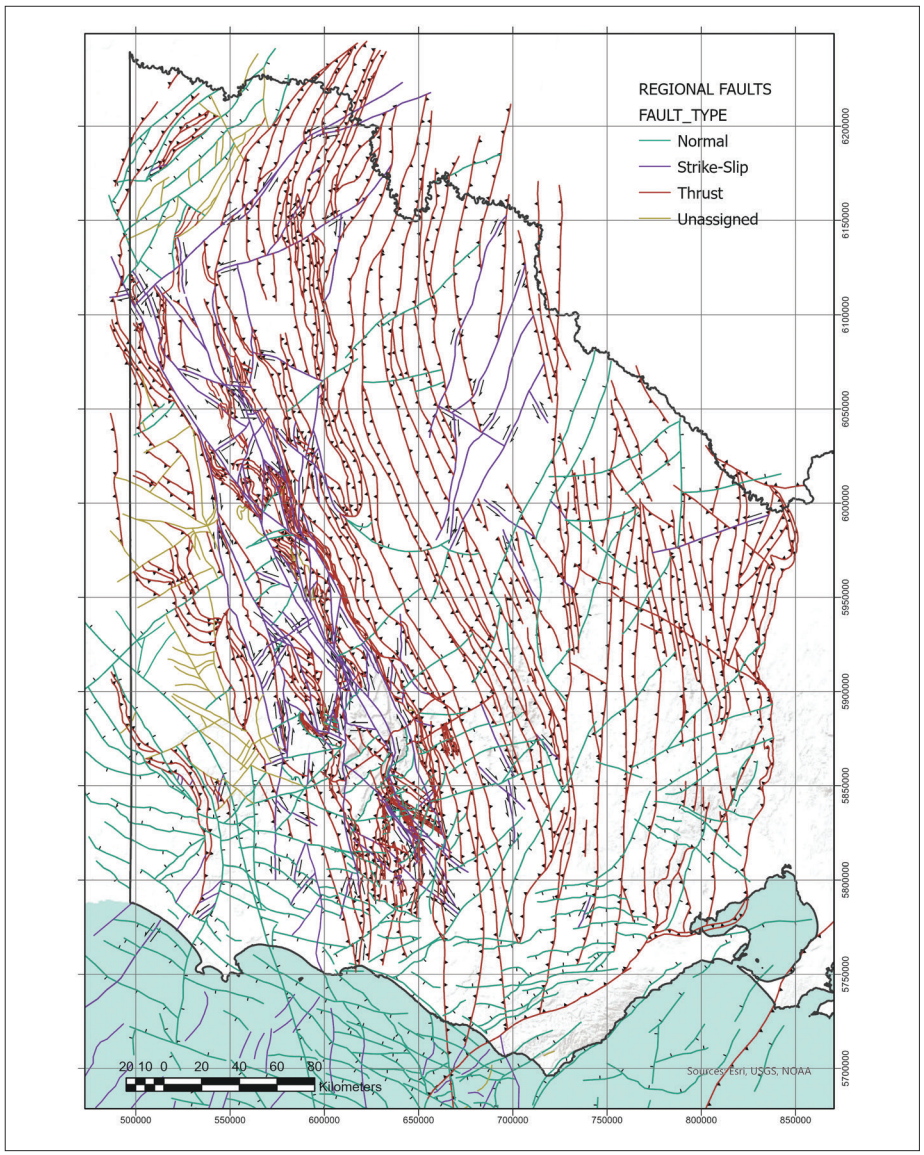


Figure 2. *Regional faults across western Victoria, coloured by fault type.*

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Boyd, M., M.A. McLean and R.A. Cayley. 2024. Structural modelling of the Portland Trough using seismic interpretation, gravity inversion and forward modelling: South west Otway Basin, Victoria. Geological Survey of Victoria Report 131. Department of Energy, Environment and Climate Action, 38 pp. www.gsv.vic.gov.au/rid/171956

Skladzien, P.B. and R.A. Cayley. 2023. Central-Western Victoria Regional Fault Data Package, Version 1.0. Geological Survey of Victoria Technical Record 2023/3. Geological Survey of Victoria, 20 pp. www.gsv.vic.gov.au/rid/171947

Southern African Geophysical Association

1– 4 OCT 2024

WINDHOEK

#18SAGA2024

The countdown to the Southern African Geophysical Association's 18th Biennial Conference & Exhibition has begun! On the back of the expansion of SAGA's geographical reach in 2022, this year, Namibia hosts the prestigious event, materially enabling greater international collaboration and driving growth across the region.

OUR STORY

Geophysical Collaboration for Growth

The new SAGA brand reflects our evolution from the South African Geophysical Association, founded in the 1970s, to one that embraces a broader geographical footprint and community.

The new brand elements encapsulate our core values of collaboration, growth, innovation, and community. It is important for us to maintain a connection with our heritage, which is why the new brand incorporates elements from our origins, with a significant new addition: the acacia tree.

This emblematic feature, an inseparable part of the Southern African landscape, symbolizes growth and connectedness spreading across the region whilst depicting our foundational roots in South Africa.

COLLABORATIVE GEOSCIENCE FOR CRITICAL SUPPLY

Convergence of the Society of Economic Geologists' (SEG) Annual International Conference with SAGA 2024 at the Windhoek International Convention Centre will enable close engagement between the disciplines of economic geology and geophysics. The consecutive events will provide opportunities to explore new partnerships and harness synergies as we meet under the theme of *Collaborative Geoscience for Critical Supply.*

As the impacts of the 4IR increase, improving operational efficiency, effectiveness & cost saving through digital transformation, key critical supply challenges remain. Materials needed to develop & power contemporary technologies, and sustainability, in areas such as water, are critical to not only sustaining life, but also to enable most industrial processes.

As we convene for SAGA 2024 in one of the top 10 most arid countries globally, we set our focus on the management and preservation of precious water resources. Namibia has a strong record of success in the application of remote sensing & geophysical technologies to explore for subsurface mineral & energy resources, & managing and preserving groundwater. Critical materials supply also directly impacts sustainable living. SAGA 2024 will showcase contemporary & innovative solutions to meet growing discovery & extraction demand as well as the necessary countermeasures. With globally increasing industrial activities, the challenge of achieving Net Zero necessarily accelerates, with geoscientific solutions such as underground carbon storage significantly mitigating the climate impact of our ever-growing demand.

THE BIG PICTURE

In an exciting development for the geoscience community, the SAGA Conference will seamlessly follow the SEG (Society of Economic Geologists) Conference in Windhoek, offering attendees a comprehensive exploration of geoscience research and applications. The SEG Conference, scheduled from 27th to 30th September, will precede the SAGA event, taking place from 1st to 4th October. Highlighting this collaboration, the 1st October will feature an overlapping day of workshops, fostering an unprecedented opportunity for knowledge exchange and networking across both conferences.

This back-to-back scheduling not only provides a deep dive into exploration, energy, mining, and engineering geophysics but also ensures a rich dialogue on global topical issues related to both above- and below-ground activities. Delegates attending these consecutive events in Windhoek will witness a vast body of research and innovation, promoting discussions and collaborations poised to shape the future of geoscience. For more details on the SEG Conference, visit the SEG 2024 website, and prepare to engage deeply in a forum dedicated to collaborative geoscience for critical supply.

Apart from the expected commercial, technical & social conferencing, this year the event will provide a platform for delegates to schedule direct business to business engagements, facilitating growth & establishment of critical networks.

OUR VENUE & SCHEDULE

The Windhoek International Convention Centre is the central point for our exploration of Namibia & the greater geophysics community this year. Situated less than an hour's drive from Hosea Kutako International Airport, the Convention Centre will accommodate our delegation to ensure maximal engagement during the formal proceedings. As the capital of Namibia, Windhoek is also a key centre for national government, academia & industry, with the event bringing together various demographics across numerous industry sectors.

Namibia has a world-renowned treasure-trove of geological sites, with a dynamic mineral exploration community who have been early adopters of geophysical technology. Due to its central location within the country, Windhoek is an ideal springboard for numerous exotic excursions in and around the country to appreciate the extensive natural and geological splendour which the region has on offer.

An integral component of the event is the exhibition & trade show which boasts comprehensive representation from the global geophysical community. Delegates will have first-hand access to view cutting edge technology demonstrations, meet with original equipment manufacturers & agencies, expert consultancies & governments, hosted within our tailormade exhibition hall and breakaway technology sessions. Exhibits will include software & services providers, remote sensing, airborne, ground & sub-surface exploration technologies.

If there is a technology or relationship you need to take your profession to the next level, it will no doubt be found in this arena. Exhibitors showcase their products and services to the largest & most diverse audience of African geophysicists – book space today by contacting exhibitions@sagaconference.co.za

SEG Workshops

SEG Conference & Exhibition

SEG & SAGA Workshops
1 October

SAGA Conference & Exhibition
2 – 4 October

EXHIBITION & TRADE SHOW

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SENSATIONAL FIELD TRIPS

The breathtaking landscape of Namibia provides a feast for geophysicists as the Earth's crust is laid bare. From Windhoek, one can proceed in any direction & find oneself amongst a spectacular array of rock formations, dunes, canyons, mineral deposits & mines.

WORKSHOPS

Partnership with SEG 2024 brings rare opportunities to collaborate across the geosciences – most especially during our overlap workshop day on 1 October. The delegations will meet to discuss a wide variety of topics spanning economic geology, geophysics & their applications to mineral systems exploration. Other workshops will focus on various themes from seismic to electromagnetic & potential field methods, with software suppliers showcasing their latest functionalities.

Web www.sagaconference.co.za

Mail info@sagaconference.co.za

Phone +27 73 435 0886

Canberra observed

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

This will be my last regular column of *Canberra observed* in *Preview*. After 25 years of contributing to this remarkable publication, it is time to retire. My association with the magazine started in October 1999 when I was appointed as Editor, and continued when Ann-Marie Anderson-Mayes and John Theodoris were Editors from 2012-2014, and when Lisa Worrall took over from then until now.

It is a remarkable publication, and I would particularly like to thank Lisa who has led it from strength to strength. Members still want to read hard copies of articles about geophysics and interesting geophysicists. It's the people who matter and she has always focused on them.

What has changed over the last 25 years?

In 1999 the ASX All Ords index was 3258, the market capital of the resource sector in the top 150 companies was $81b and there were 17 resource companies in the top 150 in the ASX. BHP was the leader of the pack.

In 2024 the All Ords index was 8000, the market capital of the resource sector in the top 150 is $566b and there are 25 companies in that segment. BHP is now the largest company registered on the ASX and has eclipsed even the big four banks.

The CPI (if you think it is relevant) has doubled from 73 to 136, compared to the market capital of the resource companies, which has increased by a factor of seven ($81 to $566b)!

The resource companies are even more important to the Australian economy now than they were in 2000, particularly in the minerals sector.

Is gold the best

Gold remains the standard bearer. In 2000 it was US$280/oz and it is now US$2171/oz. Throughout the last five years the annual investment in gold exploration has been over one billion $A.

Or is iron ore better?

In 2000 iron ore was US$25/t in 2024 it is about US$120/t. An increase by a factor of five. Fortescue benefitted hugely from the increased demand. Its market capital increased from $1.7b in 2000 to $81b in 2024. Another good investment.

Then there is volatility of nickel and lithium

The need for minerals to make batteries caused volatility in the last few years. Nickel rose from US$8600/t in 2000 to $25 800/t in 2022 before dropping to US$17 000/t in 2024. Lithium gets the prize for volatility. In 2000 lithium carbonate was priced at about US$5000/t. In 2022 it rose to US$20 000/t and by 2024 it had fallen to US$13 000/t.

Very difficult to plan for future mining.

Demand for thermal coal declines

The demand for thermal coal has recently declined from a peak of $US430/t in 2022 to US$120 in 2024. For the previous twenty years the price has oscillated around US$100/t.

As more renewable energy sources are developed, it is expected that the demand for thermal coal will continue to decline. However, the coal used for steel making is expected to remain constant for the next few years.

Decline in fossil fuel exploration in last 25 years

Offshore petroleum exploration has been declining for the last ten years from a peak of $1.1b in the June quarter of 2014 to $89m in the December quarter 2023.

Onshore has been better with the total for the December quarter increasing to $175m from a low of $75 m in 2015.

How much of this is in the Beetaloo Basin I don't know. It has always seemed very strange to me that anyone would want to explore for gas in a Palaeoproterozoic basin over 1600 million years old. One of the Beetaloo Basin's fracking corporations could be forced to return millions in wrongful public funding. It received $28.7m for "research and development", when the scheme forbids funds being used for gas exploration.

The situation with coal is that exploration is mainly limited to expanding mines that already exist.

The big problem with fossil fuels in Australia is that we are still developing new coal and gas fields when, to meet our carbon emissions targets, we should be closing them down.

The Government seems to be behaving paradoxically. On the one hand there is a policy of introducing renewable resources and on the other we are opening up new fossil fuel resources.

It does not make much sense.

Australian Government to invest $22 million in projects to grow Australia's critical minerals industry

On 8 January 2024 Minister for Resources Madeleine King announced that the Government was funding three projects from members of the Critical Minerals Research and Development Hub. These are: the Australian Nuclear Science and Technology Organisation (ANSTO), the CSIRO, and Geoscience Australia.

ANSTO has been awarded $13.9m for a research project to accelerate the discovery, extraction and processing of rare earth elements from lower grade deposits.

CSIRO has been awarded $5.2m to develop intellectual property to support downstream industries to produce high purity metals and materials, extending

value chains for lithium, rare earths and supporting value adding to tungsten ores and refractory metals.

Geoscience Australia has been awarded $2.7m for research into development opportunities of a domestic industry for critical minerals such as gallium, germanium and indium, which are often byproducts from processing primary commodities such as bauxite and zinc.

Critical minerals and rare-earth metals are commonly used in high-tech applications in quantum computing, batteries used for renewable energy technologies, precision medical equipment, and for advanced weapons' seekers and guidance equipment. Some of the more common critical minerals found in Australia include aluminium, copper, cobalt, lithium, indium, magnesium and manganese.

The funding follows the October 2022 announcement of the establishment of the Critical Minerals Research and Development Hub.

In June 2023 the government released its Critical Minerals Strategy to review Australia's critical minerals list which was designed to support the sector's growth and ensure Australia gets a share of the global minerals supply chain.

For more information go to https://www.minister.industry.gov.au/ministers/king/media-releases/boost-critical-minerals-and-rare-earths-research.

New accord for Australian universities

A new plan for the future of Australian Universities was released on 28 December 2023. (https://www.education.gov.au/australian-universities-accord). The 382-page report and the 32-page summary contains lots of good words and policies.

Basically, it states that our universities are underfunded in both the research and teaching components, and have been for many years. If we want 80% of our population to participate in tertiary education in the future, then there will have to be a huge increase in government funding (how many nuclear submarines?). The two big questions are: do we really need 80% of our population challenged by tertiary education? And how are we going to fund the sector in the future?

These questions are too big to consider in this column, but I recommend that the ASEG's Education Committee have a good look at the options and do a bit of lobbying.

I will just say that I don't think a tax on overseas students is a good idea. If we want to attract good students from overseas they should pay for their education, but to levy a tax is unfair on the most successful universities, the ones who are able to attract these students.

Just like exploring for resources, it's all about money!!

Swimming lesson drop-off time = geology classroom?

On Wednesday 19 March I attended a careers expo at one of my local high schools on behalf of the Australian Society of Exploration Geophysicists (ASEG) WA Branch.

I was nervous before the expo, not because I'm shy, but because I placed a huge weight on my own shoulders to leave a lasting positive impression on at least one student to consider a career pathway into geophysics, and I was worried no one would come up to me, but they did!

The hardest question I had to answer was "how do I become a geophysicist?".

I couldn't guarantee a Year 10 student that there would even be a clear pathway for them to become a geophysicist in two or three years when they are ready to head to uni - which is kind of sad and scary.

All I can think to do to counterbalance the decline in students taking geophysics in a tertiary setting is to increase positive awareness and visibility to students before they get there. High school career expos, university open days and other outreach events provide the perfect opportunity for this, but there are other ways to spread awareness.

Do you have kids, or do you know someone who has kids? A fellow geophysicist recently shared that for years she had been starting conversations on the five-minute drive to drop her kids and their friends off at swimming lessons. Prompting them with questions like "do you know where the materials in your ipad come from?". Those kids know what geology is now and it's probably because of those five-minute conversations. So, if you can't get to an outreach event, spark a short conversation with the young people in your life!

Thanks to Southern Geoscience Consultants & Newmont Australia for lending ASEG geophysics/petrophysics equipment for demo and to the ASEG WA Branch committee for organising the booth materials.

If you wish to take part in future outreach events on behalf of ASEG, please contact secretary@aseg.org.au.

Mikayla Sambrooks
ASEG Communication Committee Co-Chair
E communications@aseg.org.au

Education matters

Marina Pervukhina
Associate Editor for Education
E Marina.Pervukhina@csiro.au

> “Companies seek individuals with versatile skills rather than highly specialised education.

Finding an optimal balance between breadth and depth in education

Dear readers, in this issue of *Preview* we continue our series of interviews with leaders from industry, government, and academia about education in Earth Sciences in Australia. Today, our guest is Boris Gurevich, John Curtin Distinguished Professor at Curtin University.

Professor Boris Gurevich

MP: Please, tell the readers a little bit about yourself.

BG: Thank you, Marina, for the opportunity to share my story and my views with fellow geophysicists. I obtained my BSc and MSc at Lomonosov Moscow State University in 1981 and started my career at the Moscow Institute of Geosystems. My early work included numerical analysis of NMR signals and application of pattern recognition methods (a precursor to modern neural networks!) to direct detection of hydrocarbons from seismic reflection data. While working on these topics, I met Sergey L. Lopatnikov, who inspired my interest in poroelasticity and rock physics. This subject became my long-term obsession. My first steps in this area were focused on quantification of dispersion and attenuation due to mesoscopic flow in thinly-layered poroelastic systems. This research formed the basis of my PhD thesis (1988).

In 1995, after several short visiting research appointments at a number of European universities, I joined the Geophysical Institute of Israel, where I combined my continued interest in poroelasticity with development and application of new approaches to seismic imaging under the guidance of another mentor - Evgeny Landa.

In 2001, I was appointed Professor of Geophysics at Curtin University, where my research expanded into a large variety of rock physics topics, such as effective stress laws, stress dependency of rock properties and solid/fluid layered systems. At the same time, I continued to work on the topic of wave-induced fluid flow, studying such systems as patchy saturation; flow between pores and fractures; squirt flow; and heavy oil rocks. I also started to collaborate more and more with my colleagues who are experts in seismic data processing and analysis. This collaboration led to a number of interesting studies, such as development of new algorithms for estimation of azimuthal anisotropy from borehole seismic data and modelling the seismic time-lapse response of CO_2 injected into a reservoir rock. In recent years, this collaboration has expanded further and shifted the focus of my research to understanding and modelling of seismic wave amplitudes measured by distributed acoustic sensors (DAS).

Throughout my career at Curtin, I held several managerial roles such as Head of the Geophysics Department, which allowed me to better understand the business side of higher education and research. As a senior academic, I take pride in mentoring and directing junior colleagues, in addition to classroom teaching and supervision of research students. I am also heavily involved in facilitating cooperation with industry through my role as the director of the Curtin Reservoir Geophysics Consortium. For nineteen years, concurrently with my Curtin professorship, I also served as a geophysics advisor to CSIRO. Together, we have built one of the strongest rock physics groups in the world.

MP: In the current rapidly changing minerals and energy resources landscape, what does the industry expect from tertiary education? How do companies see their “fresh blood”?

BG: It’s challenging to speak about the entire industry, but from what I understand, the basic requirements are hands-on skills and the ability to contribute to projects from day one. At the same time, companies seek individuals with versatile skills rather than highly specialised education. Particularly in energy and mineral sectors, they value skills like a geophysicist’s understanding of geology and *vice versa*, along with adaptability in a changing world.

Increasingly important are also soft skills, which traditional education often neglects to provide. These skills are crucial for long-term success, alongside a mix of fundamental and practical abilities.

However, the emphasis on these attributes varies among companies. For instance, smaller companies may prioritise immediate hands-on skills, while multinationals prefer to provide comprehensive graduate training programmes. This dynamic can sometimes be viewed as a failure of university education to fully prepare graduates for industry roles. However, in a rapidly changing and diverse industry, it is impossible for universities to prepare graduates to every possible job.

The economics of higher education present additional challenges. For classes to be economically viable they need to be of a significant size, which motivates universities to offer courses that have a broad appeal and are less

specialised. Finding the optimal balance between breadth and depth in education is complex, particularly considering constraints like limited funding.

Another major challenge in higher education, especially in geosciences, is the inadequacy of STEM education at schools. Many students lack fundamental maths and physics skills necessary for highly technical fields like geophysics. This deficit poses a significant hurdle for universities in recruiting students with the required foundational knowledge.

Moreover, the nature of geoscience tools has evolved, reducing the need for users to understand the inner workings intimately. While this streamlines processes, it also introduces risks if users lack a broad understanding of the tools they're employing.

