Australian Society of Exploration Geophysicists

APRIL 2021 • ISSUE 211
ABN 71 000 876 040 ISSN 1443-2471

PREVIEW

NEWS AND COMMENTARY

Farewell Richard Lane

The Wild, Wild West

Tracking geological features

Regularising and mixing points with grids

FEATURES

Universal horizontal slab and spherical cap Bouguer corrections

The first gravity measurements in Australia

ASEG federal executive 2020–21

David Annetts: President (Conference Advisory Committee Chair, Near Surface Geophysics Specialist Group President)
Tel: +61 411 756 129
Email: president@aseg.org.au

Kate Robertson: President Elect
Tel: +61 8 8429 2564
Email: president-elect@aseg.org.au

Leslie Atkinson: Secretary
Tel: +61 414 804 028
Email: fedsec@aseg.org.au

Danny Burns: Treasurer (Finance Committee Chair, Publications Committee Co-Chair)
Tel: +61 407 856 196
Email: treasurer@aseg.org.au

Ted Tyne: Past President (Publications Committee Co-Chair)
Tel: +61 434 074 123
Email: pastpresident@aseg.org.au

Yvette Poudjom Djomani (Branch Liaison)
Tel: +61 2 6249 9224
Email: yvette.poudjomdjomani@ga.gov.au

Mark Duffett (Technical Standards Committee Representative)
Tel: +61 3 6165 4720
Email: mark.duffett@stategrowth.tas.gov.au

Marina Pervukhina (Professional Development Committee Chair)
Tel: +61 8 6436 8746
Email: continuingeducation@aseg.org.au

Ian James (Web Committee Chair)
Tel: +61 488 497 117
Email: ian@terraspect.com

Millicent Crowe (Communications Committee Chair)
Tel: +61 448 476 384
Email: communications@aseg.org.au

Suzanne Haydon (Membership Committee Chair)
Tel: +61 417 882 788
Email: Suzanne.Haydon@ecodev.vic.gov.au

The ASEG Secretariat

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

Standing committee chairs

Finance Committee Chair: Danny Burns
Tel: +61 407 856 196
Email: treasurer@aseg.org.au

Membership Committee Chair: Suzanne Haydon
Tel: +61 417 882 788
Email: membership@aseg.org.au

Branch Liaison: Yvette Poudjom Djomani
Tel: +61 2 6249 9224
Email: branch-rep@aseg.org.au

Conference Advisory Committee Chair: David Annetts
Tel: +61 411 756 129
Email: cac@aseg.org.au

Honours and Awards Committee Chair: Andrew Mutton
Tel: +61 408 015 712
Email: awards@aseg.org.au

Publications Committee Chair: Ted Tyne
+61 434 074 123
Email: publications@aseg.org.au

Technical Standards Committee Chair: Tim Keeping
Tel: +61 8 8226 2376
Email: technical-standards@aseg.org.au

ASEG History Committee Chair: Roger Henderson
Tel: +61 406 204 809
Email: history@aseg.org.au

International Affairs Committee Chair: Vacant - enquires to fedsec@aseg.org.au
Email: international@aseg.org.au

Professional Development Committee Chair: Marina Pervukhina
Tel: +61 8 6436 8746
Email: continuingeducation@aseg.org.au

Education Committee Chair: Vacant - enquires to fedsec@aseg.org.au
Email: education@aseg.org.au

Web Committee Chair: Ian James
Tel: +61 488 497 117
Email: webmaster@aseg.org.au

Research Foundation Chair: Philip Harman
Tel: +61 409 709 125
Email: research-foundation@aseg.org.au

Communications Committee Chair: Millicent Crowe
Tel: +61 448 476 384
Email: communications@aseg.org.au

Specialist groups

Near Surface Geophysics Specialist Group Chair: David Annetts
Tel: +61 411 756 129
Email: nsgadmin@aseg.org.au

Young Professionals Network Chair: Jarrod Dunne
Email: ypadmin@aseg.org.au

ASEG branches

Australian Capital Territory

President: Marina Costelloe Tel: +61 2 6249 9347
Email: actpresident@aseg.org.au

Secretary: Mike Barlow
Tel: +61 439 692 830
Email: actsecretary@aseg.org.au

New South Wales

President: James Austin
Tel: +61 2 9413 7876
Email: nswpresident@aseg.org.au

Secretary: Steph Kovach
Tel: +61 2 8960 8443
Email: nswsecretary@aseg.org.au

Queensland

President: Ron Palmer
Tel: +61 413 579 099
Email: qldpresident@aseg.org.au

Secretary: James Alderman
Email: qldsecretary@aseg.org.au

South Australia & Northern Territory

President: Ben Kay
Email: sa-ntpresident@aseg.org.au

Secretary: Carmine Wainman
Tel: +61 411 876 173
Email: sa-ntsecretary@aseg.org.au

NT Representative: Tania Dhu
Tel: +61 422 091 025
Email: nt-rep@aseg.org.au

Tasmania

President: Mark Duffett
Tel: +61 3 6165 4720
Email: taspresident@aseg.org.au

Secretary: Matt Cracknell
Tel: +61 409 438 924
Email: tassecretary@aseg.org.au

Victoria

President: Thong Huynh
Tel: +61 438 863 093
Email: vicpresident@aseg.org.au

Secretary: Nathan Gardiner
Tel: +61 431 680 488
Email: vicsecretary@aseg.org.au

Western Australia

President: Todd Mojesky
Tel: +61 450 898 751
Email: wapresident@aseg.org.au

Secretary: Partha Pratim Mandal
Tel: +61 415 998 380
Email: wasecretary@aseg.org.au

ASEG honorary editors

Exploration Geophysics: Editor in Chief
Mark Lackie
Email: eg-editor@aseg.org.au

Preview: Editor
Lisa Worrall
Tel: +61 409 128 666
Email: previeweditor@aseg.org.au

ADVERTISERS INDEX

ASEG CORPORATE PLUS MEMBERS

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

HiSeis Pty Ltd
Tel: +61 8 9470 9866
Email: admin@hiseis.com
Web: http://www.hiseis.com.au/

TOTAL SEISMIC
Tel: +61 (0)409 891 391
Email: info@totalseismic.com
Web: https://www.totalseismic.com/

ASEG CORPORATE MEMBERS

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

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

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

Down Under Geophysics
Tel: +61 8 9287 4100
Email: sales@dug.com support@dug.com
Web: https://dug.com/

FRONT COVER

Richard Lane in 1992 - deep in discussion about TEM with a team of Russians from SNIIGGIMS. For more information see Richard's obituary in this issue.

Preview is available online at
https://www.tandfonline.com/toc/texp20/current
ISSN: 1443-2471 eISSN: 1836-084X

CONTENTS

Editor
Lisa Worrall
Email: previeweditor@aseg.org.au

Assistant Editor
Theo Aravanis
Email: taravanis2011@gmail.com

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

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

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

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

Petroleum geophysics: Michael Micenko
Email: micenko@bigpond.com

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

Book reviews: Ron Hackney
Email: ron.hackney@ga.gov.au

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

Publisher
T&F Publishing
Tel: +61 3 8842 2413
Email: journals@tandf.com.au
Website: www.tandfonline.com

Production Editor
Alexandra Yates
Tel:
Email: TEXP-production@journals.tandf.co.uk

Advertising
Chris Freeman
Tel: (03) 8842 2413
Email: Chris.Freeman@tandf.com.au

Editor's desk

As this issue of *Preview* went into production, southeast Australia was being deluged by rain, resulting in major flooding. The last time Australia saw flooding on this scale was during the last La Niña event in 2010/11. Rainfall associated with that event broke the millennial drought and, from a geophysical perspective, resulted in a measurable increase in the mass of Australia, South-east Asia and northern South America (attributed to an increase in total water storage) and, it has been argued, a consequential drop in global mean sea level of around 5 mm (Boening *et al*, 2012). It will be interesting to see if the 2020/21 event has a similar impact.

Whilst it is fun to speculate about the geophysical signature of El Niño Southern Oscillation (ENSO) events, it is even more fun to speculate about the triggers for those events. In this regard I thank Michael Asten for drawing my attention to the work of Robert Leamon, Scott McIntosh and their colleagues. These solar physicists have systematically analysed variance in solar and atmospheric variability and suggest, as a consequence, that solar activity has a forcing effect on the ENSO (Leamon and McIntosh, 2017). I won't go into the details but they successfully forecast the 2020/21 La Niña event, and their latest work predicts that next significant La Niña will be in 2031/32. (Leamon *et al*, 2020). Only 11 years to wait!

Coming back down to earth, the measurement of gravity preoccupied Richard Lane in the last year of his life. Richard died on the 1st of January 2021, and his obituary appears in this issue of *Preview*. In 2020, in addition to acting as midwife to the release of the latest national gravity compilation, Richard drafted a paper on adjusting gravity calculations for the curvature of the Earth. We can thank Des Fitzgerald for the opportunity to publish this draft paper; "Universal horizontal slab and spherical cap Bouguer corrections". Des has written a preamble to the paper, which is also a tribute to Richard - a man who was greatly respected and much loved.

Also in this issue of *Preview*, Roger Henderson takes an incidentally topical look at "The first gravity measurements in Australia". David Denham (*Canberra observed*) considers the future of our universities. Marina Pervukhina (*Education matters*) reviews the most recent presentations available on the ASEG's YouTube channel. Mike Hatch (*Environmental geophysics*) invites Greg Street to share his views on geophysical interpretation strategies. Terry Harvey (*Mineral geophysics*) reflects on the good old bad old days. Mick Micenko (*Seismic window*) investigates software for tracking geological features in seismic volumes. Tim Keeping (*Data trends*) shares code he has developed for regularising and mixing points with grids, and Ian James (*Webwaves*) takes another look at who is using the ASEG website.

Enjoy!

Lisa Worrall
Preview Editor
previeweditor@aseg.org.au

References

Boening, C., Willis, J. K., Landerer, F. W. Nerem, R. S. and Fasullo, J., 2012. The 2011 La Niña: So strong, the oceans fell. *Geophys. Res. Lett.*, 39, L19602, doi:10.1029/2012GL053055.

Leamon, R.J. and McIntosh, S.W., 2017. Predicting the La Niña of 2020-21: Termination of Solar Cycles and Correlated Variance in Solar and Atmospheric Variability. *AGU Fall Meeting Abstracts 2017*, SH42A-05.

Leamon, R.J., McIntosh, S.W., Chapman, S.C. *et al,* 2020. Timing Terminators: Forecasting Sunspot Cycle 25 Onset. *Sol. Phys.* 295, 36. https://doi.org/10.1007/s11207-020-1595-3

Whilst south eastern Australia battened down the hatches, the Editor enjoyed some snorkelling time off Fitzroy Island on the Great Barrier Reef.

Letter to the Editor

Hi Lisa

I always enjoy reading *Preview* for the informative articles, but the last (December 2020) edition, was particularly enlivened by Don Emerson's article on divination.

I guess like many other geophysicists I have been both baffled and infuriated that so many non-scientific people believe this baloney, but Don has written a most entertaining and illuminating article that explains the history of divination and why it was so popular in past centuries. The detail that Don goes into is remarkable and must have consumed a lot of his time, even though he was presumably not even in lockdown! It is good to read the theoretical basis on which scientists can claim that divination is not just an untenable belief but also physically impossible. So thank you Don for a particularly fascinating *Preview* article.

Cheers

Nigel Hungerford
hnh@netspace.net.au

President's piece

The expression "may you live in interesting times" is a Chinese curse now known to be apocryphal. However, the most likely nearest expression "better to be a dog in times of tranquillity than a human in times of chaos" from a 1627 collection of short stories by Feng Menglong is no less apt.