In response to industry demands, universities often face pressure to expand their curriculum to cover a wide array of topics. However, practical constraints make it challenging to meet all these demands effectively. A more collaborative approach between academia and industry could address these challenges more successfully. By fostering closer partnerships, universities can better align their offerings with industry needs and ensure graduates are well-prepared for the workforce.

> "By fostering closer partnerships, universities can better align their offerings with industry needs.

MP: What kind of education do we need to ensure smooth and efficient transition to clean energy? This is probably the main goal of many energy companies right now and what we have to expect in tertiary education to ensure this?

BG: Universities face a significant and rapid transformation. Unfortunately, many universities seem to ignore or underestimate these changes. One major challenge is the relatively slow response of most universities to competition from online education. One can only look at the impact of the World Wide Web on various industries such as banking and travel agencies. Universities could face similar challenges, especially with many prestigious institutions offering online courses. This raises questions about the relevance of traditional universities, particularly those not at the top of global rankings. While universities are making some efforts to address these challenges, in my view, they are not doing this fast enough to compete in this rapidly changing landscape.

Universities also face competition from non-traditional education providers in emerging industries like tech. Yet another challenge comes from the rise of AI whose ramifications remain uncertain. These challenges extend way beyond energy transition but might be more acute in the areas of emerging technologies. Universities are already feeling the squeeze from these challenges. They may survive longer than expected due to tradition, reputation, and the demand for employees with university credentials. However, if they fail to adapt quickly enough, universities could face a decline in demand for their degrees.

Specifically concerning the transition to clean energy, it's evident that areas like CCS and hydrogen will require a similar range of expertise as traditional oil and gas industries. Australia may be making a mistake by not adequately supporting education in these areas. For instance, the decommissioning of offshore oil & gas wells will need many skilled professionals such as petroleum engineers. Failure to produce enough local talent could result in skill shortages and reliance on recruiting experts from overseas, posing economic challenges.

Recent trends show a significant rise in industry's interest in CCS-related industries. Numerous CCS projects are in various stages of development, although many are still in the planning stages. Training students for these projects takes time, typically four to five years. Despite being slightly behind countries like Canada, Australia's interest in CCS is rapidly growing. Recently, there has been significant pressure on the Western Australian Parliament to enact legislation on CCS. In 2023 this resulted in introduction of a bill, which, according to a press release of the WA Government (https://www.wa.gov.au/government/media-statements/Cook-Labor-Government/Cook-Government-introduces-carbon-capture-and-storage-bill---20231129):

> "proposes to enable the transport and storage of greenhouse gases in Western Australia, which aligns with net zero emissions ambitions within the WA Climate Policy and Greenhouse Gas Emissions Policy. As well as introducing a framework for greenhouse gas storage and transport, the exploration of naturally occurring hydrogen will be accommodated for as a regulated substance in the Bill".

Despite uncertainties, there is growing interest and active involvement in CCS projects, with geoscientists already engaged in various initiatives. The momentum is not limited to Western Australia; projects are also underway in the Cooper Basin and Timor Sea, among other places. CCS projects need to be substantial to make an impact, and there are already incentives for companies to invest in their own depleted fields and saline aquifers. The interest from various sectors indicates that there are incentives in place or on the horizon. Additionally, hydrogen is emerging as a significant topic of discussion, with industry showing keen interest. It is crucial to note that while traditional geoscience skills are vital, new energy projects will require additional, specialised skills. For instance, exploring and monitoring wind farms necessitates expertise in geoengineering and near-surface geophysics. Unfortunately, there's a lack of awareness among prospective students about these specialised skills, often overshadowed by perceptions of industry volatility. The emerging industry trends underscore the importance of investing in education and training to meet the demands of emerging sectors like clean energy.

> "The emerging industry trends underscore the importance of investing in education and training to meet the demands of emerging sectors like clean energy.

MP: What role does digitalisation play in the clean energy transition? What kind of education is required to guarantee efficient digitalisation of the sector?

BG: Energy transition demands extensive work with vast amounts of data. It's not just about the sheer volume of data, which presents its own challenges, but also the diversity

of data and the various ways in which we utilise it. If by "digitalisation" you mean this aspect, then computer skills, understanding of big data, and proficiency in machine learning are crucial for the future. This requirement extends beyond energy transition; it permeates all aspects of life. I recall a time when terms like machine learning and big data gained popularity, and individuals in the hard sciences initially dismissed them as tools exclusive to the soft sciences, devoid of theoretical underpinnings. However, those same individuals eventually embraced them as essential tools. This shift may be attributed to the exponential growth in computing power, enabling the application of techniques that were once inconceivable, even though neural networks had already been invented. While challenges persist, especially regarding the transparency of machine learning processes, this technology has significantly accelerated various processes and yielded remarkable results. The challenge for higher education lies in imparting fundamental machine learning and computer skills without compromising other essential skills. We must avoid producing graduates who can merely operate complex networks without understanding their underlying principles or without an ability to do anything without them. Achieving this balance is daunting, and while progress has been made in small increments, it will undoubtedly take time to fully integrate these skills into the educational curriculum.

> "The challenge for higher education lies in imparting fundamental machine learning and computer skills without compromising other essential skills.

MP: Overall, what kind of specialists are required to successfully pursue the clean energy transition in Australia?

BG: Maybe I'm attached to the old STEM education and its importance. I'm unsure how to solve this problem because it starts a deeper discussion about educating our kids in the 21st century and what interests them. In my view, Australia is putting a lot of effort into this area, perhaps learning from countries like Japan and Finland.

However, the industry needs to better understand the economics of higher education, especially in geosciences. In some countries, there's a much closer partnership between industry and higher education, where industry supports education programmes, but this isn't the case in Australia. The economics of education, particularly in niche areas like geophysics, are challenging. On one hand, the study of geophysics requires students with good maths skills. On the other hand, the number of such students is small, and small classes are uneconomic to run.

This squeeze calls for a rethinking of funding for education and greater industry involvement. While some Australian companies have considered partnerships and academies, these initiatives often fail to materialise. Companies sometimes find it easier to import overseas professionals than to invest in the Australian education system. However, there should be incentives for companies to invest in education.

MP: Thank you, Boris, for sharing your experience and wisdom with *Preview* readers.

> "The industry needs to better understand the economics of higher education.

Environmental geophysics

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

Mapping seagrass

Welcome readers to this issue's column on geophysics applied to the environment. For this issue, I spent some time learning about the importance of seagrass to coastal and, in fact, world health. It all started with an email announcement that Fugro in Italy, along with their partner CGR SpA (Compagnia Generale Ripreseaeree SpA), has just received a large grant from the Italian Government to perform a super high tech, super expensive survey of the entire Italian coast, specifically looking at seagrass habitat. This contract is part of a (much) larger Government project called the PNRR MER Project (Marine Ecosystem Restoration) – and is worth something like €400m (which in turn is sourced at least partially from an even larger EU funded project). Many thanks to the international team of seagrass experts (maybe more correctly hydrography experts) at Fugro for information about this project.

Seagrasses, of which there are approximately 72 species worldwide, are some of the most important plants on Earth (see https://ocean.si.edu/ocean-life/plants-algae/seagrass-and-seagrass-beds). On a local level they are important habitat for a huge number of species, hosting a huge number of invertebrates along with the larger creatures that live off of them. According to the South Australian Government, approximately 40 times more species live in seagrass habitat than in adjacent bare sand (https://www.environment.sa.gov.au/topics/coasts/explore-and-learn/seagrass-restoration-in-sa). Furthermore, they act as important sea-wave buffers and sand traps, reducing erosion along shorelines (every article that I read to research seagrass mentions this). But, even more importantly, they are one of the most effective sequesterers of atmospheric carbon, sequestering about twice as much CO_2 per hectare as terrestrial forests. According to the Smithsonian seagrass habitat is reducing by ~1 percent per year, with other sources that I've seen stating that whilst seagrass loss is no longer as bad as it was back in the mid to late 20th century, improvement is spotty and slow (*Nature Communications* (2019) **10**:3356). While attempts at reintroduction are improving (https://www.environment.sa.gov.au/topics/coasts/explore-and-learn/seagrass-restoration-in-sa), most species are notoriously difficult to re-establish, and then grow very slowly.

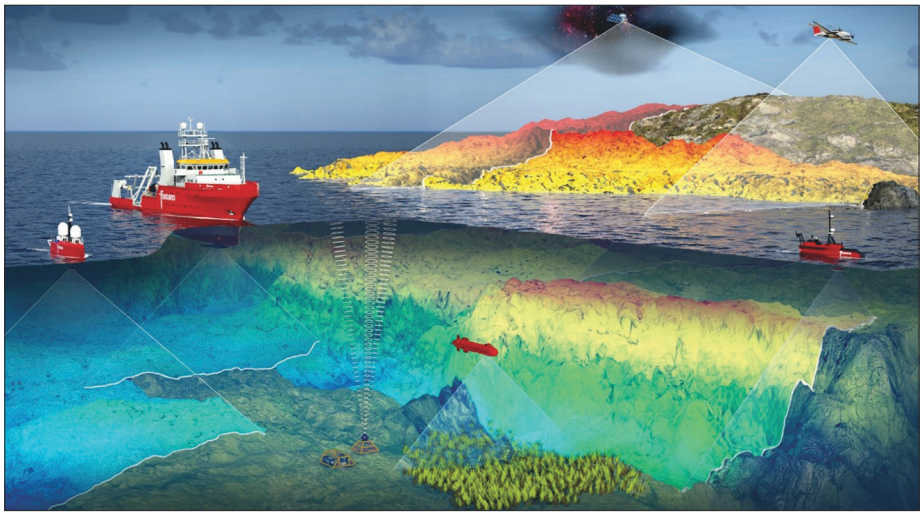

Figure 1: *Fugro-supplied graphic illustrating the tools being used to map the Italian coastline.*

So, my question to the Fugro people was - why is Italy being particularly proactive in mapping seagrass extent? Their response was - seagrass mapping is a key component of Italy's National Recovery and Resilience Plan (NRRP). More particularly, it addresses: Mission 2 - Green Revolution and Ecological Transition, Component 4 - Protection of Land and Water Resources, Measure 3 - Safeguarding Air Quality and Land Biodiversity Through the Protection of Green Areas, Soil and Marine Areas, Investment 3.5 Restoration and Protection of Seabed and Marine Habitats.

Digging a little bit, I found that this is part of the EU's "Next Generation EU" programme, which looks to me a lot like the US's Inflation Reduction Act. Both have huge budgets and are designed to act as economic stimulus, providing needed infrastructure and jobs, while addressing climate change, green economy expansion, *etc*.

Back to what the folks at Fugro say, currently 19.1% of Italian waters are under conservation measures but that is not enough. In order to reach the European biodiversity protection objectives by 2030, this percentage must increase significantly. The plan envisages large-scale actions to restore and protect the seabed and marine habitats in Italian waters, to reverse the degradation of Mediterranean ecosystems, and enhance their resilience to climate change. This will also favour maintaining fundamental activities, such as fishing, tourism, food and blue economy growth, in a sustainable fashion. Adequate mapping of seabed habitats and precise environmental tracking are considered to be a prerequisite for effective protection measures. For this reason, the national system of research and observation of marine and coastal ecosystems is being strengthened, including increasing the availability of updated research vessels. The goal is to have 90% of marine and coastal systems mapped and monitored and 20% restored by 2026.

The project, which is due to start in March 2024 and to be completed by June 2026, includes acquisition of hydrographic data utilising multiple state-of-the-art sensors, including airborne lidar, airborne gravimetry and various satellite sensors over 10 200 km^2, and the deployment of vessel-based multibeam echosounder technology over 4000 km^2. In addition, an autonomous

underwater vehicle, or underwater drone, will be used for direct observation and ground-truthing of other datasets along 4000 km of coast (**Figure 1**) (https://www.fugro.com/news/press-releases/2024/fugro-maps-seagrass-around-italy-in-a-groundbreaking-ecosystem-restoration-project).

I have to say that I spent more time on the economics of the overall project than I expected – and in all seriousness have not gotten very far in understanding the underlying EU bureaucracy. While this particular project is undoubtedly valuable (financially and environmentally), the scale is mind blowing, touching nearly all aspects of Italian life. And I am sure that Italy will not be the only beneficiary. One can only fantasise about similar projects getting off the ground in Australasia.

For more information on this and other similar projects please contact the international team of seagrass experts (maybe more correctly hydrography experts) at Fugro who provided me information for this article: Serge van de Ven, Director Brand and Communication; Marco Filippone, Global Solutions Director Ocean Science and Hydrography; and Hugh Parker, Solution Owner for Hydrography.

HENDERSON BYTE:

Natural hydrogen is the gas for the future.

Natural hydrogen, also known as geologic hydrogen or gold hydrogen, is a particular type of hydrogen gas that occurs naturally in the subsurface. Unlike other common forms of hydrogen that require extraction or conversion from gases, some resulting in the production of carbon dioxide, natural hydrogen produces no CO_2 when burned, releasing only water vapour and heat.

Global warming and the need to achieve zero emissions now provides more incentive to search for and exploit this type of hydrogen which is inexpensive and sustainable. A successful natural hydrogen well has the potential to produce for decades and at a significantly lower cost than other forms of manufactured hydrogen.

There are some geological processes that produce the hydrogen naturally. One is a high-temperature reaction called serpentinisation which occurs when water is in contact with iron-rich rocks transforming them into serpentine minerals. For example, the iron in olivine (a primary component of the Earth's mantle), oxidises by capturing the oxygen from water and releasing hydrogen. A recent occurrence of natural hydrogen formed in this way has been observed in Oman where iron-rich peridotite of the mantle is thrust upwards.

A second mechanism to produce natural hydrogen is radiolysis of water, in which radioactive rocks split the H_20 molecules into its component atoms. The hydrogen then migrates away from the radioactive rocks to accumulate underground possibly in a fracture system.

Exploitation of natural hydrogen needs minimal infrastructure. Clearing a very small footprint and drilling a shallow borehole compares favourably to the installations of solar panels and wind generators requiring tens of thousands of hectares of land. Should the amount of gas be insufficient, or the supply is declining, the oxidisation process can be stimulated by pumping in water or heating the rock. This is the only time that extra energy is needed. Drilling of a stimulation area in the Hajar mountains of Oman is planned for later this year (*New Scientist* 3 February 2024).

Natural hydrogen has already been detected in many parts of the world, often when drilling for fossil fuels, and seen bubbling to the surface in lakes. Underground reservoirs occur in USA, the mantle basement of the Pyrenees mountains of France and Spain and the mantle rocks in Oman. *New Scientist* (*17 February 2024*) reports on "the largest flow of natural hydrogen gas ever seen" bubbling in water in a chromite mine in Albania. In this case the reacting iron-rich rocks are ophiolite. Modelling suggests more hydrogen is stored deeper underground. Indeed, this idea to look deeper may be true of other occurrences.

Recent revised modelling by the USGS suggests that there could enough hydrogen gas to meet projected demand for centuries.

In Australia, new companies have recently been established to focus on natural hydrogen. For example, HyTerra**,** based in Perth, has an interest in a venture with Natural Hydrogen Energy USA which involved the world's first well specifically targeting hydrogen. Gold Hydrogen, based in Brisbane, holds leases on the Yorke Peninsular where in October 2023 'Ramsay 1' well was drilled to 1005 m. Hydrogen purity levels were up to 86% and strong levels of helium were also found. 'Ramsay 2' followed in November 2023 to a depth of 1068 m. Sources of naturally occurring hydrogen have also been identified on the Eyre Peninsula of South Australia where H2EX**,** based in Perth, has an exploration license covering 6000 km^2 and other prospective acreage of 52000 km^2.

Further developments from these companies will be of interest.

Roger Henderson

E rogah@tpg.com.au

Minerals geophysics

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

Lithium exploration from first principles

Based on present day technology, lithium is seen as essential for the proposed transition to renewables as a green source of the world's energy needs. Not surprisingly, given its strategic value, lithium exploration and production have already attracted a body of literature. Nevertheless, as a mental exercise I thought it might be instructive to postulate from first principles how geophysics could contribute to lithium exploration. As a first step in this process, it is necessary to understand the geological nature of lithium deposits and their constituent mineralisation.

Much of the world's production of lithium is sourced from two strikingly different styles of deposits – soft rock evaporites and hard rock pegmatites.

Soft rock - lithium brines

Lithium brine deposits typically occur within a closed basin, where lithium salts derived from weathering of surrounding lithium source rocks have been concentrated in saline waters contained within suitable basin aquifers (Bradley *et al*. 2013). Because the mining process requires prolonged evaporation of the brines to concentrate the highly soluble lithium salts prior to extraction, these basins necessarily are in arid environments. Typically, then, the surface expression of the basin will incorporate a dry salt lake. The playas and salars of the Atacama Desert in Chile and adjacent high Andean areas of Argentina and Bolivia typify this environment.

Geophysical exploration for lithium brines might reasonably then comprise two phases: basin delineation, and aquifer mapping and characterisation.

Basin delineation is a common aim in soft rock geophysical exploration, and techniques typically brought to bear might include reflection seismics, gravity, resistivity and electromagnetics, including MT/AMT. Reflection seismics should offer the most detailed resolution, but expense and vehicle access limitations on boggy salt lake surfaces may be considerations.

Mapping of the extent and thickness of lithium brine aquifers is rendered more amenable to geophysical exploration by the expected strong electrical conductivity of the concentrated brine. Electromagnetics would appear to be the method of choice here, particularly in mapping the limits of the brine where it interfaces with fresher water, although the generally conductive environment of salt lakes might prove troublesome. For relatively shallow aquifers, ground penetrating radar may also have a role. Once drill-testing has commenced, geophysical drill-hole logging, particularly with resistivity/conductivity and porosity tools, would contribute to the characterisation of the aquifers.

Hard rock - lithium pegmatites

Pegmatites represent the final phase of magma melts, more typically felsic, often injected into the adjacent country rock, and can be highly enriched in trace elements and volatiles (Bradley *et al*. 2017). In some cases, pegmatites can be spatially relatable to their parent magma body, in other cases, no such parental body is evident from surface mapping. From a lithium extraction viewpoint, spodumene ($LiAl(SiO_3)_2$) is the preferred lithium-bearing mineral in pegmatites; it is a non-magnetic pyroxene silicate with a density of 3.03-3.23. Lithium pegmatites are typically also enriched in other trace elements; the Greenbushes lithium pegmatite deposit for instance is also one of the world's largest tantalum deposits.

Geophysical exploration for lithium pegmatites might then comprise two phases: identification of favourable environments for pegmatite occurrence, and pegmatite location and characterisation.

The search for favourable environments for pegmatite development might reasonably focus on the location and mapping of parent magmas, most typically manifest as granite batholiths with contact metamorphism rims. In some environments, granitic rock types will have locally lower densities, and the hornfels margins, particularly those derived from basic igneous and volcanic country rocks, can be magnetically anomalous. Regional gravity and magnetic surveys would appear to offer the best chances of success in batholith identification and mapping.

Geophysical location and mapping of individual pegmatites is less straightforward. Given their typically felsic, non-magnetic and resistive nature, pegmatites may be identifiable within some mafic, magnetic or conductive country rock as areas of little or no response. But where the pegmatites have no significant contrasts in petrophysical properties with their environment, geophysics just won't be effective. Some pegmatites do feature the development of potassium feldspar, and some carry radioactive minerals such as uraninite, which offer the possibility of direct detection with radiometrics, but only for those bodies that outcrop, or are covered with residual soils or a very thin veneer of transported sediments.

As with any situation, the selection and application of geophysical exploration techniques will depend on the nature of the target sought and the environment in which it is located. There is no single suits-every-case approach.

So, in no way is the above intended to be prescriptive. Rather, it is aimed at highlighting the thought processes that might be used to select geophysical techniques appropriate to an exploration target and its environment, in this case lithium.

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Seismic window

Michael Micenko
Associate Editor for Petroleum
E mick@freogeos.com.au

Maintaining data quality in point source and receiver acquisition

This article was inspired by two articles published in the January 2024 *First Break* magazine (see references).

Several years ago, when I was working on a seismic crew, the observer and client representative would check every shot record to ensure the recorded data was "good enough" to use. If it wasn't, it was reshot, or the parameters were changed. This system worked well while trace counts were low (24-96 channels) but now surveys can have thousands of channels on distributed, cable-less nodes. It is no longer possible to view shot records in real time. So, how do we maintain quality? One way to allow for poor signal is to increase trace count and fold. But Rowse and Heath (2024) say increasing fold is a brute force way to maintain data quality – it uses the weight of numbers to allow for dead or missing traces. The trend now is to lower signal-to-noise ratio as source energy is reduced to minimise interference from blended records and noise increases with the move away from receiver arrays to single point receivers. They suggest that rather than fold or trace density, some knowledge of the signal strength is necessary to estimate and compare the relative quality of a survey. Signal strength varies with different source types and parameters, and is difficult to put a number on, but it can be improved by vertical stacking of shots and using multiple sensors at each receiver location.

There has been a trend in recent years for cable-less nodes distributed as point receivers to replace cabled geophone arrays. This has led to some discussion of the advantages and disadvantages of the two systems (Ourabah 2024). Source and receiver arrays have been used for decades to reduce noise such as ground roll in the field while single point nodes supposedly record enough data to effectively model and eliminate noise in the processing centre.

When I last worked with a seismic crew 15-20 years ago, we experimented with the use of point source receivers and were able to remove the troublesome noise that turned out to be non-random diffractions rather than random noise (this was the subject of a talk I gave at a recent WA Branch ASEG meeting). In this case rather than nodes, which were not yet mainstream, we used bunched geophones at the receiver locations. This experiment worked well, and the key was to reduce the station spacing from 12.5 to 8 m so that the noise was sampled well enough to avoid aliasing.

Using data from continuously recording nodes also poses some problems with deblending or separating one shot record from the following record. The use of arrays to reduce noise also has some draw backs with intra array variations in elevation or velocity and directionality causing a distortion of the signal that affects some surface consistent processes and AVO for example. Perhaps the solution is to have closely spaced nodes and use digital array forming to simulate a surface array and enhance weak signal and attenuate noise. And, unlike a geophone array, the use of digital array forming can be reversible.

If we go further down this path the end result will be to blanket the survey area with closely spaced receivers. There are some places in the world where we still do that, but not many.

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Spencer L Rowse, S.L and R. Heath, 2024. Has the importance of 'signal' been forgotten in the signal-to-noise ratio of land seismic acquisition? *First Break*: 42, January 2024

Ourabah A., 2024. Revisiting the single sensor vs array debate in the light of new nodal system technology. *First Break*: 42, January 2024.

BREAKING NEWS

Mick Micenko will, once again, be representing Preview and the ASEG as a media representative at the annual AEP Conference and Exhibition (formerly APPEA)

Data trends

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

NetCDF

The ASEG GDF2 text format opens on any computer, and users can open it in Excel if they need to fix anything, so many are happy that it is the default data exchange and archive format. However, extremely large statewide government airborne surveys usually exceed the 1-million-line constraint of Excel, and drone surveyors using 1000 Hz magnetometers have to severely down sample to be under that magical million line limit.

So, we (the ASEG's Technical Standards Committee) began investigating NetCDF (Net Common Data Form) as a GDF2 substitute, and it turned out that this format is not just set of HDF wrappers but was originally wrappers for NASA's Common Data Format (CDF) for storing multidimension arrays.

NetCDF was developed and is maintained by Unidata (https://docs.unidata.ucar.edu/netcdf-c/current/), part of the University Corporation for Atmospheric Research (UCAR). UCAR is funded principally by the National Science Foundation. The software is currently at version 4.9.2 (https://www.unidata.ucar.edu/software/netcdf/).

The McGill University website has a clear and concise history and descriptions https://www.bic.mni.mcgill.ca/users/sean/Docs/netcdf/guide.txn_1.html. The multidimensional aspect of the format means that it can hold multiple grids of the same dimensions, and the open source GDAL is the easiest way to convert grids to NetCDF. This would be useful if you are accumulating too many grid formats, but is it an answer for storing and exchanging large numbers of point data?

A walk-through example from McGill University demonstrates that it is easy to understand this tool. A NetCDF file has components - dimensions, variables and data, with optional attributes. Dimensions define names with lengths, that can only be integers and will define the size and shape of variables. The following is an excerpt from the McGill site's Common Data Form Language (CDL) example constructing an early NetCDF.

```
lat = 5, lon = 10, level = 4, time = unlimited
int lat(lat), lon(lon),level(level);
short time(time)
float  rh(time,lat,lon);
rh:long_name = "relative humidity";
rh:valid_range = 0.0, 1.0;     // min and max
data                    // optional data assignments
level    = 1000, 850, 700, 500;
lat      = 20, 30, 40, 50, 60;
lon      = -160,-140,-118,-96,-84,-52,-45,
-35,-25,-15;
time     = 12;
rh       =.5,.2,.4,.2,.3,.2,.4,.5,.6,.7,
.1,.3,.1,.1,.1,.1,.5,.7,.8,.8,
…etc
```

This is a nice, simple to understand example defining integer arrays with upper bounds equal to their dimension namesake. The declaration of Relative Humidity (rh) shows the logical intentions of constructing a floating-point multidimensional array with the dimensions. Range limits, long names and units can be set.

Variables are usually numeric, but the format shows its Fortran and C roots with UTF-8 character arrays instead of strings. Strings were introduced later, as was the Coordinates component allowing variables to be accessed through locations. Variables with unlimited dimensions can be appended whereas the others are set. Attributes are optional descriptions such as the long name or range.

The original point of NetCDF was to follow NASA's lead and standardise an open, portable file format and its access functions to reduce time, effort and errors by users. This aligns with the ASEG general ethos. According to the Library of Congress assessment NetCDF has few concerns beyond compression (**Figure 1**).

I downloaded a survey from Geoscience Australia GADDS 2.0 as both ASEG GDF2 and NetCDF files. They were almost the same size compressed at ~250 MB, but when expanded the GDF2 grew to 1.6 GB whereas the NetCDF stayed unchanged with built in compression.

But what can you do with it if you are not interested in programming to extract NetCDF data? Not many commercially

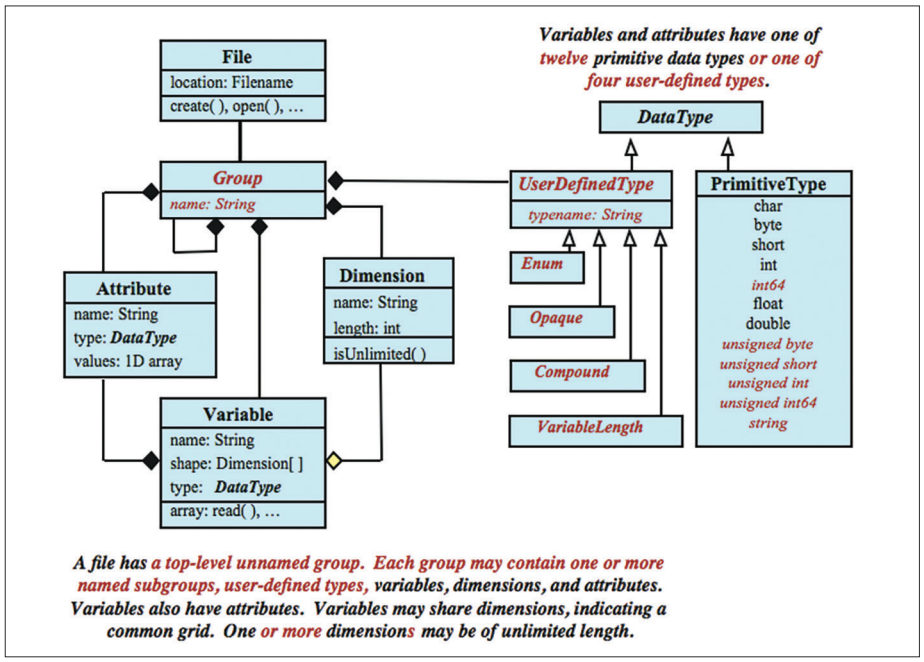


Figure 1: *Summary diagram of NetCDF file format.* https://docs.unidata.ucar.edu/netcdf-c/current/netcdf_data_model.html

available programs are capable of handling the format. Many export, but few import. Open source GDAL and QGIS open NetCDF grids but GDF2 is a vector and will not load. ESRI ArcPro was able to load the file as a table then converted into a point shape file (**Figure 2**). OriginPro (https://www.originlab.com/) and MATLAB (https://www.mathworks.comN/) will read data files in the NetCDF format.

The recent Python training course by Nathaniel Butterworth converted many grids from many file types into NetCDF to standardise file input for machine learning.

A concern is if dependencies change in the background such as HDF5 functions were incompatible with HDF4 functions, especially since HDF supplies the compression. NetCDF was not designed to be a database and write operations can be slow, at least in Python.

Note the data is effectively the same size compressed within NetCDF or Zipped text, implying software that reads text files inside zip files would result in the same file size footprint for both data exchange solutions.

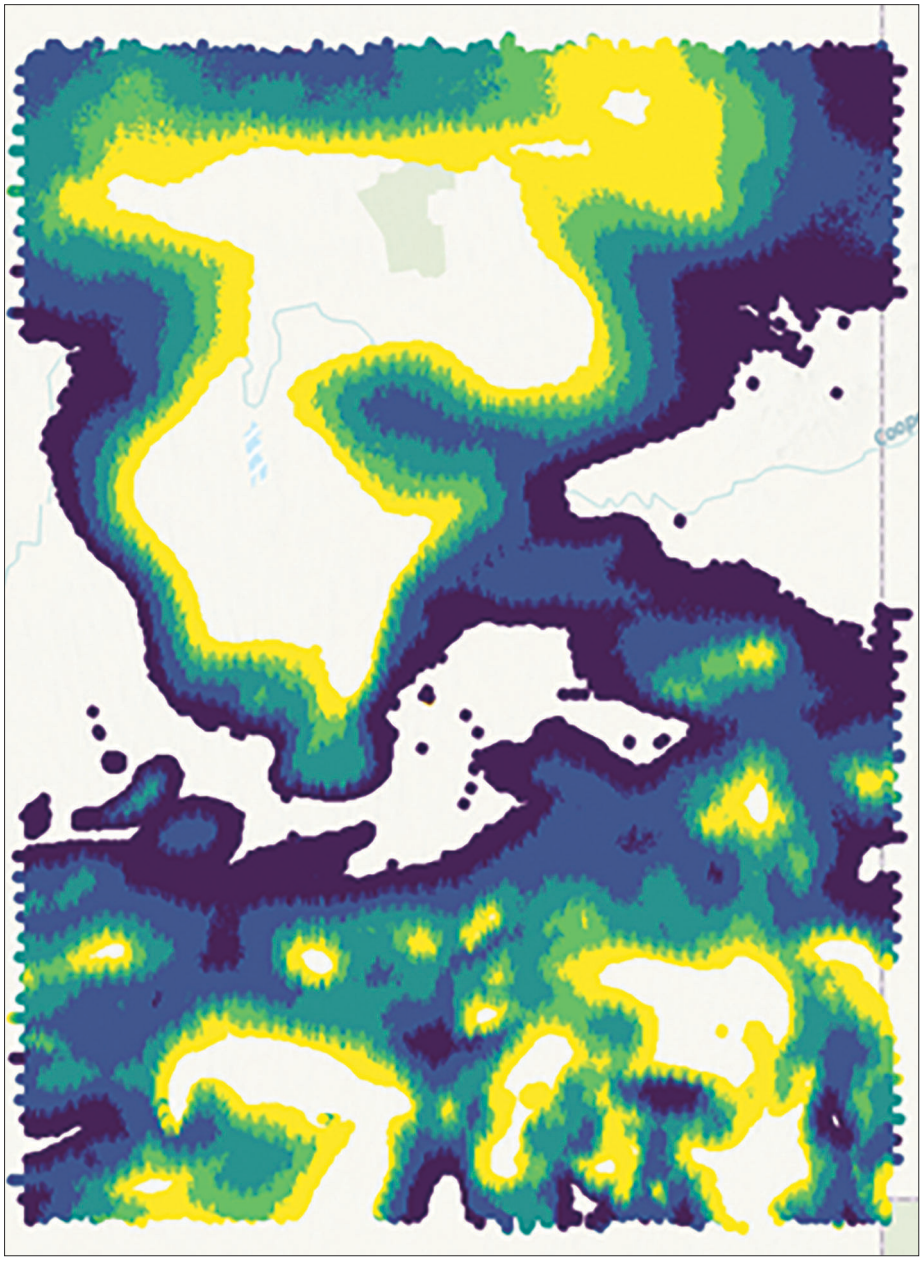


Figure 2: *Point shape file generated by ERSI ArcPro from raw magnetic survey data in NetCDF format.*

Webwaves

Ian James
ASEG Webmaster
E webmaster@aseg.org.au

Review of the ASEG website project and the road ahead

Changes to the ASEG web committee

In 2015, I joined the ASEG Web Committee as part of the team that worked on the current website, under the leadership of the, then, Webmaster David Annetts. I subsequently stepped into the Webmaster role in 2019, and have filled this role for the past five years. At the ASEG AGM in April 2024, I will be passing on the baton to Gokul Venu Sreebindu, who currently serves on the Web Committee. Gokul has been instrumental in the positive changes that are taking place in both the email hosting (transition to Google Workspace) and website refresh. My involvement in the Web Committee will continue to ensure a smooth transition. Watch this space in *Preview* 230 for an introduction to Gokul and the new website!

Website review - 2023

As we progress into 2024, we draw closer to the transition to the new website and membership database, to be launched before the end of April 2024. This transition is well overdue - the current website and database are a bit long in the tooth and cause some frustration to Members trying to interact with the Society online. Apologies for any continued issues - bigger and better things are coming soon! With the welcome demise of the current platform, it is an ideal time to perform a final annual review of the current website.

So, to 2023 on the ASEG website....

In 2023, the ASEG website was visited by a total of 18 130 users across 27 470 sessions as displayed in **Figure 1**. Here the six period spikes show the large number of users who navigate to the website as *Preview* is released. The plurality of sessions originated from internet searches (9649), followed by direct sessions (7047), referrals (1408) and various other sources.

Preview continues to dominate on the ASEG website, with the *Preview* page continuing to be the most popular followed by the Events page. This information has been absorbed into the redesign of the new website, with quick links at the top of the home page to both of these pages, thereby streamlining and simplifying user interaction. The third most popular page in 2023 was the ASEG *Extended Abstracts,* following Steve Hearn's excellent effort in getting abstracts from the last two AEGC conferences online and assigned DOIs - clearly an effort that has been appreciated by the geophysics community. As a conference year, both the current conference page and AEGC 2023 pages were popular.

The most popular Google search queries that led to clicks through to the ASEG website were:

1. ASEG
2. Australian Society of Exploration Geophysicists
3. MAG23
4. Geophysical Inversion
5. Jan Francke
6. ASEG 2023

It should be noted that the first two search queries were far and away the most popular (>1000 clicks), with the list above covering all searches leading to over 100 clicks.

The ASEG website continues to be predominantly viewed by Australian users as would be expected, however there is a global reach to the Society with most countries having had sessions. Yet, alas, still no North Korean views!

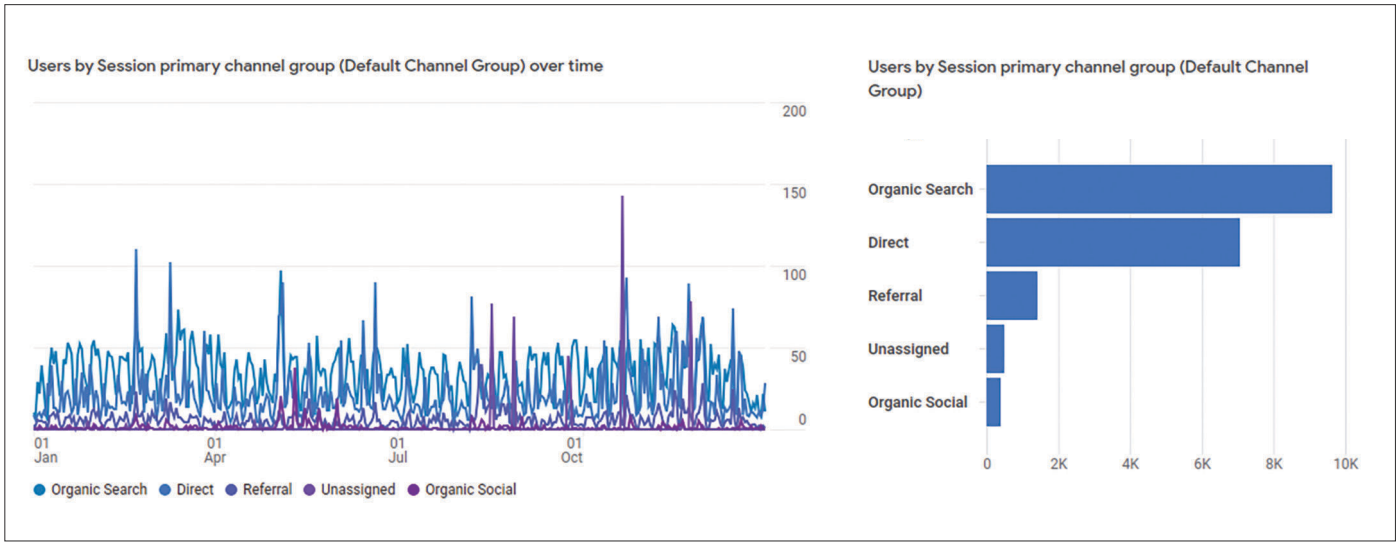
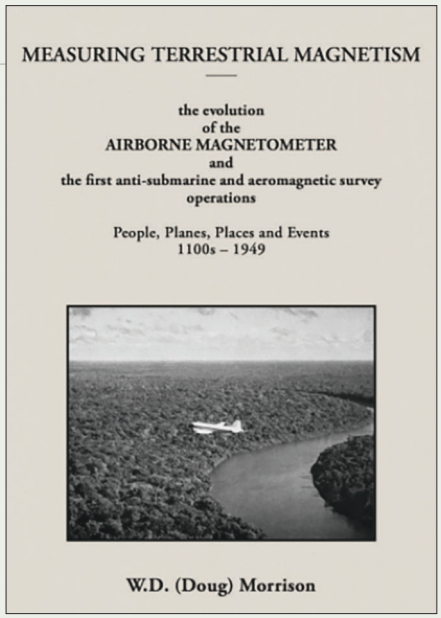


Figure 1. *User sessions on the ASEG website and number of sessions by source.*

Australian Society of Exploration Geophysicists



50TH ANNIVERSARY SPECIAL PUBLICATION

MEASURING TERRESTRIAL MAGNETISM

the evolution of the AIRBORNE MAGNETOMETER and the first anti-submarine and aeromagnetic survey operations

People, Planes, Places and Events 1100s – 1949

W.D. (Doug) Morrison

This Special Publication is co-sponsored by Geoscience Australia and ASEG

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This book, covering a global expanse of more than 800 years, recounts the largely untold story of 'measuring terrestrial magnetism' and of the extraordinary 'people, planes, places and events' that have contributed to the evolution of the magnetometer and the first anti-submarine and aeromagnetic geophysical survey operations. It is a unique journey of science and engineering, of inventions, new methods and instruments – a compelling story of how the measurement of terrestrial magnetism has influenced the history of the world.

This is an operational historical record rather than a history of the theory of terrestrial magnetism. The story begins at the earliest documented geomagnetic discoveries and moves on to observations of magnetic intensity and the first ground magnetic surveys. We see how the instruments used for geomagnetic observations from moving airborne platforms evolved in parallel with the evolution of flight from balloons (from 1784) to airships and eventually aircraft.

In the 1930s and 1940s there were major advances in magnetometry, in USSR, Japan and Germany as well as in USA and UK. In USA and UK these advances were applied in military surveillance systems, including in the detection of submarines. Landmark World War II induction coil and fluxgate instruments – the first of the modern technologies – enabled aeromagnetic acquisition, mapping and direct detections of ore bodies from the air from mid-1944 onwards, foreshadowing today's airborne magnetic surveys. The military developments of magnetometers were taken up, rapidly advanced and applied by the mineral exploration industry to find new economic deposits of magnetic mineral ores. Countries including Australia, Canada and the United States charged their national mining and geological survey departments with investigating and establishing programs of major aerial magnetic surveying and mapping in the search for minerals and energy.

The story explores the inextricable cross-discipline connections of terrestrial magnetism and magnetometers as used for navigation, geodesy, anti-submarine and military purposes, and their role in the geophysical oil and mineral exploration industry. Organisations, people and specific instruments and aircraft are noted, including (at times coincidental) Australian connections.

The extraordinary depth and scope of research, over many decades, by the author W.D. (Doug) Morrison, as well as his collection of photos and illustrations, and his astonishing attention to detail, make this book an amazing and immersive historical reading experience and a future primary reference work. Through several decades Doug has developed an extensive 'reference' network of geophysical survey practitioners, and former experts in military, aviation and maritime matters. Through their little-known stories and personal reflections, and his access to personal and official archive material from this network, Doug's narrative brings unique insights into the evolution of the airborne magnetometer. Along that timeline he has produced details that are not available in public historical material.

Measuring Terrestrial Magnetism is a major work of 630 pages, illustrated throughout with 156 plates of figures and photos, and including comprehensive Endnotes, Appendices, References and Index.