As it enters its 51st year, the ASEG faces significant challenges on a number of fronts. A worldwide trend in declining interest in earth science education noted by Peter Betts in a recent webinar was accelerated by the effects of the COVID-19 pandemic in 2020 with the closure of a number of geoscience departments, and a reduction in numbers, particularly in exploration geophysics, in others. As a result, options for undergraduate study of exploration geophysics are severely limited.

The limitations for undergraduate study of geophysics raise questions about expectations of graduates by industry and academia. Recently, the AIG (https://www.aig.org.au/education-requirements-for-aig-membership/) updated its minimum knowledge requirements for AIG membership. Granted, societies for professionals (such as the AIG) have different aims to learned societies (such as the ASEG), but the lack of a geophysics component in any minimum knowledge requirement is especially perplexing in an environment dominated by thick conductive regolith. Mineral exploration is a complex process requiring collaboration over different disciplines, and the "The Frank Arnott - Next Generation Explorers Award" (https://bit.ly/3crNKU2) is perhaps a pointer to geoscience education in the future. Similar comments could be made regarding Australia's NExUS (https://sciences.adelaide.edu.au/nexus/). Nevertheless, the paucity of formal opportunities for education in the different aspects of exploration geophysics does represent an opportunity for the ASEG to occupy this space: *si non nos ergo qui*?

Preparations for the AEGC 2021 Conference are proceeding. Although there has been excellent support for the conference from presenters and workshop convenors, suggesting that Members are eager to participate in the third AEGC, especially after various shutdowns and lockdowns of the previous 12 months, it is acknowledged that COVID-19 weighs heavily over the conference. Although six months (at the time of writing) is a long time, fortune does generally favour the bold, and luck the prepared; I am confident that the AEGC 2021 will exceed expectations.

Declining membership is another challenge for the ASEG. Whether a continuation of declining interest in geoscience, or a consequence of recent downturns in minerals and hydrocarbon sectors. As a result of the COVID-19 pandemic, the ASEG made the decision of retain fees at 2020 levels. This allowed the ASEG to extend the early-bird renewal period earlier, and provide a clearer distinction between due and overdue. Judging from *President's Pieces* in previous *Previews*, exhortations to renew membership are not new. In my view, the ASEG, in providing free access to *Exploration Geophysics* and *Preview*, reduced entry to AEGC conferences, access to the SA/NT Branch's annual wine offer amongst other benefits, provides excellent value for money. Consideration for hardship is rarely refused, and the Federal Executive is always interested to hear how the ASEG can better meet Members' needs (contact details are inside the front cover of every issue of *Preview*).

The past 12 months have been testing, and there is much that has had to be rethought. Certainly, celebrations of the ASEG's 50th year were subdued. However, many positives can be taken from 2020. Typically, the AGM's location has changed with the home state of the incoming President, limiting attendance to locals, the Federal Executive who travel and any interstate visitors. The 2020 AGM was a virtual meeting and attended by Members from all states (bar the Northern Territory) making for a national AGM. The promise of technical meetings transcending borders hinted at in 2017, when Bill Peters' talk on "Geophysics for magmatic Ni-Cu-(PGE) exploration" was broadcast worldwide has been realised in the webinars that have been hosted over the past year. It is understood that presenting in such a format is not the same as presenting to a live audience, but consider that the least-well attended webinar was attended by 21 people, and median webinar attendance was 44 people. The audience is even greater through the YouTube channel. Figure 1 plots leverage (the ratio of YouTube views to webinar attendance) as a function of days since the webinar was posted, and shows median leverage of 2.3. This is a remarkable ratio that will grow, albeit slowly, over time. A hybrid

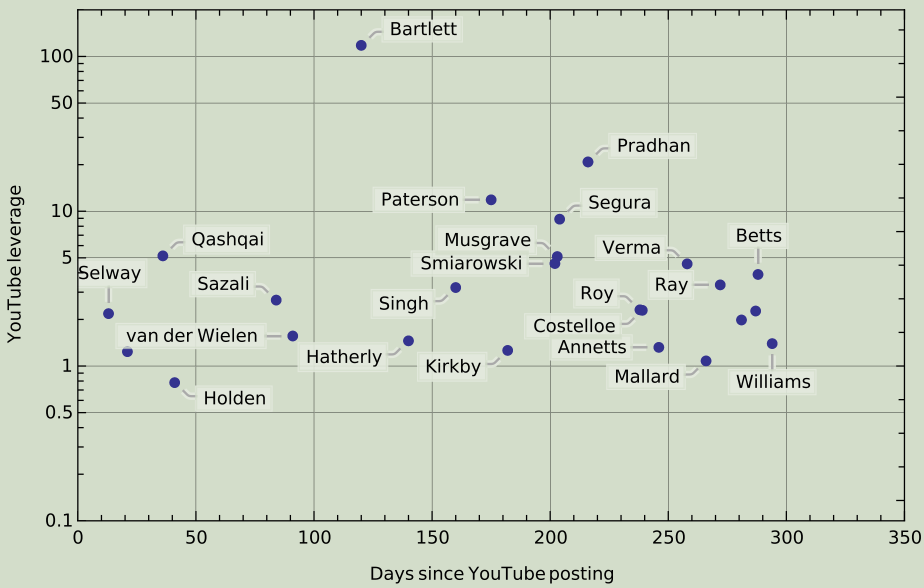


Figure 1. *Ratio of YouTube views to webinar attendance as a function of days since the webinar was posted.*

ceremony in which the ASEG's Gold Medal was awarded to Dr Brian Spies was attended by a worldwide audience. With continuous improvements to the website, through the addition of the *Preview* digital library and provision of monolithic PDF's of *Exploration Geophysics*, enhancements and refinements to the membership, negotiation of special rates for ASEG Members to attend SEG and EAGE courses and the evolution of the monthly newsletter, there is much that was positive over the last 12 months.

I mentioned the FAA earlier this column and I would be remiss if I did not congratulate the participants, including seven teams from Australia, and the organising committee. I understand that the 2021 FAA was won by Team Inca. Nominally based in Peru, this team included students from Brigham Young University and The University of Tasmania. Second place was awarded to Team UWA from the University of Western Australia. I understand that a future Preview will give this remarkable competition the more complete description that it deserves. If the diversity of entrants is any indication of the future of exploration geophysics, then the future is bright indeed.

This is my sixth and final *President's Piece*. By the time *PV* 211 is published, the AGM will have been held, and a new Federal Executive will be in place to lead the ASEG through the next 12 months. Under our next President, Kate Robertson, the ASEG is in excellent hands, and I look forward to supporting her and the 2021 Federal Executives as Immediate Past President. I would like to thank the 2020 Federal Executive for all their hard work and their initiatives towards improving the ASEG. I would especially like to thank Marina Pervukhina and Danny Burns who will step down from the Federal Executive after long-term contributions. It has been an unexpected honour and a rare privilege to serve as ASEG President in 2020.

David Annetts
ASEG President
president@aseg.org.au

Executive brief

The Federal Executive of the ASEG is the governing body of the ASEG. It meets once a month, via teleconference, to deal with the administration of the Society. The following brief reports on the monthly meetings that were held in February and March 2020. If you wish to know more about any ASEG matters, please contact Leslie at fedsec@aseg.org.au.

Finances

The Society's financial position at the end of February:

Year to date income: $138 350

Year to date expenditure: $25 133

Net assets: $1 211 633

Membership

As of 2 March 2021, the Society had 666 financial Members, compared to 733 at this time in 2020. The ASEG currently has 5 Corporate Members, including three Corporate Plus Members. A huge thanks to all our Corporate Members for your continued support into 2021. Don't forget to have a look for our Corporate Members on the contents page of *Preview* and support them as much as you can. Our state branches also have additional local sponsors, and these are shown at all branch meetings and at the beginning of all webinars.

If you have not yet renewed your membership for 2021, you still can, so please consider renewing your membership now. Five-year membership options are available to Active/Associate and Retired Members. Early and mid-career Members are also encouraged to join the ASEG Young Professionals Network at www.aseg.or.au/about-aseg/aseg-youngprofessionals.

AGM

The upcoming AGM will be held on Tuesday 6 April 2021 at 17:30 ACDT, via Zoom. We will welcome in the new federal President for 2021, Dr Kate Robertson. Nominations for all positions (except Past President and President) are very welcome. Please forward the name of the nominated candidate and the position nominating for, along with the names of two Members who are eligible to vote (as Proposers), to the President Elect, Kate Robertson at secretary@aseg.org.au.

Professor Graham Heinson will be giving a presentation entitled "Training the next generations of Geophysicists: Challenges and Opportunities". Please register for this event at https://us02web.zoom.us/meeting/register/tZ0qcOGtrjloGt0sZtdmtSvXyAg-S7S6uljn or keep an eye out for further details. It would be great to see you all there.

Positions vacant

There are vacancies for chairs on our International Affairs Committee and Education Committee. And our standing committee chairs would also welcome any additional support that you can offer. If you would like to contribute to your Society, please consider volunteering for a position on one of these standing committees. You can contact Leslie at fedsec@aseg.org.au if you have any queries.

Social media

Stay up-to-date with all the happenings of your Society on social media. You can connect to us on LinkedIn, Facebook and Twitter for all the latest news and events.

Online events

Face-to-face meetings have slowly started back up in some states, but COVID restrictions are likely to continue in many states into 2021. The ASEG will continue with the webinar series with some interesting talks as well as face-to-face meetings where possible. The webinars are coordinated and run at both state and federal level. Sessions are all recorded and available for viewing at the ASEG website or on our YouTube Channel. Keep a look out for notifications from your state branches to see what is coming and get out there and reconnect with your colleagues.

If there is anything you wish to know more about, please contact Leslie at fedsec@aseg.org.au.

Leslie Atkinson
ASEG Secretary
fedsec@aseg.org.au

Welcome to new Members

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

First name	Last name	Organisation	State	Country	Membership type
Ibrahim	Attia	South Valley Egyptian Petroleum Holding Co	Cairo	Egypt	Active
Nazir	Ahmed	Cameos Consultants	Balochistan	Pakistan	Associate
Jennifer	Chandra	University of Western Australia	WA	Australia	Associate
Chibuzo	Chukwu	Monash University	VIC	Australia	Student
Karla	Morales	University of Tasmania	TAS	Australia	Student
Anatolii	Pakhomenko	Curtin University	WA	Australia	Student
Brad	Pitts	Spectrem Air Pty Ltd	Gauteng	South Africa	Active
Irfan	Raza	University of the Punjab	Punjab	Pakistan	Student
Mosayeb	Khademi Zahedi	Curtin University	WA	Australia	Student

ASEG Young Professionals Network: Update

As we come out of summer and slowly return to a more COVID normal world, we are yet to see any significant local activity on the YP front within the states. However, we have several positive news items for those interested in attending the AEGC in Brisbane:

- The ASEG is now a Corporate Sponsor for the AEGC Student and Early Career events
- Each state has a generous budget allocated for travel bursaries to assist YPs and students to attend the conference. Please direct any enquires to your state president
- FMG are sponsoring the Early Career Networking night
- The GeoPitch flyer will be coming out very soon!

Jarrod Dunne
ASEG Young Professionals Network Federal Chair
ypadmin@aseg.org.au.

ASEG Honours and Awards - Call for nominations for 2021

Dr David Clark, the ASEG Gold Medal recipient in 2019, with then ASEG President, Dr Ted Tyne.

A reminder to all Members that nominations will be closing in July for the next series of ASEG awards, which are scheduled to be presented in conjunction with AEGC 2021, 15-20 September 2021, Brisbane, Australia. All ASEG Members as well as State and Federal executives are invited to nominate those they consider deserving of these awards. The available awards are:

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.

Honorary Membership

For distinguished contributions by a Member to the profession of exploration geophysics and to the ASEG over many years.