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https://www.aseg.org.au/publications/book-shop

Imaging the supergene search space with Ambient Noise Tomography

Anthony Reid
Fleet Space Technologies, Beverley, South Australia & Department of Earth Sciences, The University of Adelaide, Adelaide, South Australia
E anthony.reid@fleet.space

Bronwyn Murphy
Fleet Space Technologies, Beverley, South Australia
E bronwyn.murphy@fleet.space

Nicole Galloway-Warland
Thor Energy PLC, Norwood, South Australia
E nicole@thorenergyplc.com

Adebayo Ojo
Fleet Space Technologies, Beverley, South Australia
E adebayo.ojo@fleet.space

Gerrit Olivier
Fleet Space Technologies, Beverley, South Australia
E gerrit.olivier@fleet.space

Doreen Mikitiuk
DXplorer, Eatons Hill, Queensland
E dm@dxplorer.com.au

Overview

Supergene mineralisation is an important contributor to the economic viability of many mines. Supergene enrichment processes can produce elevated copper, gold, rare earth elements (REE) and other commodities in the near surface environment via a combination of acidic groundwaters and bacterial activity. Australia has widespread, deep weathering profiles that in places extend tens of metres into the bedrock. Where this weathering has overprinted near-surface sulphide accumulations there is potential for supergene enrichment. However, these weathered profiles are typically buried by younger materials, and geophysical methods are required to investigate the weathering profile. Here, we focus on Ambient Noise Tomography (ANT) as one method that can be applied to see through cover and image the seismic velocity of the subsurface in 3D. In the example of the Alford East project, in South Australia's Yorke Peninsula, the ANT models are able to detect zones of where the cover-basement interface is relatively deep, and where drilling has intersected these zones, they typically comprise strongly weathered and mineralised rock with enrichment in copper and REE. It appears basement structural controls may have localised weathering into susceptible metasomatic rock types, leading to the supergene enrichment detected in the area by drilling and, by extension, ANT. This survey is a demonstration of the benefits of combining ANT with other geological and geophysical tools to image the structural architecture of the subsurface and has expanded the search space for buried supergene mineralisation in the region.

Introduction

Upgrading of primary sulphide mineralisation can occur in the weathering environment (**Figure 1**). In many deposits, it is the supergene cap mineralisation that makes a mining operation economically viable, as a consequence of the early cash flows that can be generated from mining these uppermost portions of the orebody. Weathering processes can concentrate copper significantly, and the grades of supergene ores can be higher than the disseminated hypogene mineralisation in the basement (Sillitoe 2005; Reich and Vasconcelos 2015).

Weathering of a crystalline rock changes its petrophysical properties. As a result, deep weathering profiles may be visible in geophysical surveys. For example, in Andean porphyry deposits, the supergene zones are rich in sulphide minerals such as chalcocite, covellite, digenite as well as native copper. Conductive minerals such as these can be imaged by electrical geophysical methods such as induced polarisation, and also by airborne electromagnetic methods (Witherly 2023). Complications in EM methods caused by chargeability of surficial, weathering materials (Soerensen *et al*. 2018) and conductive saline groundwaters (Chandra *et al*. 2020) need to be screened from electromagnetic datasets when ranking conductivity drill targets. Furthermore, oxide supergene minerals are less conductive, and may not be imaged by electrical geophysics.

Weathering can produce a significant reduction in density of the bulk rock package. This will cause a decrease in seismic velocity, which can be detected by seismic methods. Both active reflection seismic and passive seismic methods are able to image the cover-basement interface. For instance, the thickness of weathering profiles can be estimated by using a low-cost passive seismic method that measures horizontal-to-vertical spectral ratios (Nelson and McBride 2019). Here we focus on another passive seismic method, Ambient Noise Tomography (ANT). The method is appealing for use in mineral exploration due to its versatility: it is possible to not only image the cover-basement interface, but also variations of seismic velocities in

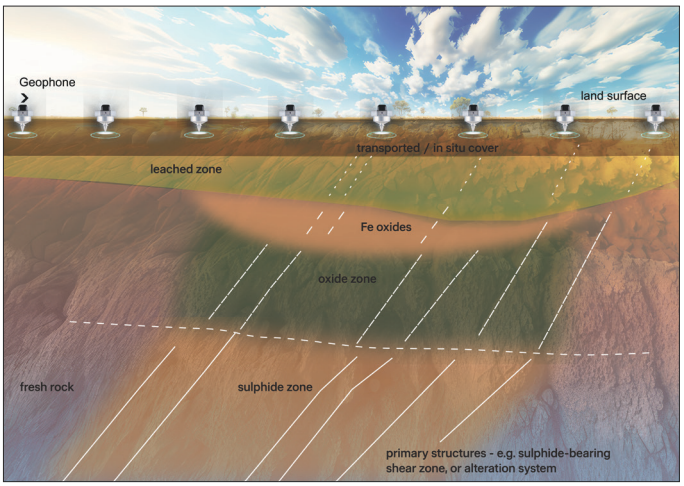

Figure 1. *Schematic image of supergene alteration and weathering above a primary (hypogene) disseminated sulphide zone (Reich and Vasconcelos 2015). Zones of iron oxide, oxide and sulphide form in response to deep weathering and will potentially have a distinct geophysical signature to the primary rock type.*

both the cover and basement due to physical processes that may be important for holistic mineral exploration. This method has been widely used over the past 20 years in studies of depth of sedimentary cover (Beard *et al*. 2022), magmatic systems (Li *et al*. 2023), active faulting (Mordret *et al*. 2019), lithospheric and continental scale structure (Bensen and Ritzwoller 2008; Saygin and Kennett 2010; Ward *et al*. 2013; Hoggard *et al*. 2020) and mineral exploration (Hollis *et al*. 2018; Li *et al*. 2020; Chen *et al*. 2021; Ryberg *et al*. 2022). Recent advances in the sensitivity of ANT seismometers mean that the cover-basement interface can now be imaged with great precision (Beard *et al*. 2022; Olivier *et al*. 2022). However, it has been less certain if these seismic methods can image variation within the cover sedimentary units, and especially to image variation in weathering intensity that might indicate the presence of supergene zones with higher prospectivity to host economic mineralisation.

Recently, Fleet Space Technologies partnered with Thor Energy PLC to investigate the use of ANT for imaging the weathered zones of primary sulphide-enriched rocks in the eastern Gawler Craton. Here we provide a brief overview of the project and the resulting ANT 3D velocity models and discuss the utility of this method for detecting highly weathered basement zones across covered terranes. With the intensity of weathering that the Australian continent in particular has been subject to, since at least the Mesozoic, but principally during the Paleogene (Hill *et al*. 2008; Bourman *et al*. 2010), the likelihood that supergene enriched zones exist in other covered areas of Australia is high, and a method that can screen for zones of possible supergene enrichment will be a useful addition to the mineral exploration tool kit.

Background: Supergene processes

Oxide ore occurs within soft and relatively easily mined saprolite and is often amenable to simpler metallurgical treatment compared to sulphide from deeper, hypogene ore. Mineralogically, supergene copper occurs as oxide minerals such as chrysocolla, malachite and azurite, or sulphide minerals such as chalcocite, which is an important aspect of many Andean porphyry deposits such as Escondida (Sillitoe 2005). Other elements are also often concentrated by weathering and deep oxidation. In examples from the Andean copper porphyry systems, weathering also releases low-grade refractory gold, making this also amenable to metallurgical processing and concentration (Sillitoe 2005). Where basement rocks are enriched in accessory phases that contain rare earth elements (REE), such as monazite, zircon or xenotime, REE may also be enriched by acidic weathering. The REE may then be found as either adsorbed ions on clays, as colloids, or as secondary REE minerals such as xenotime, or apatite (Cocker 2014; Wu *et al*. 2023).

Supergene oxide ore forms by electrochemical oxidation of sulphide-bearing bedrock in acidic conditions due to interaction between groundwaters, rocks and Fe- and S-oxidising bacteria (Sillitoe 2005). In such environments, copper is leached and transferred downward to the reduced environment, beneath the water table, forming zones of supergene enrichment and ideally, economic ore. The structure of the basement rock system is an important control on movement of groundwaters and formation of supergene enrichment, with structures providing a focus for movement of groundwaters into the deeper parts of the orebody and outwards into cover units (Arabpour *et al*. 2021).

Background: Alford East geology

The Alford East project area lies within the eastern Gawler Craton, which is host to iron oxide copper-gold deposits of the Olympic Cu-Au Province (Skirrow *et al*. 2007, 2018; Reid 2019). Hematite breccia deposits such as Olympic Dam, Prominent Hill and Carrapateena occur in continuum of Cu-Au-U deposit types that includes deposits that formed at higher temperatures such as the Hillside deposit (Conor *et al*. 2010; Ismail *et al*. 2014). The Alford East project lies in the southern region of the Olympic Cu-Au Province, near to the township of Wallaroo on Yorke Peninsula, a historical copper mining centre (**Figure 2**).

The basement geology of Alford East project area consists of Palaeoproterozoic metasedimentary and metavolcanics rocks (Wallaroo Group) intruded by and structurally interleaved with A- to I-type granites (Conor *et al*. 2010). Primary copper-gold mineralisation in the region is structurally controlled, associated with sheared metavolcanic rocks of the Wallaroo Group, metasomatic rocks of the Oorlano Metasomatite, and Hiltaba Suite granites. Cambrian and Cenozoic sedimentary rocks for a cover sequence across much of Yorke Peninsula (Zang 2006). In the Alford East region, cover is generally thin, ranging from 5 to 50 m.

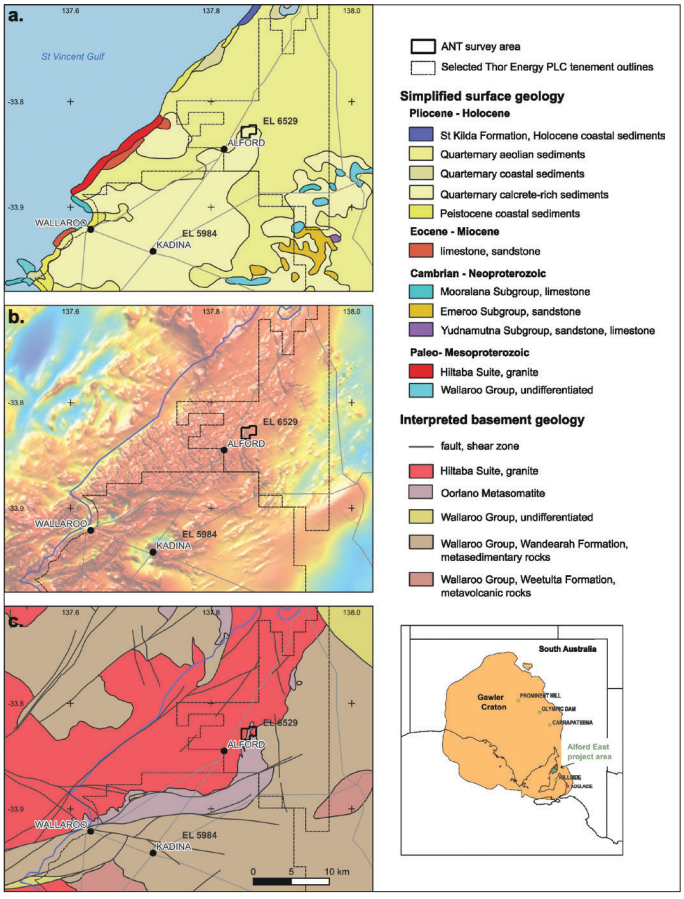

Figure 2. *Location of the Alford East project on exploration licenses of Thor Energy PLC (Els 6529, 5984), in the eastern Gawler Craton of South Australia. Location of ANT survey is shown, and the inset shows the location within South Australia. a. Simplified surface geology of the Alford East region. b. Total magnetic intensity image. c. Interpreted crystalline basement geology. Geological and geophysical data from Geological Survey of South Australia, via SARIG.*

The host stratigraphy to the Alford East prospect is the Oorlano Metasomatite which is comprised of alkali feldspar, iron-rich, carbonate and calc-silicate metasomatic rocks formed during the main IOCG mineralising event that affected large swathes of the eastern Gawler Craton (Cowley *et al*. 2003; Kontonikas-Charos *et al.* 2014). Supergene mineralisation is hosted within variably weathered and sheared metasomatic rocks. Calcrete geochemistry across the region provided an indication of buried mineralisation in the area and was followed up by drilling and identified anomalous copper in the weathered basement (Wynne *et al*. 2019). Low grade copper mineralisation is widespread throughout the project area, with chalcocite being the dominant copper mineral in the lower portion of the supergene zones along with native copper and malachite in the upper, oxide zones Wynne *et al*. 2019 (Thor Energy PLC, 2023).

Some of the best historical diamond drilling intercepts include 40.8 m @ 0.42% Cu and 0.07 ppm Au from 90 m in hole ALDDH017, and 20 m @ 0.27% Cu and 0.16 ppm Au from 196 m in hole ALDDH021 (Wynne *et al*. 2019). Based on these results Thor generated an Inferred Mineral Resource estimate 125.6 Mt @ 0.14% Cu containing 177 000 t of contained copper and 71 500 oz of contained gold (**Table 1**). Thor undertook a targeted oxide diamond drilling programme in 2021, which returned high grade intercepts up to 72.7 m @ 1.0% Cu and 0.19 g/t Au from 6.3 m, including 18.2 m @2.0% Cu and 0.34 g/t Au from 15.8 m in 21AED005 (Thor Energy 2021).

ANT methods

Ambient noise tomography utilises background seismic noise in the Earth as the signal for measuring subsurface velocity structure. An array of custom-built Fleet Space geophones (Olivier *et al*. 2022) were used to record the arrival of low-frequency surface waves created by natural and anthropogenic seismic sources. This technique relies on estimates of seismic Green's functions between station pairs, such that every receiver is turned into a virtual active source that provides information about the subsurface. The ANT survey in the Alford East project comprised two sub-surveys, an eastern and western deployment. Each consisted of 96 geodes that remained in the field between nine and eleven days. The total area surveyed was approximately 3 km.

Empirically derived Green's functions are obtained from station pair cross-correlation functions using the approach outlined by Bensen *et al*. (2007). From the processed data, a set of cross-correlations are computed for each of the unique station pairs. The resulting cross-correlation functions for each station pair are then linearly stacked.

To obtain a 3D model of the subsurface shear-wave velocities, phase velocity dispersion measurements are extracted from the cross-correlation functions using two independent methods: (1) the real part of the Fourier transform of the correlation functions is fitted with a first-order Bessel function of the first kind (Aki, 1957; Ekström *et al*., 2009) and (2) the dispersion curves on an FTAN image are automatically picked for each correlation function (Levshin *et al*. 1972; Luo *et al*. 2015). After the phase velocity measurements have been made, the approach of (Mordret *et al*. 2019) is used to regionalise the phase velocity dispersion measurements for each frequency to create phase velocity maps. This effectively creates a dispersion curve for each cell in the 2D grid, which is then inverted for a 1D velocity model at each cell. The inversion results are constrained to a library of 50 000 forward models generated by uniform Monte-Carlo sampling of the expected model space and must fit the data within an RMS error bound of 5%. The resulting ensemble of 1D models is then gridded over a domain with XYZ dimensions to recover a full 3D velocity model. The approximate resolution of the ANT model is around 10% of the depth, such that at 300 m depth, for example, the model is able to resolve features that are greater than 30 m wide.

Alford East ANT survey

The recorded ambient seismic noise was detected predominantly from the south-west corner of the survey areas (**Figure 3**). High quality surface wave noise was recorded down to 1.2 Hz. When considering the array aperture of each individual array, this enabled consistent imaging down to 500 m depth with high resolution.

Table 1. Alford East Mineral Resource Estimate as at 22 January 2021.

Domain	Tonnes (Mt)	Cu %	Au g/t	Contained Cu (t)	Contained Au (oz)
AE_1	24.6	0.12	0.021	30 000	16 000
AE_2	6.8	0.13	0.004	9 000	1000
AE_3	34.9	0.09	0.022	33 000	25 000
AE_4	8.0	0.11	0.016	8000	4000
AE_5	**11.0**	**0.22**	**0.030**	**24 000**	**11 000**
AE-8 (NP)	31.3	0.19	0.008	61 000	8000
AE-7 (LW_E)	7.7	0.14	0.025	10 000	6000
AE-6 (LW_W)	1.3	0.13	0.011	2000	500
Total	**125.6**	**0.14**	**0.018**	**177 000**	**71 500**

Note: MRE reported on oxide material only, at a cut-off grade of 0.05% copper, which is consistent with the assumed in situ recovery technique. For details see https://thorenergyplc.com/projects/alford-copper-projects/

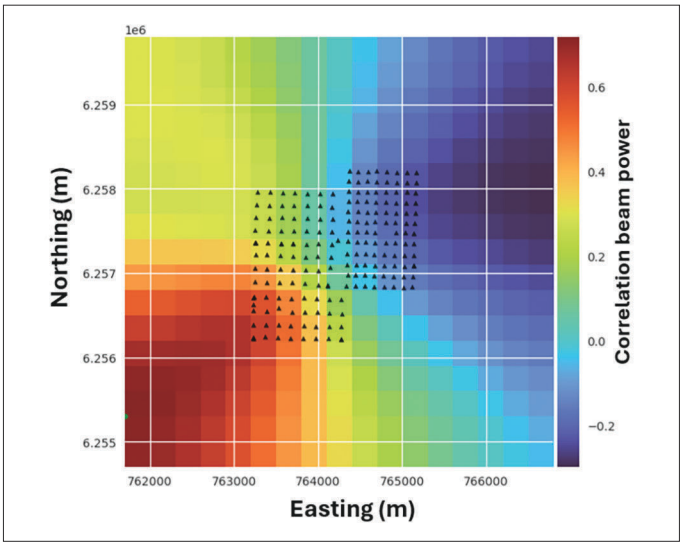

Figure 3. *Beamforming plot to locate dominant source direction and location from Alford East survey arrays. Ambient noise direction is predominantly south-west, in the direction of the township of Alford.*

The model is characterised by a low velocity near surface layer, intermediate velocity zone and a deeper high velocity zone, the latter of which represents the Proterozoic basement (**Figure 4**).

Velocity responses of the near surface layer are between ~900-1800 m/s, the middle zone ranges from ~1700-2400 m/s, and the upper zone ranges from ~2400 - 3900 m/s. The upper low velocity zone appears to correspond to the highest weathered basement rocks when compared to drill hole intersections (**Figure 4**). The intermediate zone appears to correspond to the transition from highly weathered, to less highly weathered basement.

The deeper, high velocity basement has zones of distinct velocity including a broad moderate velocity feature that is orientated towards the north-east, and at least two more narrow zones of intermediate velocity that are orientated orthogonal to that, trending towards the north-east (**Figure 5**). These velocity features are expressed across the model depth, including in the shallower portions of the model where, rather than being a relatively low velocity, in comparison to the very low velocities of the upper-most portion of the model, this north-east trending feature is expressed as a zone of relatively higher velocity (**Figure 5**).

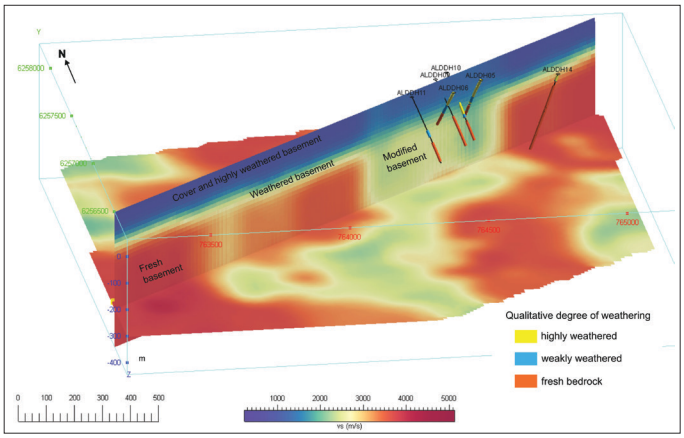

Figure 4. *Vertical and horizontal surfaces within 3D volume of ANT velocity model across the Alford East project area. Traces of selected drill holes are shown to highlight the apparent relationship between the highly and moderately weathered upper portion of the geology compared to the low to intermediate velocity zones in the uppermost portion of the velocity model. View is looking north. Model visualisation generated in Geoscience Analyst with a cumulative distribution function colour stretch.*

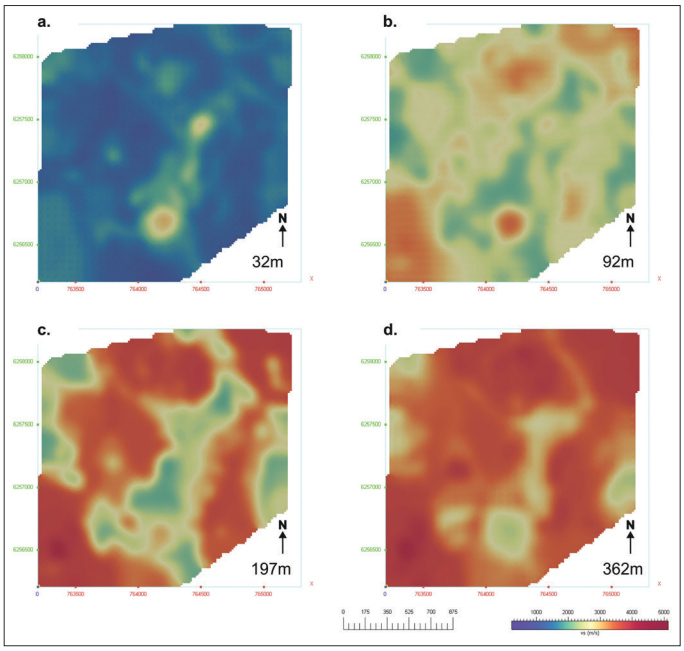

Figure 5. *Depth slice images of the ANT velocity model. All depth slices have the same cumulative distribution function colour stretch. a. 32 m depth. b. 92 m depth. c. 197 m depth. d. 362 m depth.*

Discussion

Like all seismic methods, ANT is sensitive to variations in seismic velocity. Velocity is modulated by density, porosity and mineralogy and can be influenced by the structural characteristics of the rocks being imaged. In the Alford East model, distinct intermediate velocity zones within the high velocity deeper portion of the models have a geometric arrangement that suggests they are related to structural features within the basement. Comparison between the ANT model and aeromagnetic images suggests north-east trending structures that appear to offset more north-south trending magnetic highs may be controlling the location of the prominent intermediate velocity zone in the deeper portions of the model (**Figure 6**). These intermediate to low velocity zones occur as 'troughs' in the model, that extend in places to depths of some 250 to 300 m.