Grahame Sands Award

For innovation in applied geophysics through a significant practical development of benefit to Australian exploration geophysics in the field of instrumentation, data acquisition, interpretation or theory. The nominee does not need to be a Member of the ASEG.

Lindsay Ingall Memorial Award

For the promotion of geophysics to the wider community, including geologists, geochemists, engineers, managers, politicians, the media or the general public. The nominee does not need to be a geophysicist nor a Member of the ASEG.

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. The nominee must be a Member of the ASEG and have graduated for at least 3 years.

ASEG Service Awards

For distinguished service by a Member to the ASEG, through involvement in and contribution to State Branch committees, Federal Committees, Publications, or Conferences over many years. Where the nomination details outstanding contributions to the shaping and the sustaining of the Society and the conduct of its affairs over many years, consideration will be given to the award of the ASEG Service Medal to the nominee.

Nomination Procedure

Any member of the Society may submit nominations for candidates meeting the criteria for the above awards. Details of all award criteria and nomination guidelines can be found on the ASEG website at: https://www.aseg.org.au/about-aseg/honours-awards

Proforma nomination forms are also available by contacting the Committee Chair. Nominations including digital copies of all relevant supporting documentation are to be sent electronically to the Chair, ASEG Honours and Awards Committee via email: awards@aseg.org.au

ASEG branch news

South Australia & Northern Territory

The SA/NT Branch of the ASEG held our AGM followed by our Annual Industry Sponsors night at the Coopers Alehouse on the evening of Tuesday March 9. This was a great opportunity to hear about the projects in which some of our sponsors are currently involved, or about to undertake.

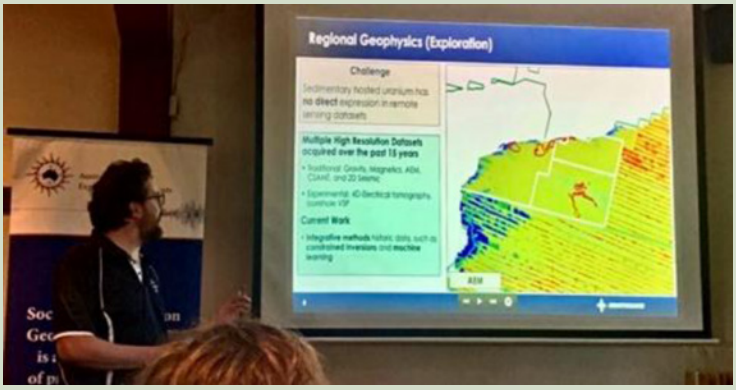
At the AGM we welcomed **Paul Soeffky** to the Branch committee, and **Matthew Hutchens** as the NT representative. A big thank you and farewell to **Tania Dhu** for her many years representing the NT. After the AGM four of our sponsors gave presentations: **Joshua Sage** from Beach Energy, **Andrew Thompson** from Oz Minerals, **Danny Burns** from Vintage Energy and **Nick Jervis-Brady** from Heathgate. This annual event is always well attended and this year was no exception, with 29 Members, students and guests taking advantage of the opportunity to discover who is doing what in the industry.

The NT section of the Branch hosted a webinar on March Tuesday 23 by **Teagan Blaikie** and **Helen McFarland** of CSIRO on "Interpreting high-resolution aeromagnetic data to aid mapping undercover and structural analysis of the Tanami Region and northwest Aileron Province".

On Tuesday April 13 the SA section of the Branch will be hosting a lunch time technical presentation (venue TBC) by **Anandaroop Ray** from GA on a new probabilistic method he's been researching on recursively inverting for regularisation, with some good examples of statistical inference, AEM and CSEM inversions using his algorithm. More details will be sent out to Members soon.

We couldn't host these fantastic events without the valued support of our sponsors. The SA/NT Branch is sponsored by **Beach Energy**, **Oz Minerals**, **Vintage Energy**, **Minotaur Exploration** and **Heathgate**.

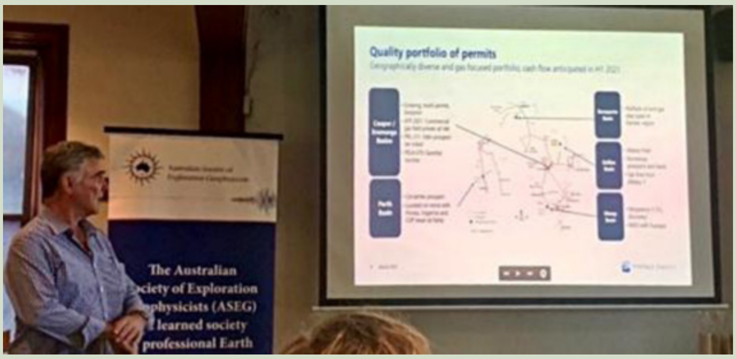
Ben Kay
sa-ntpresident@aseg.org.au



Nick Jervis-Bardy from Heathgate.

Joshua Sage from Beach Energy.

Andrew Thompson from Oz Minerals.



Danny Burns from Vintage Energy.

ASEG news

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.

Mark Duffett
taspresident@aseg.org.au

The 2021 joint annual ASEG-PESA-SPE Summer Social in full swing.

Victoria

"All this happened, more or less", isn't just one of purest opening lines from a novel (*Slaughterhouse-Five* by Kurt Vonnegut), but a great introduction to this buoyant recollection of the Victorian Branch's first event since the start of this wretched pandemic.

The 2021 joint annual ASEG-PESA-SPE Summer Social almost didn't take place after our world-leading, gold-class hotel quarantine system failed Victorians once again, and forced its citizens into a snap five-day lockdown in mid-February. I must echo journalist Leigh Sales' line of questioning to Victorian Premier Dan Andrews, "…that you apparently can't manage two to three cases of COVID a day in a population of about 6.3 million people", is a painful reminder to Victorians of the very high price we all paid after the 112-day lockdown last year. Nevertheless, the 2021 Summer Social finally took place the week following the snap lockdown at The Common Man at Melbourne's South Wharf. This was the most eagerly anticipated event in well over a year and I, for one, awaited the evening with bated breath. After all, this could be the first, last and only event for our Branch in 2021.

So, it goes…it was a mild late summer's evening. The sun was glistening off the murky, oil-filmed waters of the Yarra River where an outdoor covered area of The Common Man was our mustering point for the night. One by one, Victorian members from the three sister societies slowly but surely roused from their inactivity and jostled alongside one of the many dizzying seagull excrement-laden benches for the night. It was an unexpectedly great turn out, granted most members were crying out for some branch activity, and a rare pleasure to reconnect with some of our members.

Drinks were flowing freely, and a myriad of nostalgic conversations were being recounted. The second most popular topic of conversation on the night was the staggering number of unemployed geoscientists in Victoria, the most popular being the pandemic and lockdowns - of course. In any case, thank you to one of our unemployed geoscientists for their cryptocurrency investment tip. I will now go out and buy as many Bitcoins as I can…once I've sold the house, wife, and children to fund this and many other gambling habits I've discovered the past year…meh.

While I'm in the process of thanking members for their on-going support for our Society, and their questionable investment tips, I would like to un-thank one particular member, who shall remain nameless, for registering their attendance to the Summer Social that night via PESA rather than through their ASEG membership. No, I'm not going to give you or any of our readers advice, nor do I care to understand the reasons behind such treachery, albeit PESA is a 'well-oiled machine' when pitted against our amateur-like operations. Simply put, it was a gut punch to the Branch and to our greater Society. Admittedly, I am a member of both celebrated organisations as I have impressionable pursuits, but that's another topic for another rant in a parallel universe.

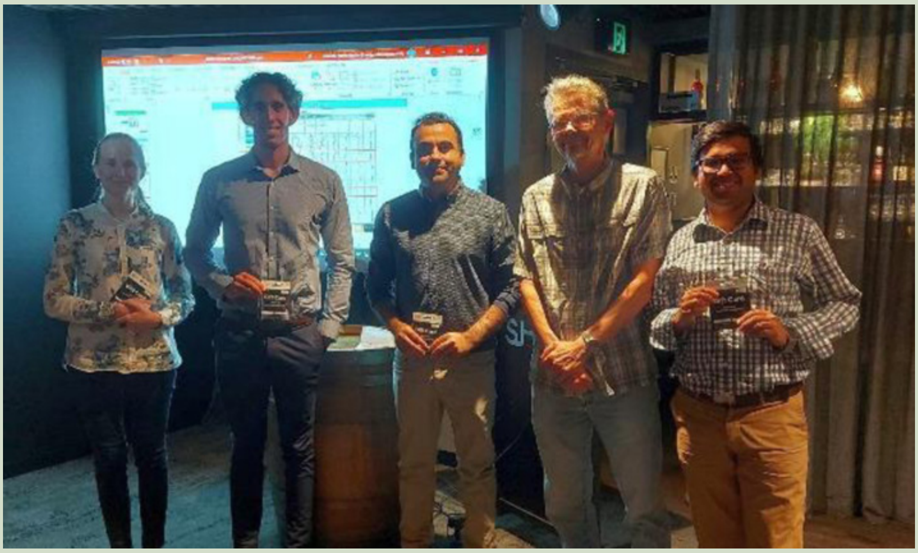
The Victorian committee is enthusiastically putting together a calendar of events for 2021. We aim to catapult the Branch into orbit with a string of stupendous technical meeting nights and other fun events, pending any drastic changes to our pandemic way of life. Please follow our various ASEG media sites for the latest updates and happenings. As always, do take care out there and always have fun (not you… traitor, you know who you are) ☺

Finally, I would like to take this opportunity to thank **Mikayla Sambrooks** for serving as the Branch's Communications officer during 2020, although I can't recall what she actually did. In fact, Mikayla fled to Queensland just as the second wave was ravaging Victorians. Despite her going AWOL and abandoning her post, the committee remained headstrong and vowed to track her down. Our bounty hunters have only just discovered her hiding away at Newcrest Mining in Western Australia, impersonating as a graduate exploration geologist. By sheer luck, the statute of limitations has saved Mikayla from the wrath of the committee…this time. We wish her all the best as her career takes off. We duly invite other members to submit their EOI for the communications officer position. It's a fun role where you get to drink lots of beer and eat lots of pizza…at home. There is also the possibility of the occasional dalliance at events to mingle with some of the most celebrated geoscientific minds, but the pandemic may save you from all of that – just ask Mikayla ☺

Thong Huynh
vicpresident@aseg.org.au

Western Australia

Greetings from Perth and WA. 2021 has not yet lived up to its name as "not-2020", but we are all moving forward. A COVID scare and lockdown in February forced us to move around our first face-face (Student) Tech Night, but we did eventually have a successful evening on February 23 at the "Shoe Bar" in Perth CBD, in the new Yagan Square. Four local graduate students presented their



Sofya, John, Atif and Partha accepting their speaker awards from the WA President.

studies to an interested crowd. **Partha Pratim Mandal** of Curtin University, **John Shepherd** of the University of Western Australia, **Sofya Popik** of Curtin University, and **Muhammad Atif Iqbal,** also of Curtin University, rounded out the bill. Although all were awarded prizes for their diligent efforts, Muhammad was voted as best speaker and received an extra award.

Speaking of students and awards, ASEG WA can announce the winners of our Student Awards! We had a number of very competitive submissions and, with the support of ASEG Australia, the WA Branch have secured funding for two additional awards, allowing us to support four geophysics students. Each student recipient will be awarded a travel grant (up to $2000) to attend this year's AEGC in Brisbane. The awardees are *almost* a complete repeat of our Student Night speakers:

- Partha Pratim Mandal of Curtin University
- Sofya Popik of Curtin University
- Muhammad Atif Iqbal of Curtin University, and
- **Mahtab Rashidifard** of the University of Western Australia

On behalf of **Tom Hoskin**, ASEG WA's Student officer, and all of WA ASEG, I'd like to congratulate all these students. Details of their formal award presentation will be forthcoming.