Interestingly, the velocity model does not highlight features that correspond perfectly with the north-south trending magnetic high zones observed in the aeromagnetic image. This lack of correspondence may be indicating that the features that are responsible for the magnetic highs are deeper than the ANT model is imaging, a possibility since magnetics is a cumulative probability function with no inherent depth constraint. In support of this, we note that the magnetic intensity image is relatively diffuse on the southern magnetic high feature compared to the central magnetic high feature. Diffuse magnetic features can be caused by increasing the overburden above the rocks that are causing the feature itself. An alternative, and perhaps more likely cause, is that the abundance of magnetite in the basement rocks is controlled by stratigraphic features that are either too thin to be imaged by the ANT and therefore are not resolved in the model, or are disconnected from the features of the basement that control seismic velocity. In such a case, the magnetism may be reflecting a primary compositional feature of the basement rocks, be that a zone of magnetite-bearing metasomatite, or metasedimentary rock (Wallaroo Group). However, the predominant control on the seismic response of the basement is a result of a process that has overprinted the primary rock type. The correspondence of the north-east trending intermediate velocity zone in the basement, with the similarly trending features that dissect the magnetic intensity image is strong evidence that the zone of depressed seismic velocity relates to faults or shear zones that overprint the north-south trending basement geology.

The ANT model therefore provides a complimentary image of structural features that are seen in the magnetic data, and highlights the north-east trending structures in the basement as significant controls on the seismic velocity profile of the survey area. The persistence of this north-east trending feature into the upper portions of the model also suggests it has its origin in the structural geometry of the basement itself. The likely increase in

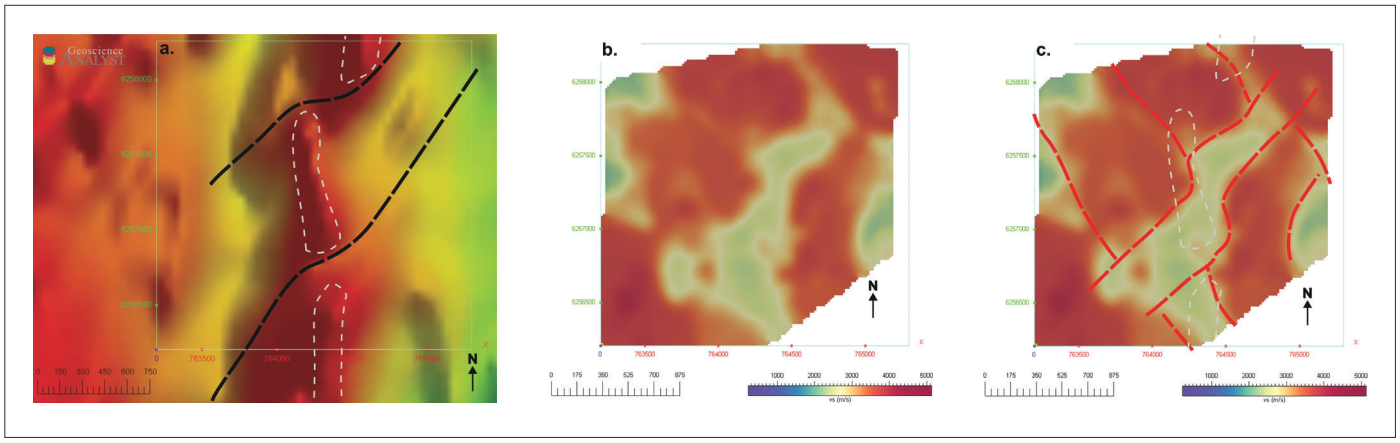

Figure 6. *Comparison between aeromagnetic intensity image and ANT model with interpretation of structural features. a. Magnetic intensity image across the survey area. Dark dashed lines represent possible north-east-trending fault set that appears to offset the more north-south-trending magnetic layering. Outline of the magnetic high features is shown in a light grey dashed line. b. ANT model at depth slice of 320 m. c. Structural zones interpreted from the ANT model traced by red dashed lines. Prominent north-east trending features appear to be influenced by (offset) the less prominent, narrower north-west trending features. Also shown is the trace of the magnetic high outlined from the magnetic intensity image.*

seismic impedance in the upper portion of the model compared to the surrounding low velocity suggests that this zone has relatively lower porosity than the adjacent material. Drill hole information indicates the lowest velocity zones are where the substrate is cover material such as Eocene sands, or is intensively weathered saprolite. Within the upper zone of the main north-east trending feature, however, the drill hole intersections are predominantly of highly weathered basement. This suggests the cover-basement interface is elevated in the region of the north-east trending feature, or that the weathering mineralogy is different in this zone to the surrounding areas. In terms of the model of supergene enrichment, it is possible to envisage that the relatively high velocity zone in the uppermost portion of the model may be indicative of the presence of minerals such as iron oxyhydroxides that can form in the leached cap zone above areas of supergene enrichment (Reich and Vasconcelos 2015). The leached cap may be expressed as a zone of increased seismic velocity perhaps as a result of greater interconnectivity of iron minerals and associated clays that result in the relative reduction in porosity of this zone compared to the adjacent saprolite.

Structural geometry of the ANT model and relationship to mineral resource estimate

A comparison between the ANT model and the shells defined by mineral resource estimate drilling shows that areas of enriched copper grade tend to be spatially related to zones of intermediate velocity (**Figure 7a**). In particular, the zone of enhanced grade known as AE-8 (NP) sits very clearly within the upper portion of the main north-east-trending zone of anomalous velocity. The resource drilling shows that the copper and gold mineralisation and associated REE grades are concentrated near the surface and extend down to depths of at least 200 m. The seismic velocity beneath the defined mineralisation shell remains relatively lower than the adjacent country rock at greater depths suggesting the structure that controls the seismic velocity continues to depth. This further supports previous inferences that there is a structural control on the supergene processes that have localised copper and gold mineralisation in the Alford East project area (Wynne et al. 2019).

The ANT model suggests similar seismic velocities extend across the model to the south-west and overlap a second pod of mineralisation defined as AE-5 (**Figure 7b**). Between the AE-8 (NP) and AE-5 pods, no significant mineralisation has been yet encountered in the drill holes. The ANT velocity model suggests that the structure that appears co-located with the other pods of mineralisation is continuous across the area and this area could be a target for further drilling.

Drilling results show that the highest-grade mineralisation is commonly hosted in sheared pelitic and carbonaceous metasedimentary rocks, particularly in areas AE-6, -7 and -8. The sheared nature of the metasedimentary rocks and later fault sets have likely facilitated deeper weathering and alteration of the basement, reflected in the lower seismic velocity beneath the defined mineralisation zones. By way of contrast, mineralisation in area AE-5 is predominantly in proximity to fault zones within interlayered dioritic and felsic intrusives, with lesser pelitic sediments. It may be that these host rocks are more competent and therefore brittle and oxide mineralisation may be therefore more concentrated along fault zones. The abundance of diorite in the bottom of the holes in area AE-5 may help to explain the relatively high seismic velocity in the ANT model beneath this zone of mineralisation, compared to some of the other mineralisation zones.

Comparison to airborne electromagnetic data

An airborne electromagnetic (AEM) survey data is publicly available across the Alford East project area. The survey was flown by Fugro Airborne Surveys for the South Australian Government in 2012 using the TEMPEST system (Lane *et al.* 1999, 2000). Note that the resolution of the AEM is less than the ANT survey because the AEM was flown for a regional survey, with flightline spacing of approximately 140 m. The AEM model shows the uppermost layers at depths around 20 m are conductive, with trends of conductivity in a similar north-northeasterly orientation to that identified in the ANT (**Figure 8**). The AEM also identifies a larger region to the east of the defined mineralisation pods that is similarly conductive at these shallow depths. The cause of this conductivity is uncertain; it may be groundwaters residing

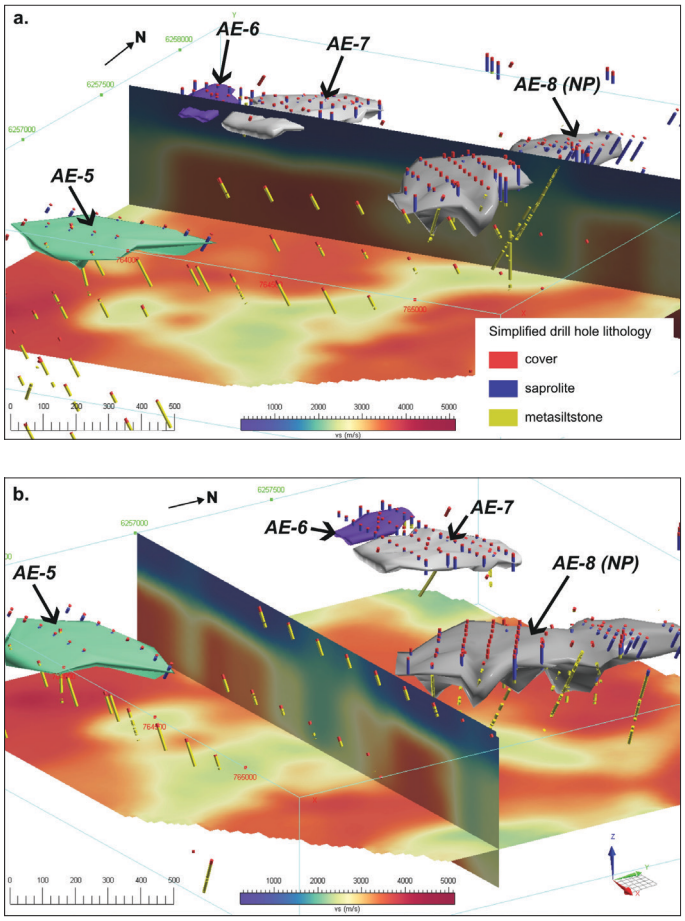

Figure 7. *ANT velocity model with mineral resource estimate shells and drill hole traces. Horizontal slice is at 317 m depth. a. View of the AE-8 (NP) mineralised pod, and cross section through the model highlighting co-location of the relatively low seismic velocity in the vicinity of AE-8 (NP) and the abundant drill holes with highly weathered lithology (saprolite). b. Alternative view of the ANT model with cross section following fence of drill holes in the central part of the survey area that do not show enhanced saprolite development.*

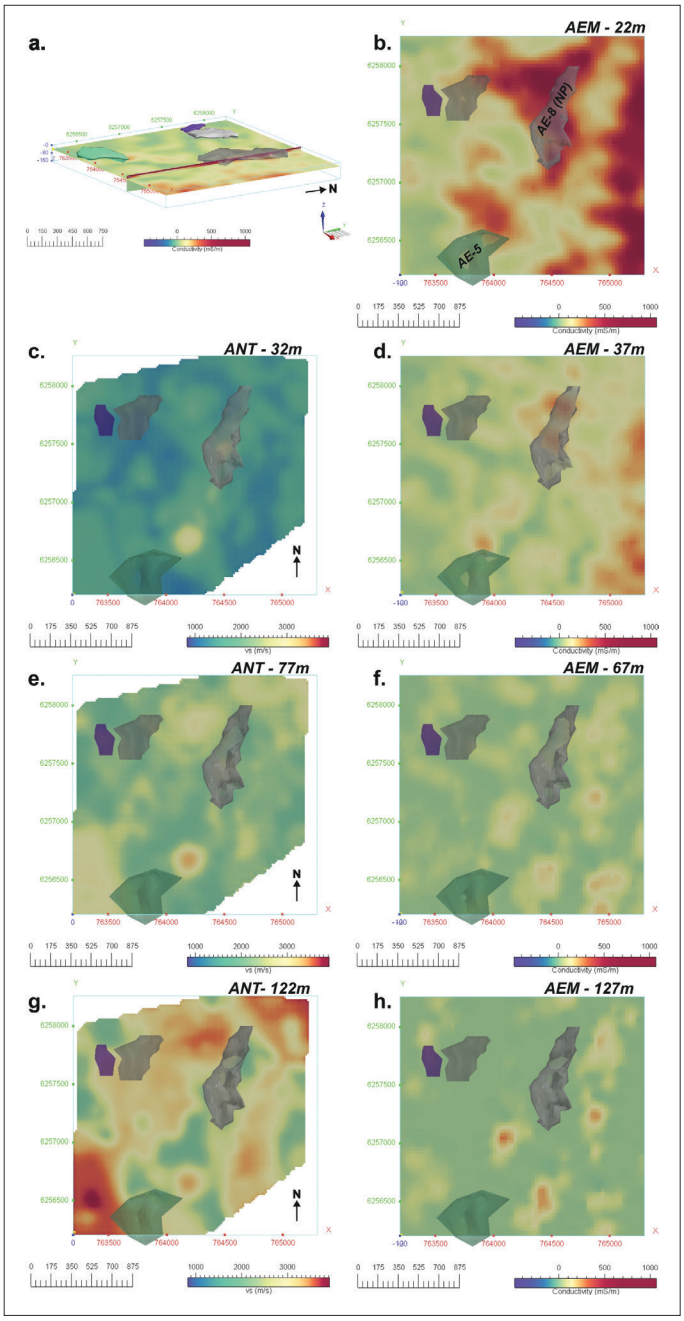

Figure 8. *Comparison of AEM and ANT results over the ANT survey area of the Alford East project. Note that the AEM results have been clipped to the bounds of the ANT survey area and are part of a much larger survey, available via SARIG https://catalog.sarig.sa.gov.au/geonetwork/srv/eng/catalog.search#/metadata/ae186f4c-30fa-476a-a159-74d2eb8bf5cc. The colour stretch for both the AEM and ANT results are cumulative distribution functions. Depth values are given relative to the surface. a. 3D view of the AEM survey results with the coppershells defined by Thor Energy PLC. b. AEM depth 22 m. c. ANT depth 32 m. d. AEM depth 37 m. e. ANT depth 77 m. f. AEM depth 67 m. g. ANT depth 122 m. h. AEM depth 127 m.*

in fractured and weathered bedrock. By depths of around 70 m – 80 m, the AEM signal is subdued, becoming more so towards the model's maximum depth of around 156 m. The comparison suggests that conductive cover material, possibly residing in the weathering zone, may be masking any signal for the deeper portions of the AEM model. In the case of targeting supergene oxide zones, AEM is less useful since the oxide is less conductive, however, if deeper supergene zones of sulphide were present, they may be able to be imaged. An interesting confluence of relatively high EM response in the zone between the AE-8 (NP) and AE-8 copper shells that follows a similar trend to the relatively low velocity features in the ANT model may add further interest to these zones as areas for future exploration interest and highlights the complementarity of having geophysical methods that target different physical properties of the subsurface.

Conclusions

The purpose of the Alford East ANT survey was twofold, to image basement-cover interface and any structure within the basement that may be controlling the location of deeper troughs of weathering and potential supergene enrichment. Both of these aims have been achieved, and the resulting 3D model has provided a complimentary view on the subsurface geology to the other available geophysical surveys. The velocity model has imaged the thickness of the cover sediments, with depths of the low velocity upper portion of the model correlating well with cover thicknesses from available drill hole data. In the Alford East example, the ANT survey provides a depth-constrained view of the subsurface geology, in an area

that is entirely concealed beneath Cenozoic sediment and soils. In particular, the zones of low velocity at shallow depths, in the range of 70 m approximately, largely correspond to regions that are dominated by pelitic metasedimentary rocks.

In the Alford East project area, troughs of deeper weathering across the region are the focus for supergene enrichment of copper and gold. These troughs appear to be structurally controlled, as they are of a similar orientation to faults in the underlying, metasomatised metavolcanic and or metasedimentary rocks, part of the highly mineralised eastern Gawler Craton. These troughs appear to be imaged as zones of lower seismic velocity in the ANT model. A key feature of the model is the presence of low velocity trends extending from the bottom of the model into the surface cover sequence, which supports the notion that these zones are structurally controlled.

The ANT method images contrasts in seismic velocity. Having been developed and utilised in regional and crustal-scale studies, the method is now becoming increasingly applied to mineral exploration problems. The method is complementary to other geophysical techniques, providing a view of the subsurface that is both sensitive to lithology and structure. The ANT survey at the Alford East project is an example where a zone of supergene enrichment that is blind at surface correlates with zones of decreased seismic velocity in the basement that correlate with broad trends of faults that are also mapped from aeromagnetic images. This has expanded the available search space for supergene enrichment in this project area and provides an example of the utility of the method in cases where mineralisation is associated with any process that modifies the seismic velocity of the mineralised rock volume compared to the country rocks.

Acknowledgements

Fleet Space Technologies acknowledges the work of the Thor Energy PLC team, and the previous explorers in this region, who have provided the geological controls on the known mineralisation. We acknowledge the work of the field crews who deployed the ANT Geodes. We also acknowledge Nick Smith and Angel Ramos for their assistance, and the anonymous reviewers and *Preview* Editor Lisa Worrall for their efforts. Mineral Resource Estimates are provided by Thor Energy PLC, details of which can be found at https://thorenergyplc.com/.

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The history of airborne radiometric surveys over the nuclear test range at Maralinga and a call for a new survey

Pat Cunneen
E pat@cunneen.biz

Introduction

On 17 March 1992, as Managing Director of World Geoscience Corporation, I instructed our airborne geophysics team in South Australia to overfly the Maralinga atomic test range. Maralinga is north of Ooldea on the Trans Australia Railway Line. I instructed the crew to fly low and slow and to set the spectrometer to best observe any gamma rays which might be emitted from the 36-year-old ground zero sites.

The first flight was a great surprise; the radiation, measured in counts per second, was 'through the roof' to the extent that the crew became slightly worried about their exposure levels.

After reviewing our own data, and all the airborne radiometric surveys since the end of testing 70 years ago, it is apparent that after all this time Maralinga has not yet been properly surveyed. A low-level close line spaced modern survey would be of great assistance to the management of the range. The raw WGC data have been lost in company takeovers and exist today only as slides salvaged by Greg Street, and the official contour maps of radioisotopes are copied from reports. Re-processing of the regional 2018 Gawler Craton survey data by Pavel Jurza, and of the 2005 SADME survey by Joe Kita, serves to illustrate how much better a new survey would be.

Background

From 1952 until 1963 the British Government exploded twelve plutonium implosion type atom bombs in Australia, seven at Maralinga in South Australia (**Table 5**). The devices were of the type exploded for the first time in the Trinity test in Los Alamos in New Mexico in June 1945, and a few months later at Nagasaki in Japan. It was on 27 September 1956 that the British exploded the first of the seven nuclear fission devices. The last took place on 9 October 1957.

Several hundred 'Minor Trials' involving fissionable material were also carried out at Maralinga. The 'Minor Trials' used explosives to blow up nuclear warheads containing plutonium, to simulate what would happen in an air crash. Also, twelve tests were conducted at the Taranaki site in 1960, 1961 and 1963, resulting in it becoming the most contaminated site at Maralinga. The tests were conducted on steel structures known as 'feather beds'. The tests produced jets of molten, burning plutonium extending hundreds of feet into the air. The damage to the feather beds and their concrete stands was much greater than anticipated, and a new feather bed was used for each round. At the conclusion of each test, all the debris was buried in nearby pits. Eventually there were 21 pits containing 830 t of material. Uranium and beryllium were similarly exploded.

Gamma ray spectrometers mounted in aircraft were not available to the British in 1967, when they first attempted to clean up the Maralinga site. It was reported that they attempted to measure ground deposition associated with the detonations, but the plume did not coincide with the sampling array. The monitoring results obtained after the event contained systematic errors greater than a factor of ten as a result of the methods used. A comparison between the levels reported by the UK at the time and the field results reported by Australian Radiation Laboratory (Lokan 1985) demonstrated an underestimate of the plutonium contamination by about an order of magnitude (MARTAC 2003).

After many ineffective clean-up attempts and a Royal Commission (Royal Commission into British Nuclear Tests in Australia 1985), the Australian Government appointed a Technical Advisory Group (TAG) to recommend final rehabilitation procedures. The TAG recommended, among other things, an airborne radiometric survey, an airborne magnetic survey and a ground geophysical survey (Australian Atomic Energy Commission 1985). They highlighted plutonium contamination as a major concern. The two latter recommendations were ignored, apart from some sporadic ground spectrometer surveys along roads and fence lines. However, the US Department of Energy was commissioned, in 1987, to conduct an airborne radiological survey. It sub-contracted EG&G Energy Measurements Inc, the manager of its nuclear test facility in Nevada, to fly the survey.

Details of surveys

Apart from the survey by EG&G, four other radiometric surveys were undertaken over Maralinga, between 1992 and 2018, for diverse purposes (**Table 1**).