And, we will be continuing our return to face-face Tech Nights here in WA, but with webinars included - of course.

Todd Mojesky
wapresident@aseg.org.au

Muhammad Atif Iqbal receiving his best speaker award from the WA President.

Australian Capital Territory

On Tuesday March 16**,** Dr **David Upton** from *Precompetitive Review* gave an online seminar on **"**Helping explorers find the nuggets in precompetitive". Covering how Australian precompetitive data and research is having a big impact on mineral discovery, he gave valuable insights into what we are doing well as an industry and where we are missing the mark.

The ACT Branch AGM will be held on March 30, when we have the honour of hosting guest speaker Dr **Richard Blewett**, PSM, who will give us his perspective on applied geophysics in Australia over his distinguished career. It will also be an opportunity to thank the ACT ASEG committee who have put together a packed programme over the last year, despite a difficult working environment.

On Wednesday April 7, Dr **Jack McCubbine** from Geoscience Australia will give a talk on "Using airborne gravimetry data to improve the Australia model of zero height". His talk will be about the new (2017) Australian quasigeoid model (AGQG2017) that was released with accompanying map of uncertainty values. He will discuss recent work Geoscience Australia has undertaken in partnership with The South Australian Department of Planning, Transport and Infrastructure, The Surveyor-General Victoria within the Department of Land Water and Planning and The Geological Survey of Victoria within the Department of Jobs, Precincts and Regions.

We would like to take this opportunity to thank our ASEG family for the outpouring of support after the sudden death of **Richard Lane**. Your emails, phone calls, messages and flowers meant a lot to Leigha and Richard Lane's Geoscience Australia family. We would like to thank everyone who donated to the ASEG Research Foundation in memory of Richard; your generosity is appreciated.

Marina Costelloe
actpresident@aseg.org.au

New South Wales

The NSW Branch committee sailed into uncharted territory for the first meeting of 2021 – the magic of technology (with a few teething issues) saw us livestreaming an in-person event for the February technical presentation. This would not have been possible without the support from the ASEG Secretariat and event coordinator – thank you! Fingers crossed that by the time you read this the March meeting would have taken place with even less issues as the process is refined.

Apart from the technological frontiers, there was much excitement at the February meeting. The AGM saw a new President elected, **Jim Austin** (CSIRO Mineral Resources), with the rest of the committee remaining the same; **Steph Kovach** as Secretary, **Ben Patterson** as Treasurer, and **Josh Valencic** as Social media officer. ASEG NSW cannot extend enough gratitude and thanks to **Mark Lackie** for his 14 years as president of the NSW committee, and we hope he

ASEG news

Clive Foss making the first technical presentation in 2021.

Members of the NSW Branch with the Branch's first presenter for the year. Left to right - Steph Kovach (Secretary), Clive Foss, Jim Austin (President) and Dave Pratt.

enjoys his newfound freedom in country Victoria. A big red cheers to Mark!

Clive Foss (CSIRO Mineral Resources) gave the technical presentation at the February meeting, "From Tenterfield to Mars: Magnetic modelling with terrain". We learnt about some aspects of the magnetic field of Mars, saw the results of the Tenterfield magnetic field modelling, examined the TMI and vector component magnetic field data, and applied lessons from the Tenterfield study to Mars. The audience was amazed by the scale of Noctis Labyrinthus (which all but dwarfs the Grand Canyon), and we saw the importance of multi-component vector magnetic field data for exploring the remanent magnetization of planets. The presentation was followed by ample questions and discussion.

An invitation to attend NSW Branch meetings is extended to interstate and international visitors who happen to be in town at the time, or would like to join us online. Meetings are generally held on the third Wednesday of each month from 1730 at Club York. Meetings notices, addresses and relevant contact details can be found at the NSW Branch website. All are welcome.

Stephanie Kovach
nswsecretary@aseg.org.au

Queensland

On Tuesday February 9 the Queensland ASEG welcomed **Tim Pippett** of Alpha Geoscience who presented "The world of environmental geophysics (geophysics in the near-surface)". The talk was well received and gave the audience from a wide variety of geophysical disciplines a broad overview of the use of geophysics for environmental applications. It was again excellent to see Members face to face at the XXXX Brewery and we hope that face to face meetings will continue throughout the year.

We have a number of technical talks lined up for later in the year, details of which will be released as soon as speakers and dates are confirmed.

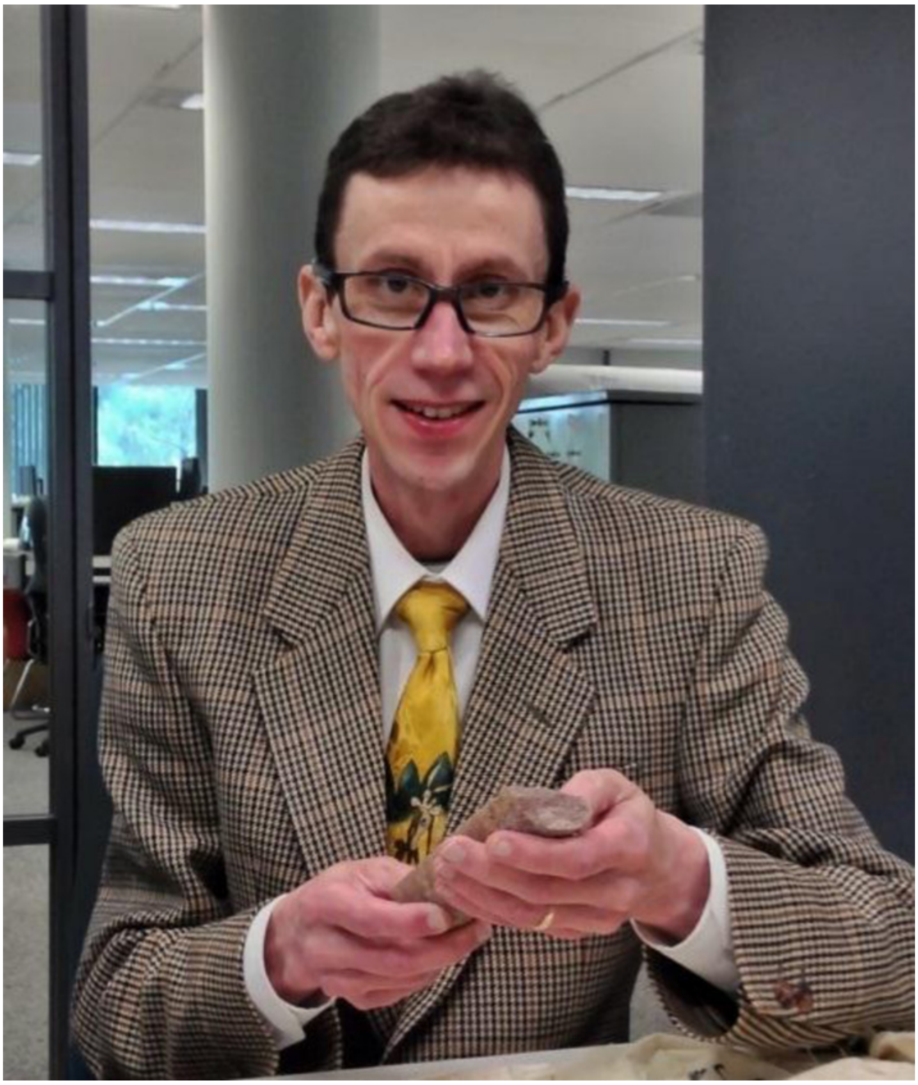
The Queensland Branch would like to thank Velseis for once again agreeing to host a student half-day trip planned for April 9. Trips like this are extremely valuable for giving students a taste of what is involved in field surveys and the state-of-the-art equipment used.

James Alderman
qldsecretary@aseg.org.au

ASEG national calendar

Date	Branch	Event	Presenter	Time	Venue
ASEG Branch face-to-face meetings have resumed in all states. Many branches are still hosting webinars. Registration 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 information about upcoming webinars and other on-line events					
06 Apr	National	AGM	Graham Heinson	17:30 (ACDT)	https://us02web.zoom.us/meeting/register/tZ0qcOGtrjloGt0sZtdmtSvXyAg-S7S6uljn
07 Apr	National	Webinar	Jack McCubbine	16:00 (AEDT)	https://us02web.zoom.us/webinar/register/WN_gyOaiZS-RwWMQh2DJBD2aQ
13 Apr	SA-NT	Tech night	Anandaroop Ray	TBA	TBA
21 Apr	NSW	Tech night	TBA	17:30	Club York, York Street, Sydney

Vale: Richard John Llewellyn Lane (1962-2021)



Richard Lane

Many members of the *Preview* family will have been distressed to hear of the death of Richard Lane on January 1, 2021. Richard's funeral was held in Canberra on January 12. The funeral was streamed online and "attended" by many of Richard's friends and colleagues, including ASEG friends and colleagues, from around the world. Marina Costelloe and Bob Smith participated in the funeral service. They also contributed to this obituary. Numerous other tributes to Richard appeared online after his death. One of these tributes, posted to SEGMIN by Nick Williams, is reproduced in this obituary.

A draft of the paper that Richard was working on at the time of his death also appears in this issue of *Preview*. The paper is proceeded by a preamble written by Des Fitzgerald, who tells us a little more about the man – who was greatly respected and much loved.

Marina Costelloe writes:

Richard Lane was a true pioneer and leader in the field of exploration geophysics. He was well-steeped in the science of geophysics but, more importantly, passionate about its application and sharing his passion and knowledge. He learnt from the best and his career took him around the world.

Richard obtained a BSc (Honours) in geology and geophysics from the University of Melbourne in 1983. He joined CRA Exploration (subsequently Rio Tinto Exploration) as a graduate geophysicist in 1984. Over the following 12 years, he worked for CRAE on Australian and overseas projects, based in Adelaide, Perth, Canberra, Thailand/Laos, Alice Springs, Melbourne, Brisbane and Mount Isa. Richard had several different roles in CRAE and its petroleum exploration subsidiary Pacific Oil and Gas, before deciding to pursue other opportunities in 1996. During his time in CRAE Richard contributed to a variety of exploration activities, including both hard rock minerals and petroleum. He attended and presented at several overseas meetings, including Moscow and Toronto, and gained a broad understanding of geophysical applications for various commodities and in a wide range of field conditions. His keen analytical mind and deep practical understanding of the geophysical profession and exploration industry impressed all those who worked with him, and he built a wide circle of contacts in both industry and academia.

From 1996 to 2001 Richard worked with World Geoscience Corporation/Fugro Airborne Surveys, based in Perth as Chief Geophysicist Product Development. His primary responsibility was to oversee the development of the TEMPEST Airborne EM system, a role that required him to integrate engineering, geophysical and software development. He was Program Leader of the Airborne EM Systems Program of the Cooperative Research Centre for Australian Mineral Exploration Technologies (CRCAMET) from 1997 to 2000, during which time the TEMPEST AEM system was successfully developed and commercialised. TEMPEST became operational in 1999 as a state of the art AEM system with innovative technology that is still evolving.

In 2001 Richard joined the Australian Government geoscientific agency, Geoscience Australia (GA), based in Canberra. In the role of Senior Geophysicist in the Onshore Energy & Minerals Division (OEMD), he made an outstanding contribution to national geophysics. His principal achievements at GA have been establishing 3D potential field inversion methodologies, which now underpin all regional geophysical interpretation projects. He also demonstrated the application of AEM methods to groundwater projects and instigated large regional AEM surveys as part of the 2006 Onshore Energy Security Program.

Richard was instrumental in the development of the Geomodeller 3D geological modelling package since 2005 and has been intimately involved in the work to restructure and expand the GeoModeller geophysical modelling capabilities. Richard's other ongoing activities at GA include leadership of the OEMD efforts to develop a national rock property database, input into the development of the GeoSciML information model and data interchange format (with the goal of facilitating the exchange of geoscience information and processing services), and championing the use of high performance computing (HPC) facilities (multicore computers, internal distributed and parallel computer networks within GA, external GRID, and Cloud facilities, etc.) for geophysical processing and modelling.

He received a Geoscience Australia Individual Award for Achieving Results in Geoscience in 2004, and was the recipient of the Sir Harold Raggatt Award for Distinguished Geoscience Australia Lecturer in 2004.

In conjunction with his role at GA, Richard organised numerous pertinent and timely industry seminars for industry geoscientists, as well as mentoring many younger scientists and graduates in the application of numerical methods for geoscientific problems. Richard played a major role in the conduct of three airborne gravity workshops at ASEG conferences in Sydney (2004), Sydney (2010) and Adelaide (2016). In each case Richard undertook the role of technical editor, resulting in a comprehensive proceedings volume which was published by Geoscience Australia. These have become significant international records of the "state of the art" in airborne gravity, and they are widely recognised around the world. He also undertook a similar role for a "Natural Fields EM" workshop/forum, held at the ASEG conference in Brisbane in 2012.

He was member of the Society of Exploration Geophysicists (SEG), Australian Society of Exploration Geophysicists (ASEG), Environmental and Engineering Geophysical Society (EEGS), American Geophysical Union (AGU), and International Association for Mathematical Geology (IAMG). He was recognised by SEG as an "outstanding reviewer" in 2007 and was nominated as an SEG Honorary Lecturer in 2011. He toured extensively in this role, throughout Australia and the South Pacific.

Richard was inspiring scientific leader, widely recognised throughout the global geophysical community for his keen intellect and insight into geophysical methods in both mining and petroleum, and for his frequent contributions at conferences both in Australia and overseas. Throughout his career Richard has set a benchmark in terms of technical excellence. His service to the industry has been truly significant and he is widely regarded as a substantial pillar of our discipline. It is fitting that Richard's distinguished career encompassing a broad range of technical achievements, combined with his positive influence on other members of the profession, was recognised in 2017 with the award of the ASEG Gold Medal.

Richard's most recent work focussed on airborne gravity and its many applications, particularly to the Global positioning system - GPS. The recent release of the updated national gravity data compilations merging ground, offshore and satellite data will change the way we understand Australia's resource potential.

In each generation, every profession is gifted with only a few exceptional individuals like Richard. People like Richard really are key in defining who we are and how human innovation leads to progress for the betterment of society. Richard, you leave a rich legacy and you, our friend, will be greatly missed.

Marina Costelloe
Marina.Costelloe@ga.gov.au

Bob Smith writes:

I first met Richard in late 1983 or early 1984 when I was part of a panel interviewing new graduates for a job with CRA Exploration. The applicants were mainly geology graduates with a few who also had some geophysics as we were hiring both at the time. I think Richard may have been the only geophysicist on this particular day. As part of the interview, we showed all the participants a geological map of part of Northern Victoria, which was mainly under cover, with only a few scattered outcrops, and a magnetic contour map of the same area, on a transparent base, which could be easily overlain on the geological map. There was a prominent magnetic "anomaly" near Lake Boga, and we used to ask, "What do you think this could be?"

Most of the interviewees opted out by saying "I didn't take the geophysics option" or something similar without really trying. Richard was the only one who overlaid the magnetic map, observed that there was a granite outcrop mapped exactly where the magnetic anomaly occurred, and suggested that it was probably the source of the anomaly. This was not rocket science but simple observation and typical of Richard's uncomplicated approach to our science. He got the job and joined CRAE as a geophysicist in 1984, based in Adelaide. I was also based in the Adelaide office so got to know him well while he was there. It very quickly became apparent that Richard was an exceptional scientist with a deep understanding of the physics and mathematics of his profession and the ability to convey it, in simple terms, to his colleagues. He mentored many of them in CRAE and I believe this continued throughout his career.

Subsequently, Richard moved to several other locations with CRAE, including Perth, Canberra, Thailand/Laos, Alice Springs, Melbourne, and Mount Isa. After working in mining exploration, he eventually transferred to Pacific Oil and Gas (still within CRAE), with headquarters in Box Hill although he was initially based in Alice Springs. This seemed to necessitate frequent visits to Box Hill, with accommodation at The Tudor, a motel nearby where Leigha worked as a receptionist. Eventually, the reason for these visits became clear, and Richard and Leigha married in April 1994. I was present and most impressed by Richard's skill on the dance floor, the result of some intense coaching by a lady in our Box Hill office who was an accomplished ballroom dancer.

Richard and Leigha on the dance floor at their wedding in 1994.

Richard Lane deep in discussion about TEM with a team of Russians from SNIIGGIMS. Left to right: Victor Surkov (Director of SNIIGGIMS), Dr Vasilii Lotyshev (Science Secretary SNIIGGIMS), Dr Gennadii Isaev (Department Chief, SNIIGGMS) , Richard Lane and Kevin Tuckwell (Chief of Pacific Oil and Gas, CRAE).

During these years in CRAE I had frequent contact with Richard, and we travelled together to several overseas locations, including Russia, Sweden, Canada etc. Richard worked closely with a Russian team from Novosibirsk who came to Australia in 1991, with their TEM equipment, and conducted surveys in SA and NT, under Richard's supervision. We both subsequently attended the first SEG conference in Moscow in 1992.

Richard left CRAE in 1996 to join World Geoscience Corporation, based in Perth, from 1996 to 2001. He then moved to Geoscience Australia, in Canberra where he stayed for the rest of his career. Although I had less direct contact with Richard after he left CRAE, we remained firm friends and collaborated on organising several workshops at ASEG conferences. These included three workshops on Airborne Gravity (2004, 2010 and 2016) and one on Natural Fields EM (2012). In each case Richard took on the job of editing all the presentations and subsequent publications, a job no one else wanted, but also one he handled extremely well. There were many eminent geophysicists who were surprised when their submissions were rigorously checked and returned covered in "red ink" for corrections. Ultimately, they all agreed and complied. All the workshops were well attended and papers from the first three were eventually published in reports by Geoscience Australia. Richard's health was declining at the 2016 conference, but he attended and participated throughout the conference.

Richard won many awards and recognition by his professional colleagues and these have been recorded elsewhere. I particularly remember being present at his recent award of an ASEG Gold Medal, in Canberra, in 2017. Although he was not well, we were all delighted that he and Leigha were able to attend and participate.

Richard was an outstanding geophysicist, but I think we will also remember his modest manner and approachability. He was always willing to discuss and/or explain some of the difficult concepts we encountered, to mentor his friends and colleagues as required, and to provide exceptional leadership in his profession. We are all lucky to have known Richard and will sorely miss him. My deepest sympathy goes out to Leigha, who has supported him over many difficult years. His work here is done, may he rest in peace.

Bob Smith
greengeo@bigpond.net.au

Nick Williams writes:

Richard's enthusiasm for the science and the people in geophysics has had a profound influence that goes well beyond the lengthy contributions listed in the announcement of Richard's passing by Geoscience Australia.

Richard and I both started work at Geoscience Australia in 2001. I was a young geologist in my first job, and he was already a leading geophysicist. In just the second year of my career I was lucky enough to have Richard teach me all of the fundamentals of gravity, magnetics, physical properties, and inversion, helping me transition to being a geophysicist. I don't know how I got to be so lucky, but for a few hours every week for most of a year, I would sit in his office, and he would slowly and thoughtfully unpack and describe every single detail I needed to know to be an effective geophysical practitioner. It was a private, personalised education. I learned so much in such a short period of time, and it was always a joy.

I didn't realise at the time, but we were pioneering the use of integrated 3D geologically-constrained inversion, with me riding his coat-tails. He set GA up with the UBC-GIF gravity and magnetic modelling codes (only three years after Yaoguo and Doug published their 3D gravity inversion paper), and laid the foundation for all the integrated 3D modelling that followed. Just one of many achievements in his long and illustrious career, but so crucial for my own.

His clarity of thought and depth of knowledge was astounding. His patience knew no end. He would always find time for me, and he was always genuinely interested in me and my career. I know there have been many others before and since that would have had very different careers without his deep passion for both the people and science. He would often stop by one's cubicle for long chats about life and geophysics – seeking nothing, always giving and supporting.

Everything I do in geophysics everyday is a reflection of the foundations he gave me. He suffered much, but now it is our turn to suffer without him.

Nick Williams
orerocks@outlook.com

Geoscience Australia: Tasmanian Tiers survey and updated AusAEM-1 interpretation

With our key collaborative State Agency partners of Western Australia, South Australia, Northern Territory, Queensland, New South Wales, Victoria and Tasmania, GA continues to acquire and process high quality pre-competitive geophysical products to build Australia's future. Along with highlights below, a summary of programs and survey locations can be found in Figure 1 and the tables following this section.

Tasmanian Tiers airborne magnetic and radiometric survey

The Tasmanian Tiers survey (Figure 2) is located just to the south of Launceston and will fill a 4300 km^2 'gap' in Tasmanian magnetic and radiometric coverage with high resolution, 200 m line spaced data. Flown as a combination of fixed wing (central block) and rotary (western and eastern margins), the initial 25 000 line km programme will be completed by March. The programme is fully funded by Mineral Resources Tasmania (MRT), with Geoscience Australia providing project management, data QC and final product delivery. Primarily aimed at facilitating base metal and gold exploration in the 'Tiers' province, the survey is the first step to filling gaps in high-resolution magnetic and radiometric coverage across all of Tasmania.

Survey preparation included the establishment of a hover-calibration range near Deloraine for ground 'truthing' of radiometric counts and localised radon correction. This data will be published as part of the final contractors report.

Geoscience Australia updates AusAEM-1 interpretation

As part of Exploring for the Future, Geoscience Australia released an updated interpretation of the AusAEM-1 survey covering part of the Northern Territory and Queensland on 22 February 2021 (Figure 3). These new data advance our understanding of regional structural and physical characteristics under cover, and have proven useful in exploration for groundwater, energy and minerals resources. The data can be accessed through the Exploring for the Future portal: https://portal.ga.gov.au/persona/eftf