Fallout and detection of soil activation isotopes

The half-lives of isotopes directly or indirectly observed by the five surveys at Maralinga are listed in **Table 2**.

The half-lives of isotopes observed by EG&G were used to calculate values at the time of subsequent surveys. The specifications of the AGSO survey were such that only caesium 137 was detected. WGC and AGSO could not detect americium-241 because the lower level of the total count window was set too high at 300 keV, which was normal for geological surveys of naturally occurring elements.

Maximum activity concentrations of isotopes present at the time of the surveys were calculated by multiplying the maximums observed by EG&G by an absorption factor of 1.33 (to correct for gamma rays absorbed by the soil cover) and then applying the half-life of the particular isotope (**Table 3**). Cs-137 and Co-60 concentrations declined in accordance with their respective half-lives but Am-241, with a half-life of 432 years, increased over time because its parent plutonium 241 has a shorter half-life of only 14 years (Burns *et al*. 1995).

Table 1. Details of airborne radiometric surveys over Maralinga.

Date, surveyor, and reference	Aircraft	Speed (m/s)	Line spacing (m)	Sensor height (m)	Controller	Na I Sensor (l)	Crystal layout	Energy range (keV)	Channels recorded
1987, EG&G/EM, Tipton *et al.* 1988	Wessex HC Mk2 Helicopter	30	50	30	REDAR IV	26	40x 0.65 l	38- 3026	256
1992, AGSO, Minty *et al.* 1994	Twin Otter	80	1500	150	AGSO Own Design	33	8x 4.13 l	300-3000	256 (every 100 s)
1992, WGC	Cessna 206	50	50	40	Geometrics GR800	33	8x 4.13 l	300-3000	256
2005, Fugro, Fugro 2005	Aero Commander 500S	70	400	80	Exploranium GR820	33	8x 4.13 l	0-3000	512
2018, Thomson Aviation, Thomson Aviation 2020	Cessna 210	70	200	60	Radiation Solutions RSX-4	33	8x 4.13 l	0-3000	512

Table 2. Half- lives of isotopes observed at Maralinga.

Isotope	Symbol	Half-life
Potassium 40	K-40	1.25 billion years
Uranium 238	U-238	4.5 billion years
Uranium 235	U-235	708 million years
Thorium 232	Th-232	14 billion years
Plutonium 239	Pu-239	24,100 years
Plutonium 241	Pu-241	14 years
Americium 241	Am-241	432 years
Cobalt 60	Co-60	5.27 years
Europium 152	Eu-152	13.5 years
Caesium 137	Cs-137	30.17 years

Table 3. Maximum activity concentrations in kBq/m2 of elements present at the time of each survey. Those detected are highlighted in red.

Change in activity concentrations in kbq/m² of elements over time at Maralinga						
Isotope	Half-life	1987	1992	1992	2005	2018
		EG&G	AGSO,	WGC	FUGRO	THOMSON
		Observed x 1.33	Calculated	Calculated	Calculated	Calculated
Cs-137	30.17 years	**18.6**	**16.6**	**16.6**	**12.3**	**9.1**
Co-60	5.27 years	**465**	241	**241**	**44**	**7.9**
Am-241	432 years	**133**	138	138	**149**	**159**

Data examples

In 2018 Thomson Aviation flew a survey area for Geoscience Australia (**Figure 1**) that included the Maralinga Test site. The co-ordinates of this survey, part of the Gawler Craton survey, are listed in **Table 4**.

When this (Thomson) data was reprocessed for caesium 137, plumes of this isotope could be seen streaming away from the test site (**Figure 2**).

By way of comparison with the reprocessed Thomson data, the caesium 137 data extracted from a survey flown by World Geoscience Corporation in 1992 over the area of the test range are presented. The fallout patterns illustrate the wind direction at the time of each test and the northeast, southwest direction of the sand dunes (**Figure 3**).

The ground zero sites and other information of the various tests are presented in **Table 5**.

Figure 1. *The R1B area flown by Thomson Aviation over Maralinga in 2018.*

Table 4. Coordinates of Thomson Aviation survey over Maralinga (area R1B) in 2018 (Thomson Aviation 2020).

Longitude	Latitude
131.5°	-29.5°
133.5°	-29.5°
133.5°	-30.5°
131.0°	-30.5°
131.0°	-29.65°
131.5°	-29.65°

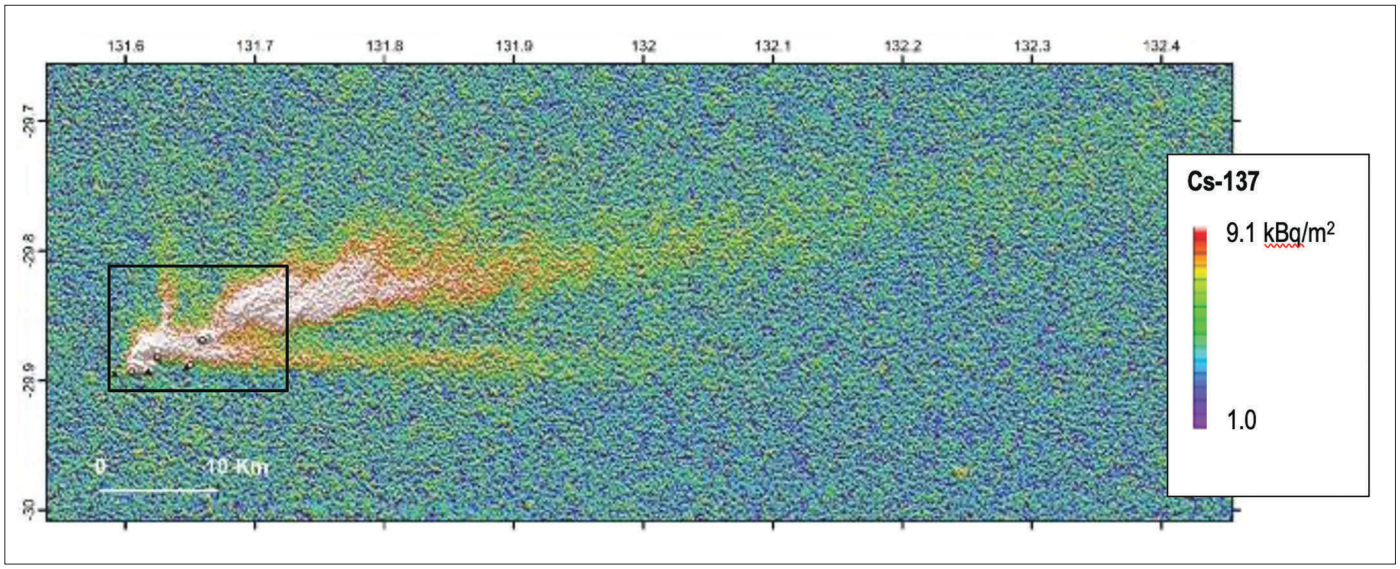

Figure 2. *Caesium 137 Thomson Aviation 2018 survey with calculated activity concentrations in kBq/m². Ground zero sites are indicated with small circles and triangles. The square marks the test range (data and image processing by Pavel Jurza).*

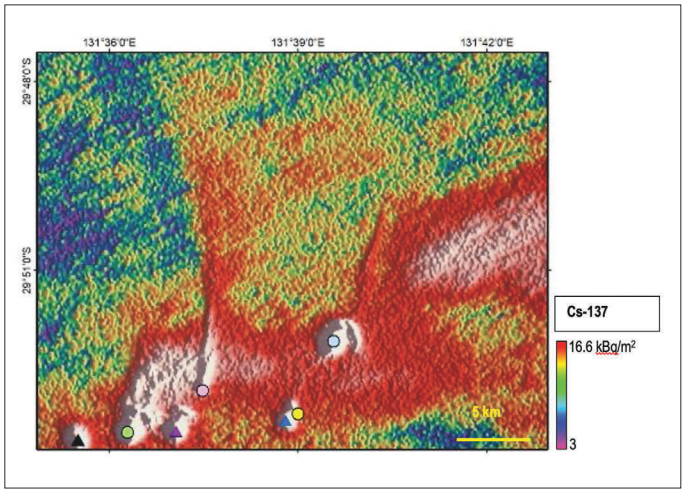

Figure 3. *Caesium 137 image from World Geoscience Corporation's 1992 survey over the test range. Ground zero sites are named and indicated with circles and triangles as in Table 5. The activity concentrations in Becquerels per square metre are indicated in the colour bar. The northeast-southeast striations are due to sand dunes.*

Table 5. Details of the nuclear explosion events (atom bombs) at Maralinga between 1956-1957 with series, dates and yields.

Symbol	Series	Ground zero site	Date	Yield (kt)
●	Buffalo	One Tree	27/9/1956	15
●	Buffalo	Marcoo	4/10/1956	2
●	Buffalo	Kite	11/10/1956	3
●	Buffalo	Breakaway	22/10/1956	10
▲	Antler	Tadje	14/9/1957	1
▲	Antler	Biak	25/9/1957	6
▲	Antler	Taranaki	9/10/1957	27

Systems, surveys and processing

The data collection and processing of the five surveys could be seen to fall into two distinct categories. The first survey by EG&G is a 'Military' type. The EG&G Redar IV was built solely to measure man-made radioisotopes whilst 'Modern' systems were designed to discover uranium ore for the nuclear reactors and are observed to be more sophisticated.

EG&G/ Energy Measurements, Inc.

The first survey was conducted in 1987 by EG&G/Energy Measurements Inc (EG&G), who were contracted by the United States Department of Energy on behalf of the Australian Government. Cosmic radiation, the naturally occurring radiation from potassium, uranium and thorium, the Compton continuum, variations due to aircraft radiation, humidity and aircraft height were treated as 'noise' to be eliminated. This was achieved by dividing the 'Signal Window' containing the gamma photopeak of the desired element by an adjacent, higher energy 'Background Window' (**Table 6**).

The Signal Window 38 keV-74 keV for the americium photopeak at 59.5 keV was lower in the energy spectrum than windows typically employed by all but the most recent of 'Modern' spectrometers. EG&G also conducted a ground survey to calibrate the airborne data. They employed a high purity

Table 6. The 'Signal Windows' EG&G used to capture isotopes and the 'Background Windows' by which they were divided (Tipton *et al* 1988).

Isotope	Signal Window keV	Background Window keV
^{241}Am.	38-74	74-102
^{137}Cs	590-734	734-854
^{152}Eu, ^{60}Co	974-1550	1550-3026

germanium detector for this purpose (**Figure 5**). Each spectrum reading took 10 minutes and there were 100 such readings. The Signal Windows are superimposed on one of the spectrums taken at the Taranaki site shown in **Figure 6**.

EG&G aircraft and equipment

The crystals were assembled in two pods mounted below a British Wessex helicopter.

A military system

Data was collected from 0 keV to 3026 keV in 256 channels. EG&G used their proprietary Redar IV system linked to forty sodium iodide thallium doped (NaI(Tl)) crystal surface area 330 cm^2 and volume 645 mL making 26 litres of crystal total. The large number of small crystals was used to increase sensitivity.

The first detector array was composed of 39 detectors to achieve adequate sensitivity (**Figure 7**). A second was composed of only one crystal to be interrogated when the radiation was too high for the first array. Each detector was 12.7 cm diameter x 5.1 cm deep - volume 645 ml.

The volume of NaI in the first array was 39 x 0.645 litres (25.2 litres) and the surface area 1.3 m^2. The volume of the single crystal detector was 645 ml with a surface area of 330 cm^2.

The crystals were kept under power 24 hours a day to keep them at constant temperature (changes in temperature can cause gain shift moving a photopeak out of its window.)

The small, thin sensors increased the sensitivity by allowing most of the incident photons to escape before they caused Compton scattering, however, practicality demanded that a single photomultiplier must serve nine or ten crystals making it almost impossible to track the drift in gain for each crystal in 39 of the crystals. The fortieth detector had its own photomultiplier. Drift in the gain was somewhat controlled by keeping the system at constant temperature but the system was inherently noisy. Calibrations were performed before and after flight using americium 241 and sodium 22 sources.

Survey specifications

The lines were either 50 m or 100 m apart east-west and the height was 30 m. The airspeed was 30 m/s

Processing

Gamma emissions from naturally occurring elements of potassium, uranium and thorium, together with cosmic rays

Figure 5. *High purity germanium detector at Taranaki (Tipton* et al. *1988).*

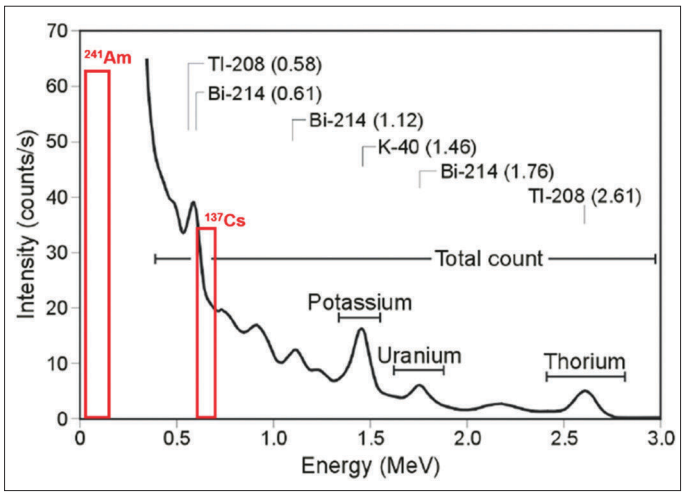

Figure 4. *A typical gamma ray spectrum illustrating 'windows' used to measure total count, potassium, uranium and thorium in a geological survey and Cs-137 and Am-241 from nuclear experimentation. Note the position of the photopeak for Cs-137 (0. 662 MeV) partially overlapping the Bi-214 at 0.609 MeV. The Am-241 photopeak at 0.0595 MeV is too low in the energy spectrum to be observed by typical survey instruments which are set at higher energies to capture naturally occurring radiation (Minty* et al. *1997).*

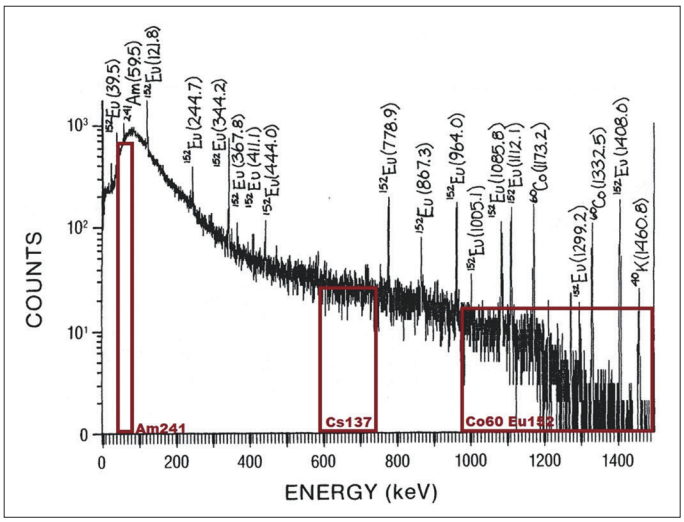

Figure 6. *Gamma ray spectrum from a high purity germanium detector - set at one metre above the ground at Taranaki bomb site and measured for a period of 10 minutes. Windows of investigation as selected by EG&G for the processing of data from their airborne survey for Am-241, Cs-137 and combined Co-60 and Eu-152 are indicated. Note K-40 peak at 1406.8 KeV is included in this signal window (Tipton* et al. *1988).*

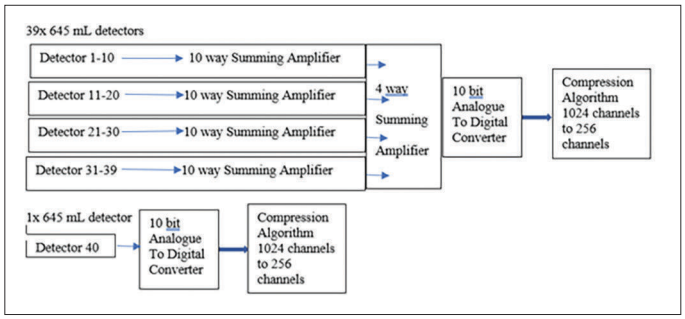

Figure 7. *Block diagram of the Redar IV military system (Tipton* et al. *1988).*

the Compton continuum, background contamination from the aircraft and atmospheric conditions were eliminated by dividing the 'Signal Window' readings by an adjacent higher energy 'Background Window' to determine a constant **K** (the relationship had been empirically observed to be a constant)

The signal response **S** in counts per second was taken to be as follows:

S=A-KB.

Where **A** is the signal window and **B** is the Background window.

In the absence of radioisotopes, the signal response oscillates around a zero baseline. The presence of an isotope caused the baseline to rise above zero.

The raw data were then subjected to two filters. The first was a simple along line three part moving average. The second involved 24 adjacent readings (6 points along line across four lines) averaged to give just one reading for an area of 200 m by 200 m. Due to distortions introduced by this second step the results obtained were only used to define the outer edges of the plumes.

The activity concentrations were then calculated and corrected to make them consistent with the values obtained by the carefully conducted ground surveys. The data were then presented as hand contours (Tipton *et al*. 1988).

Results

The contour maps for caesium 137 (**Figure 8**) and americium 241 (**Figure 9**) are shown as presented by EG&G in their report (EG&G 1988). Caesium 137 is a fallout product. Americium 241 plumes are largely the result of plutonium metal ejected explosively in the Minor trials. Cobalt 60 and europium 152 are neutron (or soil) activation products created when the sand directly beneath the nuclear blast is bombarded by neutrons. Europium 152 proved impossible to extract due to its many photo-peaks. Cobalt 60 counts were separated by special methods which were not detailed by EG&G and are not shown (Tipton *et al.* 1988).

Conversion of americium 241 to plutonium 239

In 1989 the Australian Radiation Laboratories determined the Pu-239 to Am-241 activity ratio at Maralinga to be 7.4 ± 0.6. The ratio changes with time because the amount of Am 241 increases for over 70 years from its creation in the nuclear reactor due to its parent Pu-241 (half- life 14.4 years) decaying faster than the daughter Am-241 (half- life 432 years).

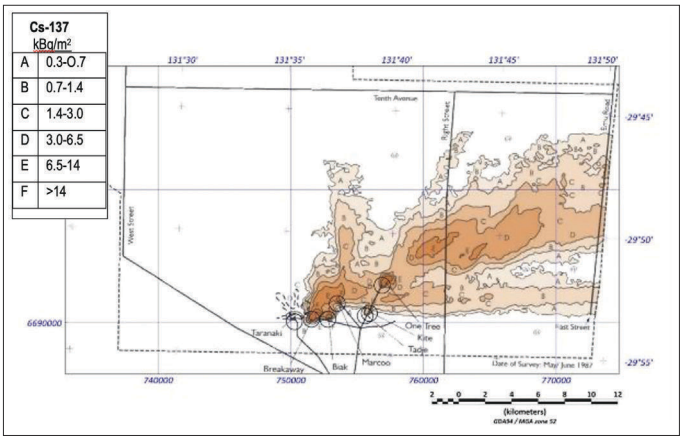

Figure 8. *Caesium 137 from EG&G 1987 survey (Tipton* et al. *1988).*

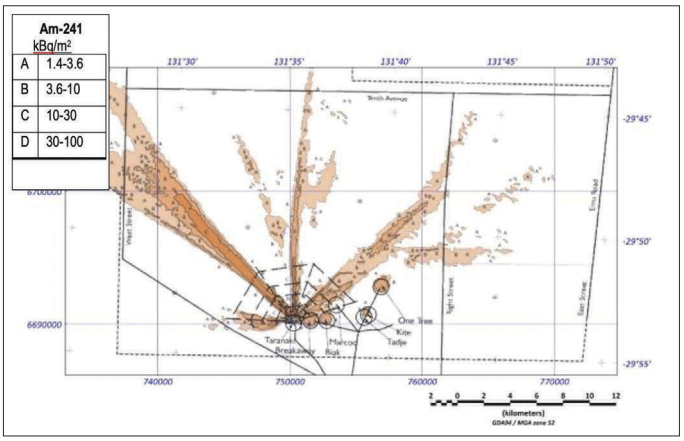

Figure 9. *Americium 241 from EG&G 1987 survey. Four contour levels are used, and ground zero sites are annotated (Tipton et al. 1988).*

In 2002 the Maralinga Technical and Rehabilitation Commission determined a ratio of 6.9 ± 1.2 and calculated that in 1985 the ratio would have been 8.3 ± 1.4 rather than 7.4 ± 0.6.

Before the activity ratio is applied the gamma radiation seen on the surface must be multiplied by 1.33 which is the 'Absorption Factor' This is the correction to take account of the absorption of a portion of the 59.5 keV gamma rays in the soil. By applying an absorption factor of 1.33 and an Pu-239/Am-241 factor of 8.3 we can convert airborne Am-241 observations in 1987 to Pu-239 activity ground concentrations in 2018 (**Table 7**).

Table 7. Activity concentrations in kBq/m² of Am-241 in 1987 and Pu-239 in 2018 at Maralinga.