Mike Barlow
Geoscience Australia
Mike.Barlow@ga.gov.au

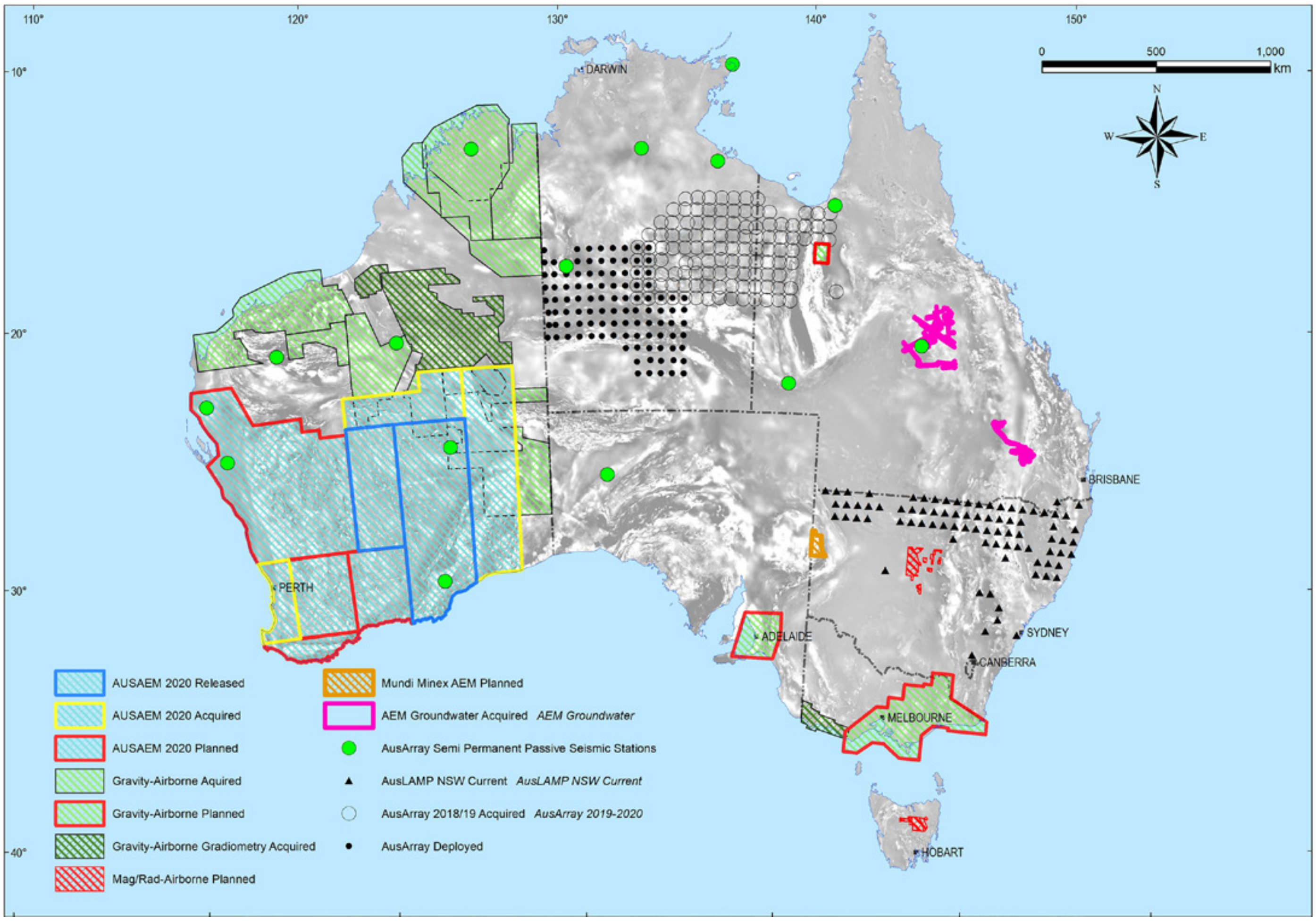


Figure 1. *2019 -2021 geophysical surveys – in progress, planned or still for release by Geoscience Australia in collaboration with State and Territory agencies.*

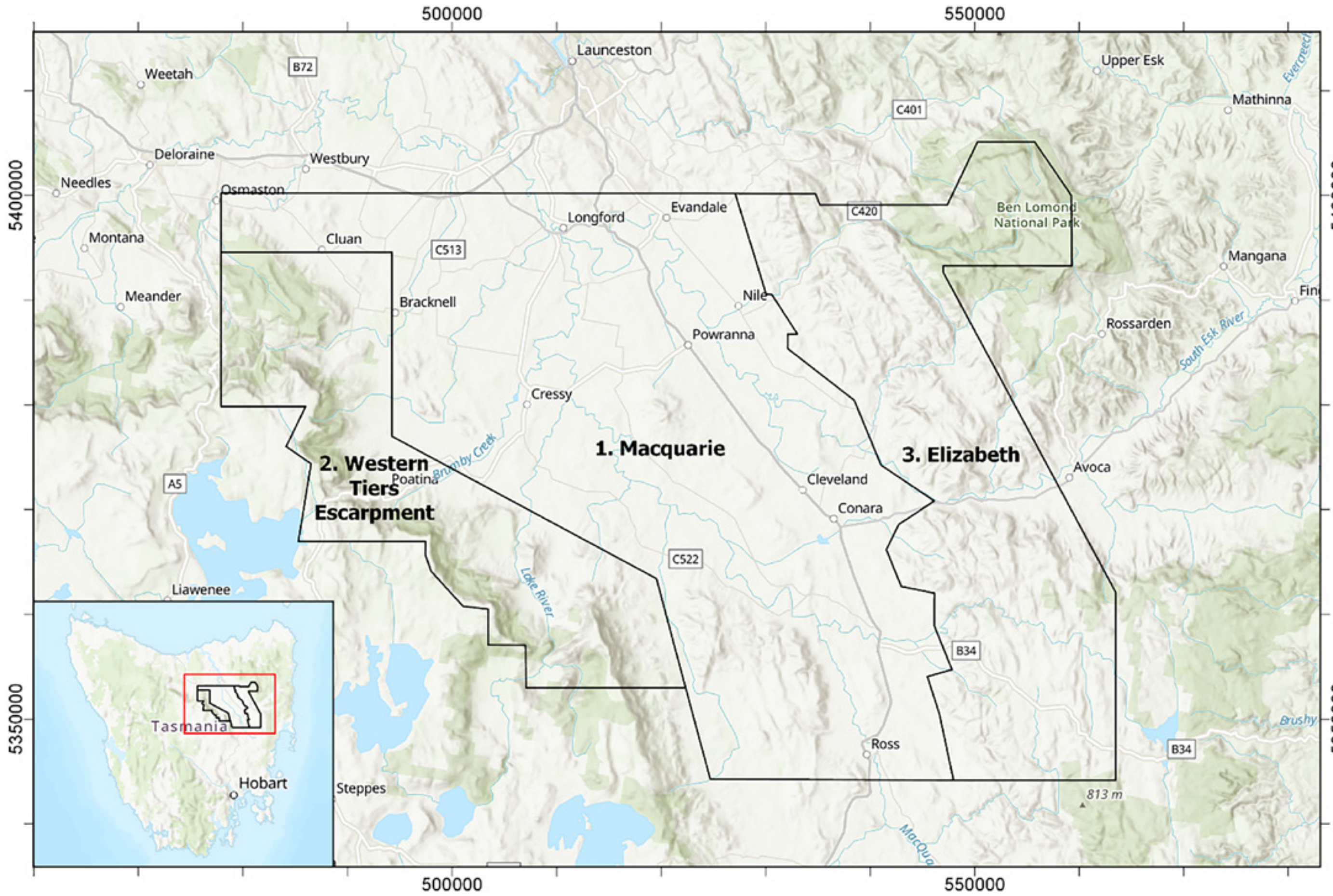


Figure 2. *Tasmanian Tiers airborne magnetic and radiometric survey outlines, 2021.*

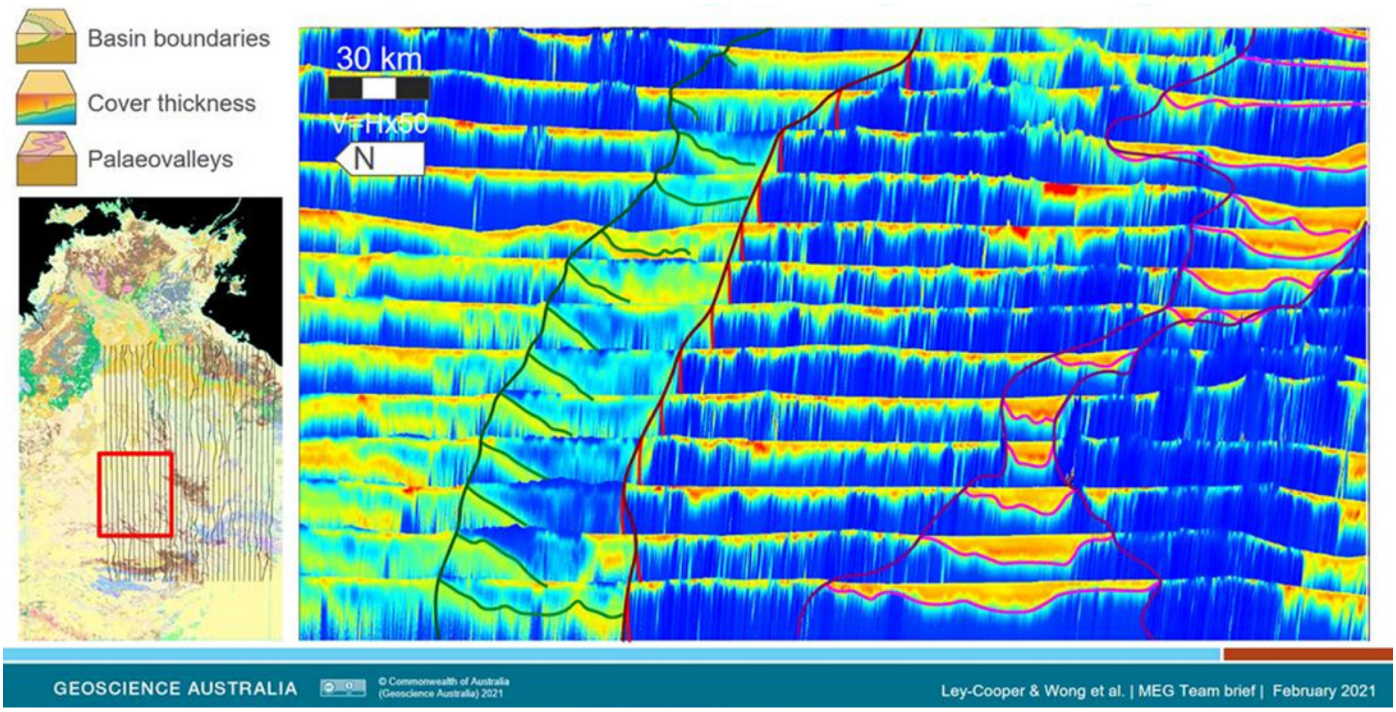


Figure 3. *Updated interpretation of AusAEM-1 data in the Northern Territory showing signatures of the Willowra Suture, Lander Trough and palaeovalleys.*

Update on geophysical survey progress from Geoscience Australia and the Geological Surveys of Western Australia, South Australia, Northern Territory, Queensland, New South Wales, Victoria and Tasmania (information current on 12 March 2021).

Further information about these surveys is available from Mike Barlow Mike.Barlow@ga.gov.au (02) 6249 9275 or Marina Costelloe Marina.Costelloe@ga.gov.au (02) 6249 9347.

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
Tasmanian Tiers	MRT	GA	MAGSPEC	Mar 2021	Up to an estimated 25 000	200 m 60 m N–S or E–W	4300	May 2021	TBA	See Figure 1 in previous section (GA News)	TBA
Cobar	GSNSW	GA	GPX	~ Jun 2021	46 000	200 m	9200	Before end of 2021	TBA	See Figure 1 in previous section (GA News)	TBA

TBA, to be advised.

Table 2. Ground and airborne gravity surveys

Survey name	Client	Project management	Contractor	Start survey	Line km/ no. of stations	Line spacing/ station spacing	Area (km²)	End survey	Final data to GA	Locality diagram (*Preview*)	GADDS release
Melbourne, Eastern Victoria, South Australia	AusScope	GA	TBA	~May 2021	137 000	1–5 km	146 000	TBA	TBA	See Figure 1 in previous section (GA news)	TBA
Kidson Sub-basin	GSWA	GA	CGG Aviation	14 Jul 2017	72 933	2500 m	155 000	3 May 2018	15 Oct 2018	See Figure 1 in previous section (GA news)	Set for release before Jun 2021
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	Set for release before Jun 2021
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	Set for release before Jun 2021
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	Set for release before Jun 2021
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)	Set for release before Jun 2021
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 National database by Dec 2020

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
Mundi	GSNSW	GA	NRG	Mar 2021	1900	2.5	~ 5000	May 2021	TBA	See Figure 1 in previous section (GA News)	TBA
Surat-Galilee Basins QLD	GA	GA	SkyTEM Australia	2 Jul 2017	4627	Variable	57 366	23 Jul 2017	Nov 2017	188: Jun 2017 p. 21	TBA
AusAEM20	GSWA	GA	CGG & SkyTEM	Aug 2020	62 000	20 km	1 240 000	Dec 21	TBA	See Figure 1 in previous section (GA News)	TBA. Survey in production

TBA, to be advised

Table 4. Magnetotelluric (MT) surveys

Location	Client	State	Survey name	Total number of MT stations deployed	Spacing	Technique	Comments
Northern Australia	GA	Qld/NT	Exploring for the Future – AusLAMP	366 stations deployed in 2016–19	50 km	Long period MT	The survey covers areas of NT and Qld. Data to be released early 2021.
AusLAMP NSW	GSNSW/ GA	NSW	AusLAMP NSW	224 stations deployed in 2016-19	50 km	Long period MT	Covering the state of NSW. Acquisition ongoing. Phase 1 data release: http://pid.geoscience.gov.au/dataset/ga/132148.
Southeast Lachlan	GSV/GSNSW/ GA	Vic/ NSW	SE Lachlan	Deployment planned to commence early/mid-2021	~4 km	AMT and BBMT	~160 stations in the Southeast Lachlan. Acquisition delayed due to COVID-19 travel restrictions.
AusLAMP TAS	GA	TAS	King Island MT	4 stations completed	<20 km	Long period MT	Covering King Island. Acquisition completed.
Cloncurry	GSQ/GA	QLD	Cloncurry Extension	500 stations have been acquired	2 km	AMT and BBMT	Data acquisition complete.
Spencer Gulf	GA/GSSA/ UofA/ AuScope	SA	Offshore marine MT	12 stations completed	10 km	BBMT	This is a pilot project for marine MT survey https://www.auscope.org.au/news-features/auslamp-marine-01

TBA, to be advised

Table 5. Seismic reflection surveys

Location	Client	State	Survey name	Line km	Geophone interval	VP/SP interval	Record length	Technique	Comments
Eastern Goldfields	GSWA	WA	L132 1991 Eastern Goldfields Seismic	260	40 m	160 m	20 s	2D deep crustal seismic explosive reflection seismic	GSWA and GA signed an MoU to reprocess legacy explosive data acquired by GA's predecessor agency, the Bureau of Mineral Resources in 1991. GSWA contracted Velseis Processing Pty Ltd. to reprocess these data set using modern processing techniques, which were unavailable at the time of the original data acquisition and initial processing. GA will provide Quality Control and monitoring of the data reprocessing; and provide ad hoc advice for the project. The improved seismic data will complement other geoscience datasets in GSWA's Eastern Goldfields Reinterpretation Project, and GSWA's Accelerated Geoscience Programme. The work is funded by the WA Government's Exploration Incentive Scheme.

(*Continued*)

Table 5. Seismic reflection surveys (*Continued*)

Location	Client	State	Survey name	Line km	Geophone interval	VP/SP interval	Record length	Technique	Comments
Southeast Lachlan	GSV/ GSNSW/ GA/ AuScope	Vic/NSW	Southeast Lachlan	629	10 m	40 m	20 s	2D deep crustal seismic reflection	The survey covers the Southeast Lachlan Orogen crossing the Victoria–New South Wales border. Data acquisition was completed in April 2018. Raw and processed seismic data are available from Geoscience Australia and state geological surveys: http://pid.geoscience.gov.au/dataset/ga/122684
Kidson	GA/ GSWA	WA	Kidson Sub-basin	872	20 m	40 m	20 s	2D deep crustal seismic reflection	The survey is within the Kidson sub-basin of the Canning Basin and extends across the Paterson Orogen and onto the eastern margin of the Pilbara Craton. Data acquisition was completed in Aug 2018. Raw and processed seismic data are available from Geoscience Australia and the Geological Survey of Western Australia: http://pid.geoscience.gov.au/dataset/ga/128284
Barkly/ Camooweal	GA/NTGS	NT	Barkly Sub-basin	813	10 m	30 m	20 s	2D deep crustal seismic reflection	The aim of the project was to acquire 2D land reflection seismic data to image basin and basement structure in the Barkly region in the Northern Territory. Data acquisition was completed in Nov 2019. Raw and processed seismic data are available via Geoscience Australia and the Northern Territory Geological Survey: http://pid.geoscience.gov.au/dataset/ga/132890
East Kimberley	GA	WA/NT	Bonaparte Basin	619	Variable	Variable	Variable	2D reflection land seismic	GA commissioned reprocessing of selected legacy 2D seismic data in the East Kimberley, onshore Bonaparte Basin as part of the Exploring for the Future (EFTF) programme. Reprocessing of these data occurred between September 2017 and May 2018. Reprocessed seismic data are available via eCat http://pid.geoscience.gov.au/dataset/ga/135578

Table 6. Passive seismic surveys

Location	Client	State	Survey name	Total number of stations deployed	Spacing	Technique	Comments
Northern Australia	GA	Qld/NT	AusArray	About 135 broad-band seismic stations	50 km	Broad-band 1 year observations	The survey covers the area between Tanami, Tennant Creek, Uluru and the Western Australia border. The first public release of transportable array data is expected by the end 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: http://pid.geoscience.gov.au/dataset/ga/135284 http://pid.geoscience.gov.au/dataset/ga/135130 http://pid.geoscience.gov.au/dataset/ga/135179 http://pid.geoscience.gov.au/dataset/ga/134501
Northern 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" www.iris.edu

Geological Survey of South Australia: Full sets of merged GCAS grids now available

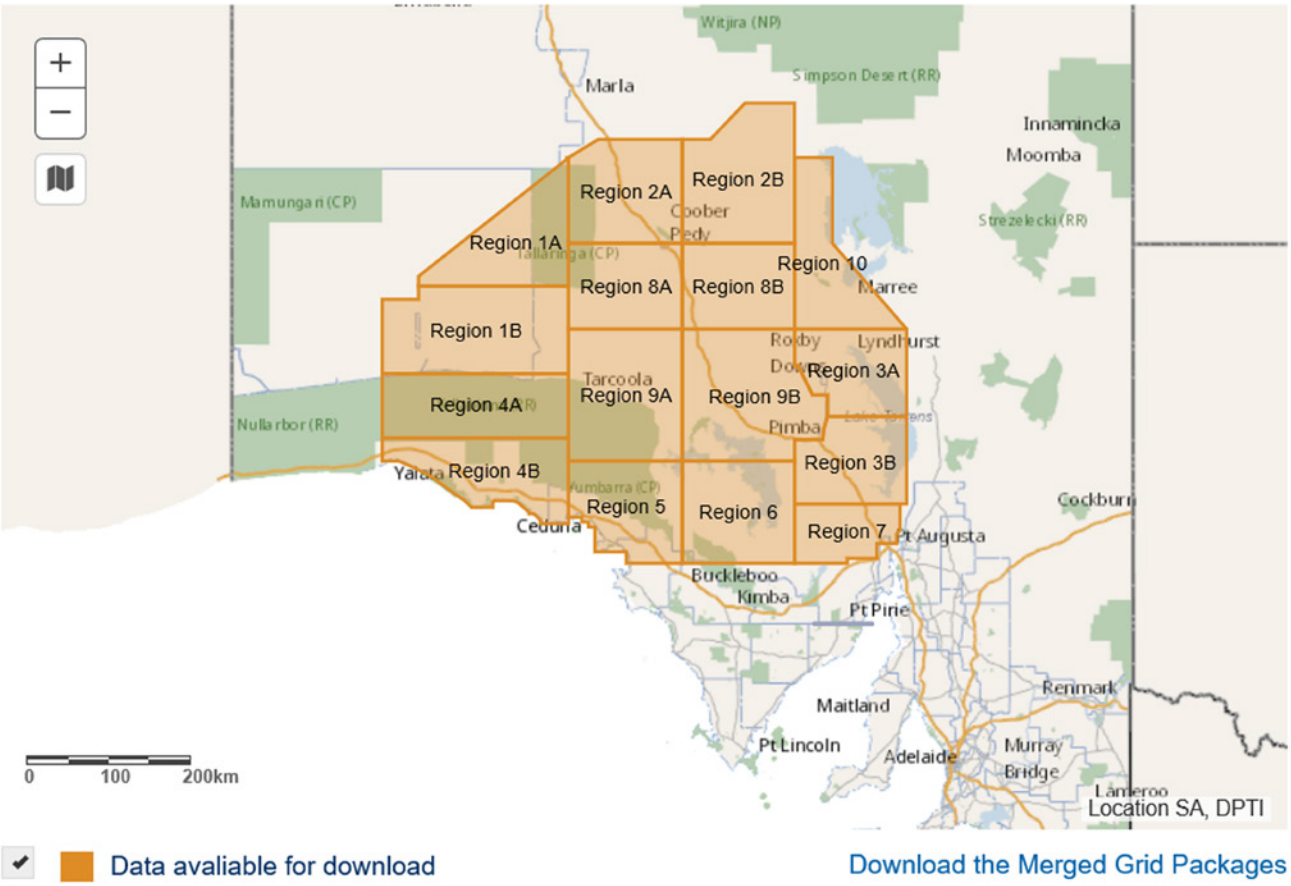


Figure 1. *The GCAS community information package contains an interactive map illustrating the survey area.*

In 2017 the Government of South Australia, in partnership with Geoscience Australia began the world's largest airborne geophysical and terrain imaging program, the Gawler Craton Airborne Survey (GCAS). GCAS captured approximately 1 660 000 line kilometres of new magnetic, radiometric and digital elevation data over an area of 295 000 km^2.

The GCAS was divided into 16 regions (Figure 1) and a series of products for each region have been released. These include new magnetic, radiometric and elevation data and images, as well as value-added magnetic data products and models of depth to prospective rocks.

The latest products to be released are a series of magnetic, radiometric, laser and radar elevation datasets. These have been meticulously merged to provide seamless, internally consistent sets of gridded data across the entire GCAS area.

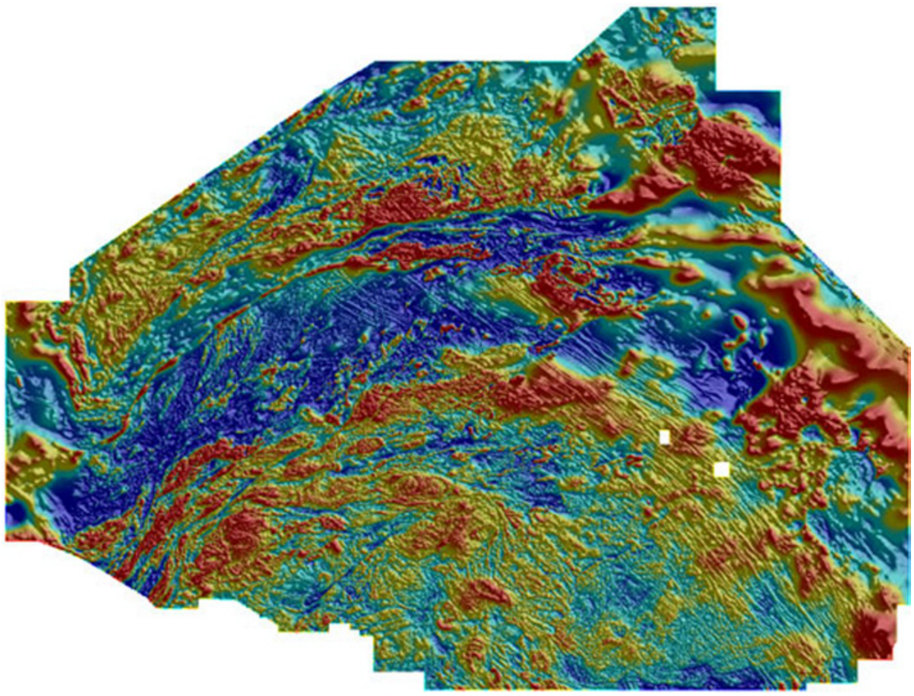


Figure 2. *The merged TMI grid shown above has a "variable reduction to pole" (VRTP) filter applied and is one of 22 TMI and enhanced TMI grids available in the TMI download package.*