Am241 and Pu239 activity concentrations in kBq/m²				
	Am-241 1987	**Am-241 1987**	**Pu-239 1987**	**Pu-239 2018**
	Surface observed	**Surface X 1.33 absorption factor**	**Pu-239/Am-241 X 8.3 activity ratio**	
A	1.4-3.6	1.86-4.79	15.4-39.8	15-40
B	3.6-10	4.79-13.3	39.8-110.4	40-110
C	10-30	13.3-39.9	110.4-331.2	110-331
D	30-100	39.9-133	331.2-1,103.9	331-1,104

Modern systems

AGSO (1992), WGC (1992), Fugro (2005) and Thomson (2018) surveyed with modern spectrometers and processed the data with computer gridding and contouring followed by image processing. These systems and methods were first employed by an Australian Company, Austirex, in Iran in 1976 when they installed a Geometrics GR-8000 gamma ray spectrometer combined with a Geometrics 50 litre main pack detector and 8 litre upwards-looking detector (Richardson 2021). 256 channels were acquired, and the data were computer contoured and image processed. Later Austirex became a subsidiary of World Geoscience, who used their processing package on the Maralinga data.

In 1976 EG&G bought Geometrics Inc and formed EG&G Geometrics which they held until 1997 when they sold it to OYO of Japan. Therefore EG&G, through their subsidiary EG&G Geometrics, were manufacturers of modern spectrometers at the time of the Maralinga survey but chose to use the Redar IV. At the time EG&G/Energy Measurements Inc. were managers of the US government's nuclear test facility in Nevada and were experienced in mapping radioisotopes (Briener 2024)

Modern spectrometer systems have generally similar architectures, employing eight large (4196 mL) hexagonal Sodium Iodide (thallium activated) crystal detectors making 33.6 litres in total. The systems are continually stabilised by locking on to naturally occurring photo peaks. The output of each sodium iodide crystal is computer controlled with automatic gain correction. Each block of four crystals has its own Data Processing Unit (**Figure 10**).

The AGSO (Geoscience Australia) 1992 airborne survey

Equipment

AGSO collected data from 300-3000 keV in 256 channels restricted to four windows

The spectrometer was an Exploranium GR800 with 8 NaI(Tl) 4.2 litre detectors making 33.6 litres in all. The equipment was mounted inside a Beechcraft Twin Otter aircraft. Each detector had its own photomultiplier.

Surveying

In 1992 AGSO was flying the Maurice 1:250 000 sheet in South Australia as part of the coverage of Australia.

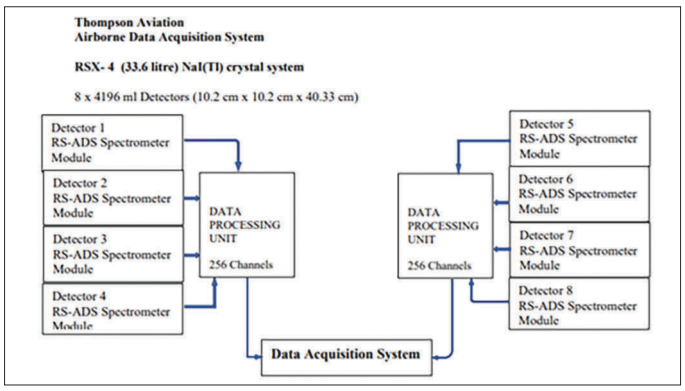

Figure 10. *Block diagram of a modern RSX-4 spectrometer with 33.6 litres of NaI (Tl) crystal sensor (Thomson Aviation 2020).*

The flying height was 100 m and the line spacing was 1500 m. The direction was east west. The airspeed was 70 m/s. 4 windowed channels were recorded. 256 channels were recorded every 100 s (summed over the previous 100 s).

Processing

When the data processors began the routine removal of radiation from radon gas, they discovered an elevation of the background total count window in the order of 150% over Maralinga. Suspecting the influence of Cs-137 (photopeak 662 keV) on the radon daughter photopeak Bi-214 (609 keV) (**Figure 4**) they determined to test for Cs-137. Brian Minty and Ross Brodie devised a simple method of isolating man-made elements from naturally occurring elements. They first created a pseudo total count window by exposing the sensors of the spectrometer to clean radioactive sources of potassium, uranium and thorium. This was done on the ground. The sensors were partially shielded with wood panels to simulate the attenuation of response to be expected from an air column of 100 m, which was the flying height of the aircraft. The three spectra were normalised with observed counts from the survey and then summed. The pseudo total count obtained thereby was subtracted from the observed total count to yield man-made isotopes.

Results

The procedure was successful in isolating Cs-137 (**Figure 11**). The plume of Cs-137 was estimated to be about 10 km long. Neither americium, cobalt 60 or europium 152 was observed (Minty *et al.* 1994).

The World Geoscience (WGC) 1992 airborne survey

In 1992 WGC was in the vicinity Maralinga area and decided to fly the test range on their own initiative.

WGC equipment

WGC collected data from 300-3000 keV in 256 channels. The spectrometer was an Exploranium GR800. A data acquisition system interrogated two crystal packs each containing four

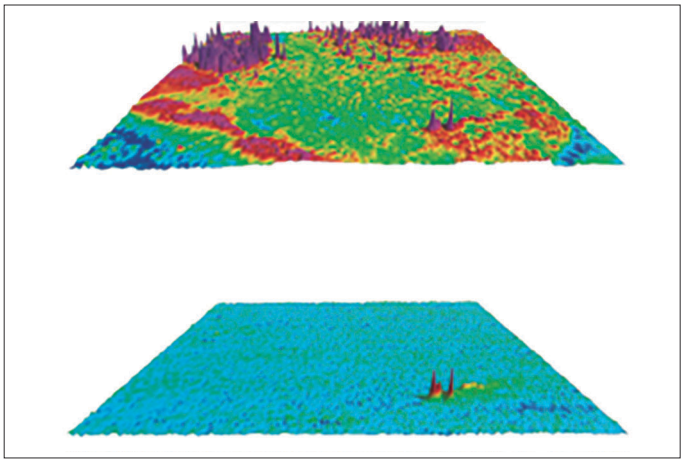

Figure 11. *AGSO 1992 survey: Perspective image of stacked profiles of the total count in part of the Maurice 1: 250 000 sheet showing the observed data in the top image and the extracted Cs-137 image in the bottom image. The plume from the Maralinga site extends to the northeast for an estimated 10 km (Minty* et al. *1994).*

rectangular blocks measuring 10.2 cms x 10.2 cms x 40.33 cms. The volume of NaI(Tl) crystal was 33.56 litres with a surface area of 1.482 m^2. The equipment was mounted inside a Cessna 206 aircraft. Each of the eight detectors had its own photomultiplier

Surveying

The flying height was 40 m and the line spacing was 80 m. The direction was east west. The airspeed was 70 m/s. 256 channels were recorded every second.

Processing

With access to the EG&G report WGC decided to use identical signal windows (**Figure 6**).

The Cs-137 window selected for processing was 590 keV to734 keV and the window at 974 keV to1550 keV was selected to capture Co-60 and Eu-152. Am-241 was not detected as the spectrum measured began at 300 keV and was much higher than the Am-241 photopeak at 59.5 keV.

Results

The caesium 137 window (590 -734 keV) contained only one strong peak. The counts as measured were divided by those captured in the K40 window (1370-1570 keV) to achieve a caesium/potassium ratio. The actual concentration value for caesium was calculated from the observed values obtained by EG&G in 1987 with half-life calculations for 1992 applied (**Figure 12**).

The neutron activation products cobalt 60 and europium 152 were processed using a broad window (974-1550 keV) that captured the photo peaks of both elements. The results were presented in the original cps which ranged up to 16 000 (**Figure 13**).

The images obtained were draped over topography from a SPOT satellite image showing roads, vegetation and sand dunes.

The Fugro 2005 airborne survey

The Pace One Tree survey was flown by Fugro Airborne Surveys for Geoscience Australia

Equipment

Fugro collected data from 0-3000 keV in 256 channels. The spectrometer was an Exploranium GR 820. A data acquisition system interrogated two crystal packs each containing four rectangular blocks measuring 10.2 cm x 10.2 cm x 40.33 cm. The volume of NaI(Tl) crystal was 33.56 l with a surface area of 1.482 m^2. The equipment was mounted inside an Aero-Commander 500S aircraft. Each of the eight detectors had its own photomultiplier.

Surveying

The flying height was 80 m and the line spacing was 400 m. The aircraft speed was 70 m/s.

The survey contained 36 141 line km flown as one area over 51 flights. The area lies within the Ooldea, Nullarbor, Maurice, Barton and Tallaringa 1:250 000 map sheets (Fugro 2005).

Processing

An area over Maralinga was excised from the survey and a window from 0.600 keV to 0.700 keV (raw spectrum channels

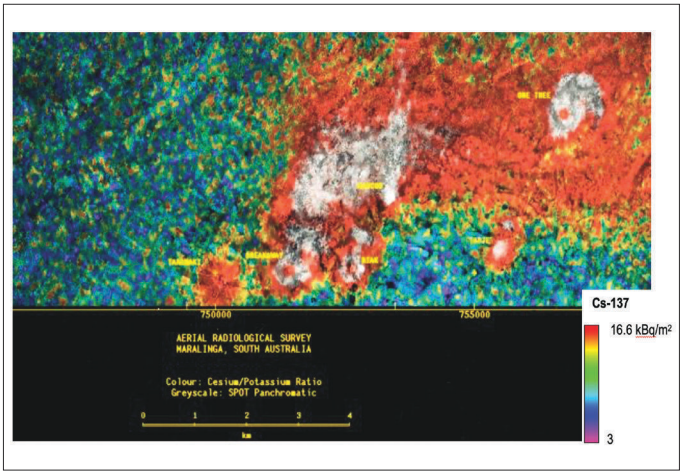

Figure 12. *Ratio of caesium/potassium WGC 1992. Raw counts in the 590 -734 keV window were divided by the counts in the 1370-1570 keV window. Concentration values for caesium 137 in Bq/m^2 are indicated with values calculated from those observed in 1987. Image overlays SPOT panchromatic satellite image.*

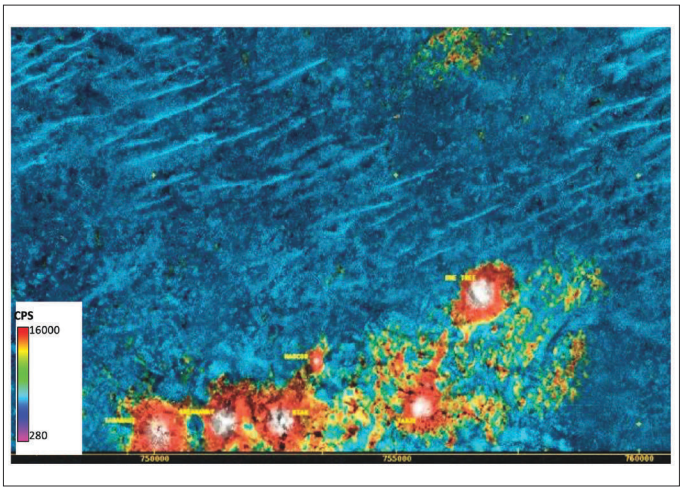

Figure 13. *Image of neutron activation elements products cobalt and europium presented as an aggregate from the 1992 WGC survey. The nuclear test sites are labelled. The chosen window (974-1550 keV) contains five photo-peaks of Eu-152, two of Co-60 and one of K-40. The activity of these elements is measured in counts per second. The background topography is a monochrome SPOT satellite image. Roads, bushes and sand dunes are visible.*

55, 56 & 57) was chosen to capture the Cs-137 peak at 0.662 keV divided by a raw potassium window (1.370 MeV to 1.570 Mev) For caesium activity concentration a half-life decay of 30.17 years from the 1987 values to 2005 was applied (**Table 3**). The data was presented as an image (**Figure 14**).

The Thomson Aviation 2018 airborne survey

The Thomson Aviation Gawler Craton Survey was flown for Geoscience Australia.

Equipment

Thomson Aviation collected data from 0-3000 keV in 256 channels. The spectrometer consisted of two linked RSX 4 systems. The data acquisition system interrogated two crystal packs each containing four rectangular blocks measuring

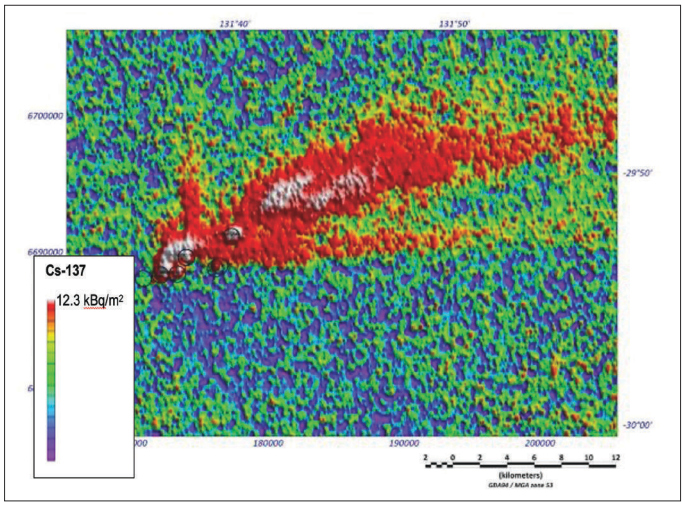

Figure 14. *Fugro 2005 survey. Cs-137 activity derived from Cs-137/K-40 ratio normalised from EG&G values. Ground zero sites indicated by circles (processed by Joe Kita).*

10.2 cm x 10.2 cm x 40.33 cm. The volume of NaI(Tl) crystal was 33.56 litres with a surface area of 1.482 m^2. The output of each sodium iodide crystal was computer controlled with automatic gain correction. Each block of four crystals had its own Data Processing Unit. The equipment was mounted in a Cessna 210 aircraft.

Surveying

The flying height was 60 m and the line spacing was 200 m. The aircraft speed was approximately 70 m/s.

Processing

In processing the Thompson Aviation 2018 survey the full spectrum processing method was employed involving the Praga-4 full spectrum processing extension of Geosoft Oasis Montaj software. The Cs-137 photopeak at 66.2 keV was extracted directly by full-spectrum fitting method, whilst a ratio of Signal Window and Background Window was used to extract the Am-241 response. The Signal Window around 59.5 keV was set to 6-80 keV whilst the Background Window was set to 100-180 keV.

The weighted least-square fitting process uses a set of detector adjusted model responses to find contributions of individual nuclides to the input spectrum. Corrections for scattering and attenuation by air column are included in the design of the detector model response.

Results

The caesium 137 image is illustrated in **Figure 2**. Am-241 is imaged in **Figure 15** whilst activity of Am241 was converted to those of Pu-239 by multiplying by an absorption factor of 1.33 and then by a ratio Pu 239/Am241 of 8.3. The new values thus obtained are illustrated in **Figure 16**. No account had been taken of the final clean up at Taranaki. This will clearly distort the calculations as the higher values will be absent in the cleaned-up area. The values can only therefore be indicative.

The americium contour map of Maralinga was compiled by EG&G in 1987 (**Figure 9**) before the major clean-up of the early 1990s. The **Figure 16** image (processing and imaging by Pavel Jurza) is post clean up-revealing the reduction of plutonium close in to the test ground zeros (as indicated by the arrow).

Discussion

Plutonium 239

Weapons grade plutonium is created in a nuclear reactor by neutron bombardment of uranium 238. Plutonium 238, plutonium 239, plutonium 240, plutonium 241 and plutonium 244 are created in various combinations depending on the time spent in the reactor. The isotope plutonium 241 is usually about 2% of the mix. Its daughter, americium 241, has a strong gamma photopeak at 0.0595 MeV which serves to identify plutonium isotopes to a survey aircraft.

Most forms of plutonium emit alpha particles, which are not very harmful outside the body, but can be very damaging when inhaled. When plutonium particles are inhaled, they lodge in the lung tissue. The alpha particles can kill lung cells, which causes scarring of the lungs, leading to further lung disease and cancer. Plutonium can enter the blood stream from the lungs and travel to the kidneys, meaning that the blood and the kidneys will be exposed to alpha particles. Once plutonium circulates through the body, it concentrates in the bones, liver, and spleen, exposing these organs to alpha particles.

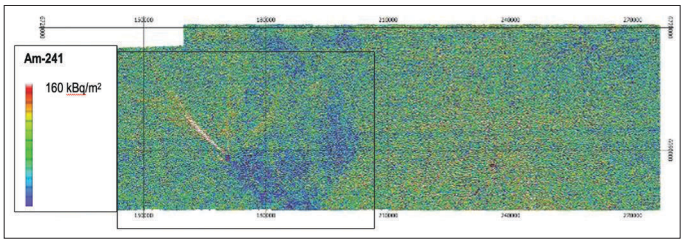

Figure 15. *Am-241 activity image, Thomson survey 2018 (GDA94/MGA53 projection).*

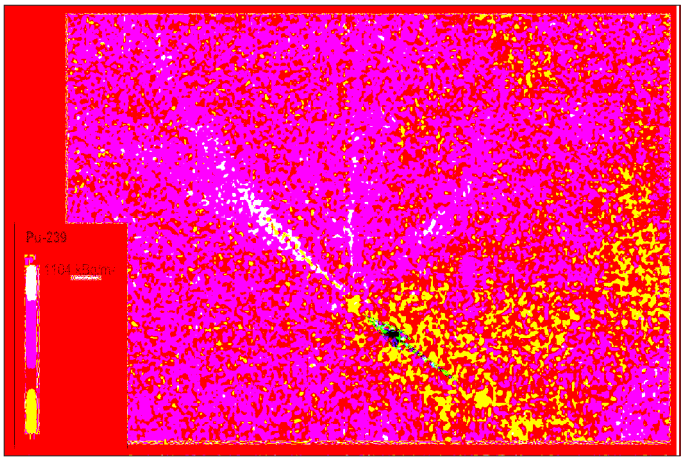

Figure 16. *Pu-239 Thomson survey 2018 (GDA94/MGA53 projection). The Taranaki ground zero Pu-239 activity is minimal which may indicate effects of the final clean up (arrow). The striations northeast/southwest are the effects of sand dunes intercepting the Pu239 particles (processing and imaging by Pavel Jurza).*

In a report published in 2021, a Monash University team led by Megan Cook concluded that plutonium rich nano particles are quite likely to become available to humans at Maralinga, not only by inhalation in windy, dusty conditions but also through ingestion if plants and animal from the area are eaten. They also concluded that the smaller the particles the greater the toxicity (Cook *et al.* 2021).

In 1987 The Australian Radiation Laboratories conducted ground-based surveys along the Oak Valley Road and Western Avenue using a high purity germanium detector to ascertain, among other things, the level of plutonium likely to affect Aboriginal township of Oak Valley. Measurements were confined mostly to roads and tracks and no grid pattern was attempted. They reported that these traverses were difficult to establish, and positions estimated along them must be considered approximate with a likely accuracy of plus or minus 500 m, see **Figure 17** (Johnson *et al*. 1989).

Johnson *at al.*'s 1989 map guides the monitoring of the site today. The ten observation points are visited annually, and americium levels are obtained (Long and Green 2012):

Of the five surveys reviewed over Maralinga, none were completely fit for the purpose. The EG&G survey suffered from antiquated equipment and primitive processing techniques. The World Geoscience survey suffered from ignorance of tracking anthropogenic radioisotopes. The other (government) surveys were designed for acquisition of regional data for geological mapping. The remarkable results from the Thomson Aviation survey point to what could be possible if a modern survey was flown with specifications designed to detect man-made isotopes. Now is the optimum time for such a survey, as the plutonium marker isotope Am 241 has been increasing for about 70 years and is at or near its maximum (**Table 3**).

Unfortunately, the recommendations of the Australian Government's Technical Advisory Group report were only partially followed through. No airborne magnetometer survey was conducted. No systematic ground geophysical surveys were conducted.

Conclusion

The regional information that the authorities responsible for Maralinga are forced to use is seriously deficient. Toxic plutonium 239 is effectively with us forever. An airborne magnetic/radiometric survey should be flown to Geoscience Australia standards at a flying height of 40 m and a line spacing of 40 m. This could be economically performed by a light aircraft such as a Cessna 206 (**Figure 18**) with an across-ground speed of 60 m/s.

Selective helicopter surveys over major contamination should follow. The position and activity concentration of the plumes would be known for the first time as would the effectiveness of the various clean-up efforts. The value of Maralinga as an historical area in a stable pristine environment for the study of anthropogenic radioisotopes is rarely appreciated. It should be regarded as a place for the study of radioisotopes.

A helicopter electromagnetic survey should also be flown over the area of the pits, containing as they do many hundreds of tonnes of steel. In addition, a ground based, fully gridded electromagnetic, magnetic and radiometric survey over selected pits and plumes should be conducted to give custodians of the range, now and in the future, the management tools they need.

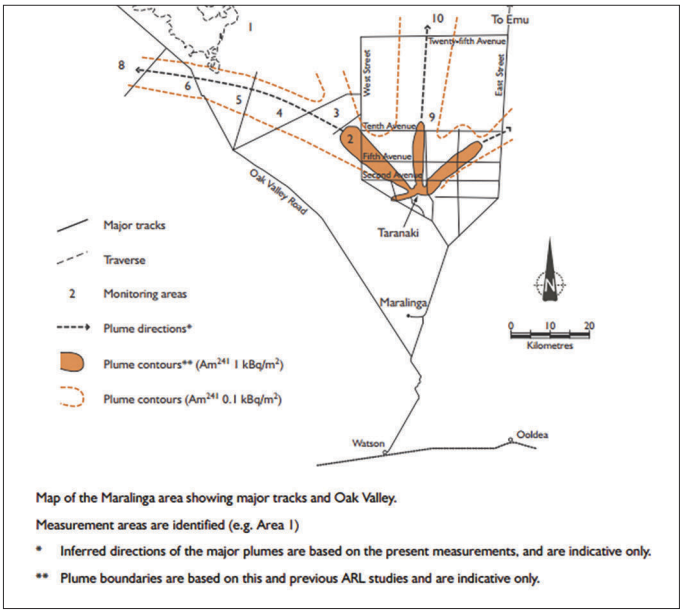

Figure 17. *Map of the Americium plumes used for rehabilitation and testing showing ten sampling points and plume contours compiled by Johnson* et al *in 1989.*

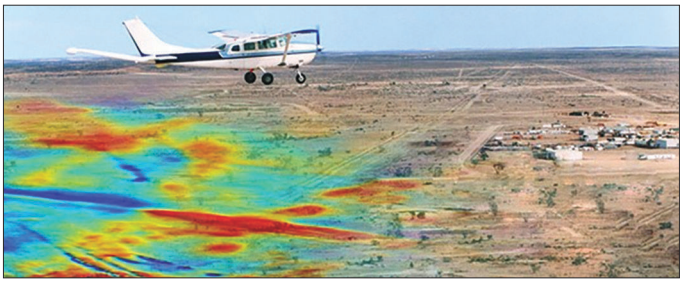

Figure 18. *Cessna 206 engaged in Airborne Radiometric/Magnetic survey Coober Pedy South Australia (Source SADME).*

Today's GPS based positioning would provide, via these new surveys, an accurate set of maps suitable for soil geochemistry sampling and analysis and other studies. The present system of relating samples to roads and tracks is just too antiquated. The readings may be accurate, but they are only as good as their positioning.

Acknowledgements

Bob Pavlik, Joe Kita, Pavel Jurza, Jane Cunneen, Bob Timmins and Greg Street gave generously of their time and expertise, but I thank them mostly for their patience, which, I'm afraid, I sorely tested.

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Preview crossword #31

Famous ships

Across

2. The 'unsinkable' British passenger and mail carrying ocean liner that sank in the North Atlantic Ocean on 15 April 1912 as a result of striking an iceberg during her maiden voyage from England to the United States

6. One of the most feared German battleships of WWII

7. A Brigantine ghost-ship, discovered adrift with its cargo largely intact and ample food and water but with no crew onboard

9. Famed for taking English naturalist Charles Darwin on his first expedition around the world in 1831

10. One of the greatest and most powerful battleship ever built by the Imperial Japanese Navy

12. British Royal Navy research vessel that Lieutenant James Cook commanded on his first voyage of discovery from 1768 to 1771

13. A former British Royal Navy minesweeper converted into a research vessel for the oceanographic researcher Jacques Cousteau

Down

1. The world's first electric and self-propelled container ship

3. Starship NCC-1701

4. The world's first practical submarine, built in 1620

5. Amundsen's expedition departed Oslo for the South Pole on this ship

8. The largest of the three ships used by Christopher Columbus in his first voyage across the Atlantic Ocean in 1492

9. English armed transport ship remembered for the mutiny of her crew on April 28, 1789, while she was under the command of Capt. William Bligh

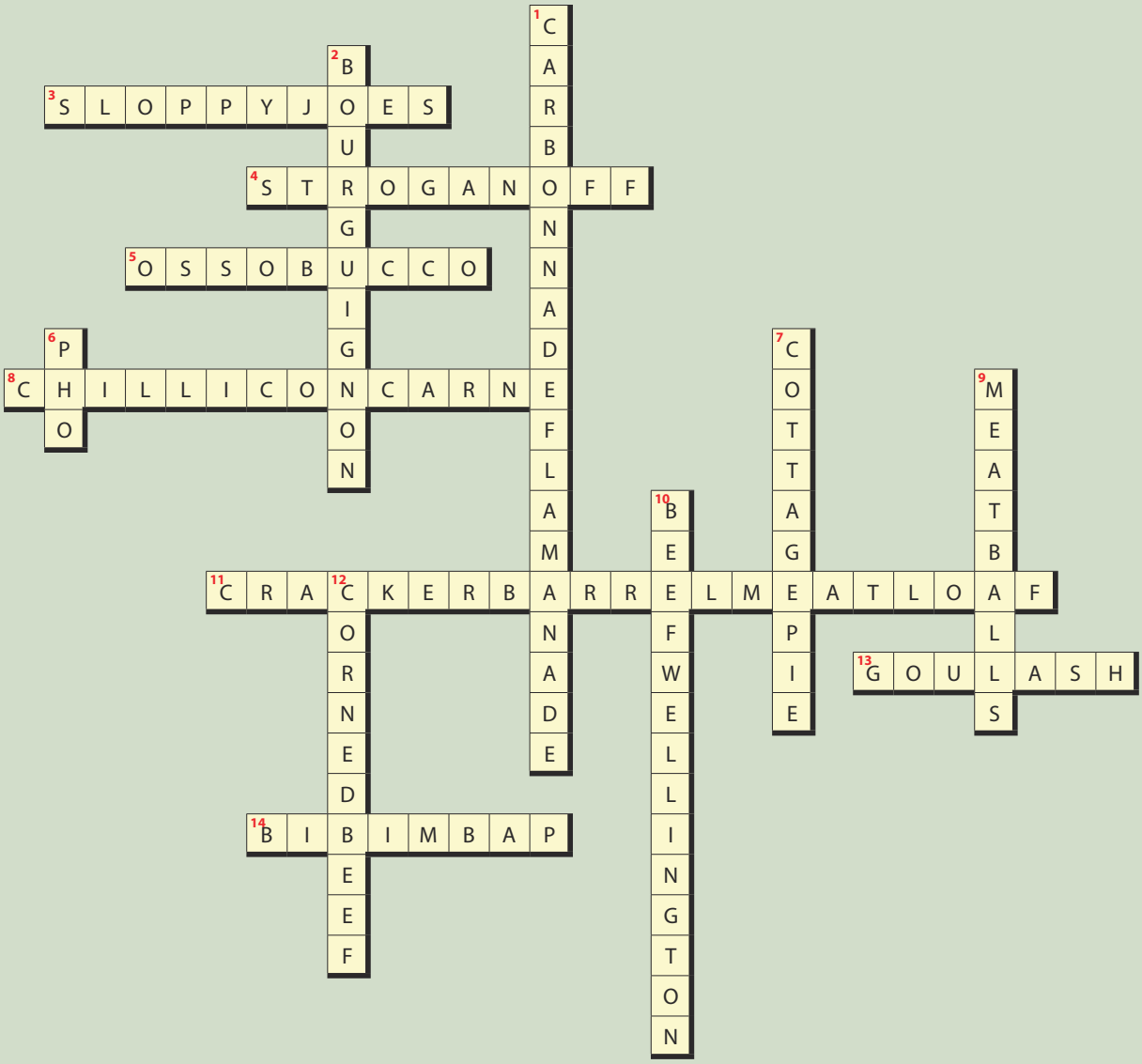
11. The ship that carried the Pilgrims from England to Plymouth, Massachusetts, where they established the first permanent New England colony in 1620

Play to win!! Send your answers to previeweditor@aseg.org.au. The first correct entry received from an ASEG Member will win two Hoyts E- CINEGIFT passes. The answers will be published in the next edition of *Preview.*

Good luck!

Preview crossword #30 solution

I have a beef with you



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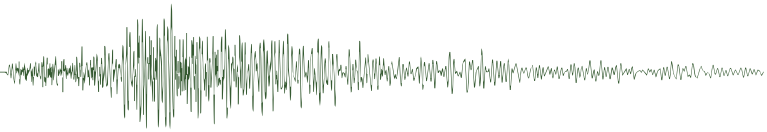

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A.B.N. 71 000 876 040

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Application for Active & Associate Membership 2024

INSTRUCTIONS FOR APPLICANTS

1. Determine the membership level you wish to apply for, according to the eligibility criteria outlined in Section 2.
2. Fill out the application form. Note that applicants for Active Membership must nominate a proposer and a seconder who are Active Members of ASEG. Under exceptional circumstances the Federal Executive Committee may waive these requirements.
3. Submit the two pages of your application to the Secretariat at the address shown on the top of this page, retaining a copy for your own records. The Secretariat will generate an invoice for payment that includes payment instructions.
   The invoice will be sent electronically so please check your email inbox and spam folders.

Section 1. Personal Identification

Surname		Date of Birth
Given Names		Title
Address		
Country	State	Post Code
Organisation		
E-mail		
E-mail (alternate)		
Mobile	Phone (W)	Phone (H)

Section 2. Choice of Membership Grade (Active or Associate)

❑ Active	Please complete all sections
❑ Associate	Please complete all sections apart from Section 4 (Nominators)
❑ Graduate	Please complete Active or Associate application and also check this box
Student	Please complete the separate Student Membership Application Form

Active – an applicant must be actively engaged in practising or teaching geophysics or a related scientific field. Conditions for Active Membership include a relevant academic qualification. Any person who does not have such qualifications, but who has been actively engaged in the relevant fields of interest of the Society for at least five years, shall also be eligible for Active Membership upon the discretion of the Federal Executive Committee.

Associate – an applicant must be actively interested in the objectives of the Society. Associate Members are automatically eligible for election to Active Membership after five years as an Associate Member.

Graduate – Active or Associate membership is subsidized by 50% for no more than two years after completion of studies. Members accepting the graduate grant are expected to contribute to society activities and publications with the goals of raising their profile in the society and showing ASEG's support of young professionals.

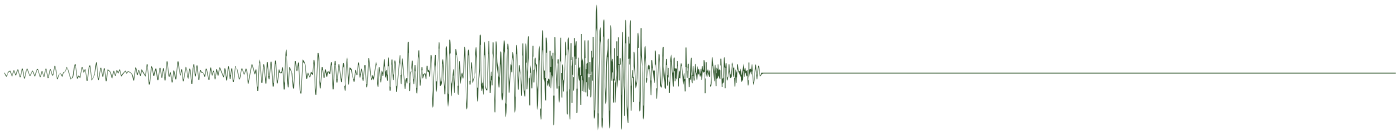
Student – an applicant must be a full-time graduate or undergraduate student in good standing, registered at a recognised university or institute and working towards a degree in geophysics or a related field. Eligibility for Student Membership shall terminate at the close of the calendar year in which the Student Member ceases their graduate or undergraduate studies. The duration of a Student Membership is limited to five years.

Section 3. Academic and Professional Qualifications

Month/Year (From – To)	Organisation/Institution	Position/Degree (incl. Major)	Professional Record Only: Years of Independent Work
Online profile (eg LinkedIn, Google Scholar)		University/ Professional webpage	

Section 4. Nominators of Active Membership applicants must be ACTIVE Members of ASEG

Nominator	Name	Postal or e-mail address	Phone/Fax
Proposer			
Seconder			



Section 5. Membership of Other Societies

Australian:

❑ Aus IMM Grade _____ ❑ AIG Grade _____ ❑ GSA Grade _____ ❑ PESA Grade _____

International:

❑ AAPG Grade _____ ❑ EAGE Grade _____ ❑ SEG Grade _____ ❑ SPE Grade _____

❑ Others _____

Section 6. ASEG Member Record

Include me in the ASEG Member Search on the Secure Member Area of ASEG's Website (search is only available to current ASEG members who opt-in)

❑ **Yes** ❑ **No**

Please complete this section for the ASEG membership database.

Employment area:

❑ Industry ❑ Contract/ Service Prov ider ❑ Government ❑ Student

❑ Education ❑ Consulting ❑ Other _____

Type of Business:

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❑ Minerals ❑ Petrophysics/ Log Analysis ❑ Research/ Education ❑ Data Acquisition

❑ Solid Earth Geophysics ❑ Archaeology/ Marine Salvaging ❑ Computer/ Data Processing ❑ Other_____

Section 7. Membership Grades and Rates

❑ Active/Associate (Australia) - $204.60 (incl GST)	❑ Active/Associate 3 Year Membership (Australia) - $613.80 (incl GST)
❑ Active/Associate (Group IV Countries) - $186.00	❑ Active/Associate 3 Year Membership (Group IV Countries) - $558.00
❑ Active/Associate (Group III Countries) - $55.80	❑ Active/Associate 3 Year Membership (Group III Countries) - $167.40
❑ Active/Associate (Group I & II Countries) - $20.50	❑ Active/Associate 3 Year Membership (Group I & II Countries) - $61.50

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3) I understand and agree that *Exploration Geophysics* articles shall not be networked to any other site, nor posted to a library or public website, nor in any way used to substitute for an existing or potential library or other subscription.

4) I understand and agree that any member who is discovered by the publisher to be in breach of these conditions shall have their subscription access immediately terminated, and the publisher shall have the right to pursue recompense at its discretion from that member.

❑ **Yes** ❑ **No**

Preview is published bi-monthly and is available for open-access at www.aseg.org.au/publications/PVCurrent.

ASEG Members can elect to have hardcopy of *Preview* delivered to their nominated address (offer does not apply to Student members). In 2024, a fee rebate (approx 15%) is available to members who choose to not receive hardcopy *Preview*.

❑ **Yes, I would like to receive hardcopy *Preview*** ❑ **No *Preview* hardcopy (apply the 2024 fee rebate)**

Section 9. Promotional Opportunities

The ASEG provides opportunities for special category listings (eg. Consultants, Contractors) from the ASEG Internet Web Page.

❑ I (or my business) am interested in having a link from the ASEG Internet page. Rates will be advised when links are implemented. (Corporate and Corporate Plus Members get a complimentary link.)

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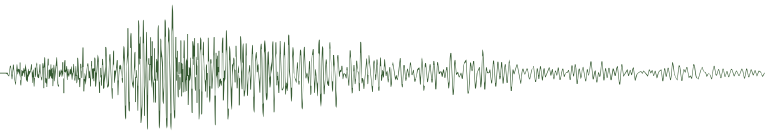
*Signature:*_____ *Date:*_____



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3. A member shall inform a client or employer of any business connections, conflicts or interest, or affiliations, which might influence the member's judgement or impair the disinterested quality of the member's services.
4. A member shall accept financial or other compensation for a particular service from one source only, except with the full knowledge and consent of all interested parties.
5. A members shall refrain from associating with, or knowingly allow the use of his/her name, by an enterprise of questionable character.
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3. Submit your application to the Secretariat at the address shown on the top of this page, retaining a copy for your own records.

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Given Names		Title
Address		
Country	State	Post Code
E-mail		
E-mail (non-University alternative)		
Mobile	Phone (W)	Phone (H)

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Institution	
Department	
Major Subject	Expected Year for completion of studies
Supervisor/Lecturer	Supervisor Email

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❑ Student (Group III Countries)	FREE
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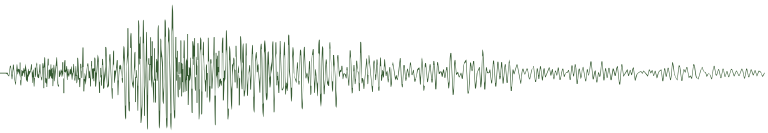
3) I understand and agree that any member who is discovered by the publisher to be in breach of these conditions shall have their subscription access immediately terminated, and the publisher shall have the right to pursue recompense at its discretion from that member.

❑ **Yes** ❑ **No**

Section 5 Declaration

I, _____ (name), agree for the Australian Society of Exploration Geophysicists to make all necessary enquiries concerning my application and suitability to become a Member. By lodging this Application and upon being accepted in my membership, I agree to be bound by the Constitution of the Australian Society of Exploration Geophysicists, including its ethical and professional standards.

Signature: _____ Date:



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5. A members shall refrain from associating with, or knowingly allow the use of his/her name, by an enterprise of questionable character.
6. A member shall advertise only in a manner consistent with the dignity of the profession, refrain from using any improper or questionable methods of soliciting professional work, and decline to accept compensation for work secured by such improper or questionable methods.
7. A membership shall refrain from using unfair means to win professional advancement, and avoid injuring unfairly or maliciously, directly or indirectly, another geophysicist's professional reputation, business or chances of employment.
8. A member shall give appropriate credit to any associate, subordinate or other person, who has contributed to work for which the member is responsible or whose work is subject to review.
9. In any public written or verbal comment, a member shall be careful to indicate whether the statements or assertions made therein represent facts, an opinion or a belief. In all such comments a member shall act only with propriety in criticising the ability, opinion or integrity of another geophysicists, person or organisation.
10. A member will endeavour to work continuously towards the improvement of his/her skills in geophysics and related disciplines, and share such knowledge with fellow geophysicists within the limitation of confidentiality.
11. A member will cooperate in building the geophysical profession by the exchange of knowledge, information and experience with fellow geophysicists and with students, and also by contributions to the goals of professional and learned societies, schools of applied science, and the technical press.
12. A member shall be interested in the welfare and safety of the general public, which may be affected by the work for which the member is responsible, or which my result from decisions or recommendations made by the member, and be ready to apply specialist knowledge, skill and training in the public behalf for the use and benefit of mankind.

International calendar of events 2024–25

April	**2024**		
14–19	EGU 2024 https://www.egu24.eu/	Vienna	Austria
May	**2024**		
7–8	International Mining Geology 2024 https://www.ausimm.com/conferences-and-events/mining-geology/	Perth	Australia
6–9	Oshore Technology Conference (OTC) https://2024.otcnet.org/	Houston	USA
13–15	6th Asia Pacific Meeting on Near Surface Geoscience and Engineering https://eage.eventsair.com/6th-asia-pacific-meeting-on-near-surface-geoscience-and-engineering/	Tsukuba	Japan
June	**2024**		
10–14	85th EAGE Annual Conference & Exhibition https://eageannual.org/	Oslo	Norway
17–19	The Unconventional Resources Technology Conference (URTeC) https://urtec.org/2024	Houston	USA
August	**2024**		
12–13	3rd EAGE Conference on Carbon Capture and Storage Potential https://eage.eventsair.com/3rd-eage-conference-on-carbon-capture-and-storage/	Perth	Australia
14–15	4th EAGE Workshop on Fiber Optic Sensing for Energy Applications https://eage.eventsair.com/4th-eage-workshop-on-fiber-optic-sensing-for-energy-applications/	Perth	Australia
14–15	1st EAGE/SUT Workshop on Integrated Site Characterisation for Offshore Wind in Asia Pacific https://eage.eventsair.com/eagesut-workshop-on-integrated-site-characterization-for-offshore-wind/	Perth	Australia
18–23	Goldschmidt2024 https://conf.goldschmidt.info/goldschmidt/2024/meetingapp.cgi	Chicago	USA
25–31	International Meeting for Applied Geoscience & Energy (IMAGE) https://www.imageevent.org/	Houston	USA
September	**2024**		
8–12	EAGE Near Surface Geoscience Conference & Exhibition 2024 https://eagensg.org/	Helsinki	Finland
October	**2024**		
15–18	ASEG DISCOVER 2024 https://asegdiscover.com.au/	Hobart	Australia
22–24	Gold24 International Symposium https://www.aig.org.au/events/gold24-international-symposium/	Perth	Australia
November	**2024**		
13	MAG24 Modern Applications of Geophysics	Perth	Australia
August	**2025**		
24–29	International Meeting for Applied Geoscience & Energy (IMAGE)	Houston	USA
September	**2025**		
8–11	Australian Exploration Geoscience Conference (AEGC) 2025 2025.aegc.com.au	Perth	Australia

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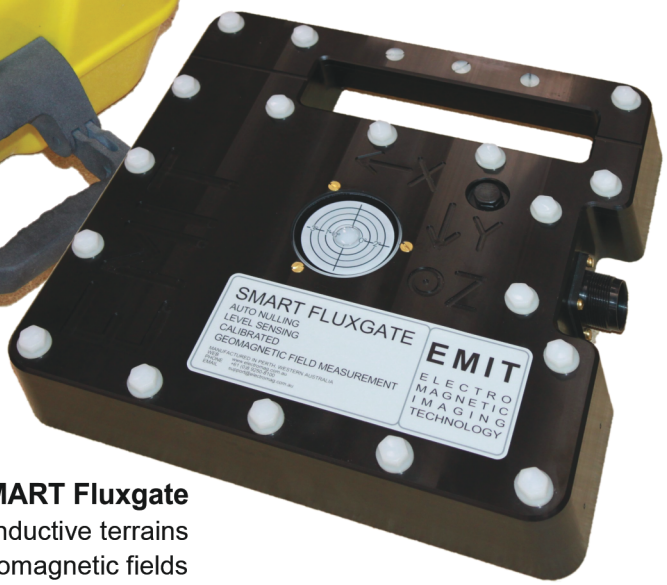

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