Figure 3. *This ternary radiometric grid is one of the six grids in the radiometrics download package.*

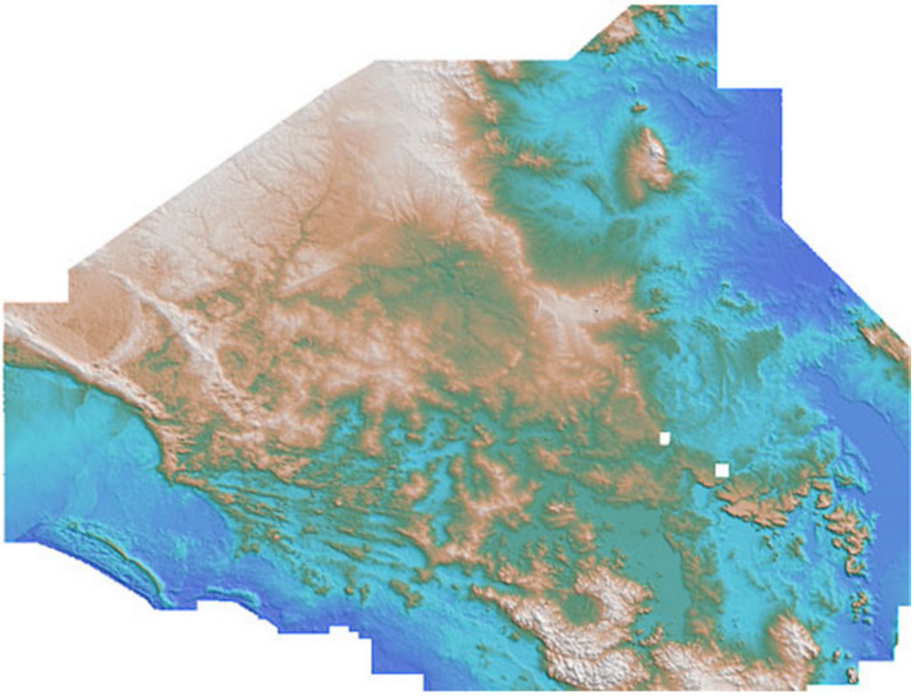


Figure 4. *Both laser (displayed) and radar derived elevation models are provided in the GCAS elevation data package.*

The TMI data package contains a total of 22 TMI and filtered TMI grids - an unprecedented number of additional filters and magnetic tensor components to provide the most comprehensive set of magnetic transforms ever released by the Geological Survey of South Australia.

The radiometric data package of six grid products was produced after careful reprocessing of the raw data, ensuring system calibrations were applied consistently across regions flown by each platform, and signal loss through processing was kept to a minimum. A new filter, piecewise normalisation was applied to the merged radiometric grid, providing an additional dataset for radiometric interpretation.

The elevation data package of two grid products, radar and laser DEMs are provided for completeness.

All of the grid products were produced to be co-nodular (grid cells line up perfectly between datasets with no resampling during processing) were gridded and supplied in the coordinate system of the data capture: Geodetic GDA94. Grid cell size is 0.00036 decimal degrees, equating to 40 metres (1/5th of the survey line spacing).

The merged GCAS grid products are now available in three packages (TMI, Radiometrics and DEM), including a fourth package containing the individual reprocessed radiometric located data and grids.

Datasets can be downloaded via SARIG (scroll down on the home page and click "Gawler Craton Airborne Survey data releases" to view the layers. Once a layer is selected, click the Active Layers tab and use the downward pointing arrow to download the layer). The merged datasets can also be downloaded via the link under the map on energymining.sa.gov.au/minerals/gcas (see Figure 1). For assistance with downloading data sets, please contact Customer Services resources.customerservices@sa.gov.au

The GCAS team gratefully acknowledge Des Fitzgerald and Rainer Wackerle (Intrepid Geophysics) for assistance with scripts, Matthew Hutchens (now with GSNT) for QA/QC work, Mark Baigent (Baigent Geosciences) for QA/QC and post-processing work, Brian Minty (Minty Geophysics) for test range comparisons, Clive Foss (CSIRO) for producing the first set of TMI enhancements and depth-to-basement work (available in a separate download package), John Paine (Scientific Computing and Applications; WinDisp software) for valuable programming assistance, everyone at GA who were involved in the GCAS project, and of course all the survey companies - GPX Surveys, MagSpec Airborne Surveys, Sanders Geophysics, Thomson Airborne – without whom these data wouldn't exist.

Laz Katona, Gary Reed, Tim Keeping and Philip Heath
Geological Survey of South Australia
Laz.Katona@sa.gov.au

Mineral Resources Tasmania: Tiers airborne magnetic and radiometric survey update

After a long gestation period, the Tiers airborne magnetic and radiometric survey spanning central and eastern Tasmania was flown through February and March, with acquisition likely completed around the time *Preview* goes to press. The survey is primarily funded by the Tasmanian Government through Mineral Resources Tasmania, and managed by Geoscience Australia. First glimpses of the results show a diverse range of interesting features, with possible implications for natural resource management as well as gold, base metal and bauxite prospectivity and regional tectonic history. It is intended that the data will be made publicly available as soon as possible following final acceptance. Full specifications of the survey are given in Geoscience Australia's regular roundup in this edition of *Preview*.

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

Figure 1. *Calibration of the radiometric system in progress after its installation in the survey helicopter, in conjunction with ground spectrometer measurements at the test site established near Meander in northern Tasmania (see GA's column in this edition of Preview), 24 February 2021. Photo: Mark Duffett*

Geological Survey of Queensland: New Economy Resources Initiative geophysics programmes and Cloncurry extension MT results released

The Department of Resources' recent funding package, the New Economy Minerals Initiative (NEMI) aims to continue to drive exploration and understanding of the range of metals and minerals found in Queensland that will be required for emerging technologies. This year sees the commencement of the acquisition of more pre-competitive airborne geophysics as well as a study into mineralisation conduits using broad scale magnetotellurics.

Under this funding, GSQ will be extending our 100 m magnetic and radiometric data coverage in Northwest Queensland, with the Kamilaroi survey well into the planning stages. This survey will extend the 100 m coverage to the north of the recent Central Isa and Cloncurry North surveys (see Figure 1) and was selected as it follows a trend of structures hosting cobalt mineralisation and copper deposits in the south. The survey will cover an area of ~6000 km^2 with flying expected to be underway by May.

The Canobie Airborne Gravity Gradiometry survey will provide an improvement in the gravity resolution to the north of Cloncurry in an area of cover. The survey will be flown with a line spacing of 1 km and will cover an area of ~5000 km^2 in an area prospective for IOGC deposits. Planned integration of the airborne data with the existing 2 km spaced regional ground gravity data which covers the whole Mt Isa Inlier will be done to determine the value of future coverage in this region. Flying is expected to commence mid-year.

MT in Queensland

In addition to the pre-competitive airborne geophysics collected under NEMI, the GSQ will also be embarking on an in-house field campaign to acquire broadband MT data along the previously acquired 14GA-CF2 and 14GA-CF3 seismic lines in the southwest (see Figure 2).

This survey is the first phase of a campaign of work aimed at better defining the enigmatic Carpentaria Conductivity Anomaly (CCA). The CCA is spatially associated with mineralisation in the Cloncurry area, but little is known about the extension of this feature to the south. The 2021 acquisition will act

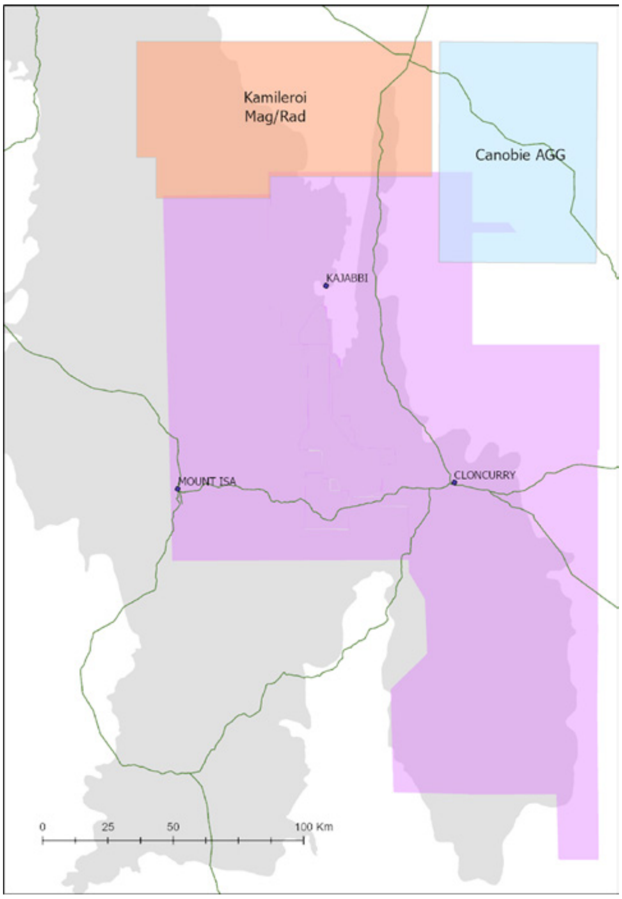


Figure 1. *Map showing bounds of airborne geophysical surveys to be collected as part of NEMI. Purple shading indicates past 100 m survey coverage.*

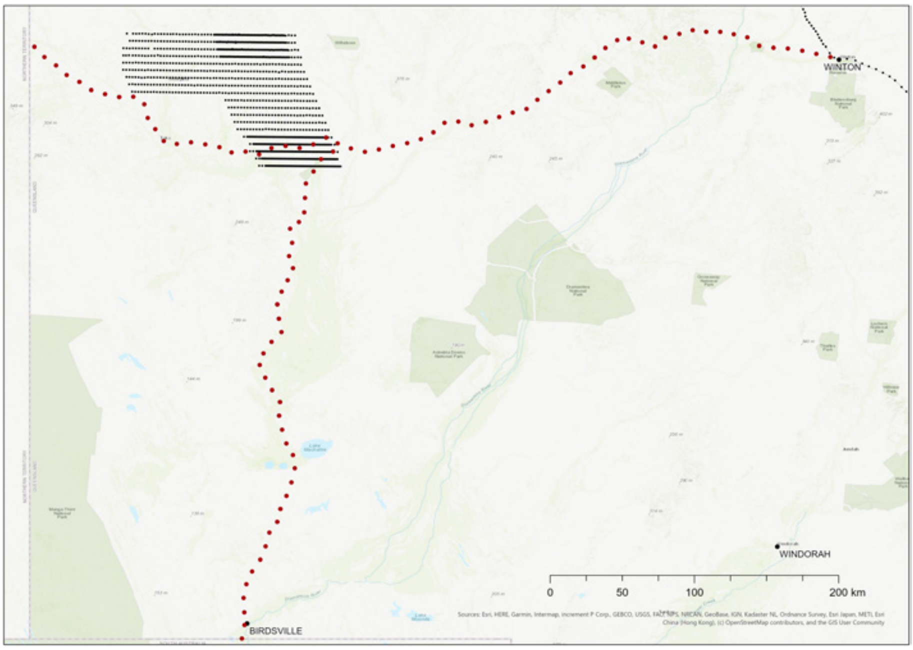


Figure 2. *Map of the existing Boulia MT survey sites in black and the new CCA phase one planned deployment sites in orange.*

as reconnaissance for the larger survey planned in 2022.

Finally, the much-anticipated Cloncurry Extension MT survey results and analysis are now available on the GSQ Open Data Portal. The accompanying report contains data analysis and some preliminary inversions (see Figure 3). Work is ongoing to produce a 3D inversion of the dataset.

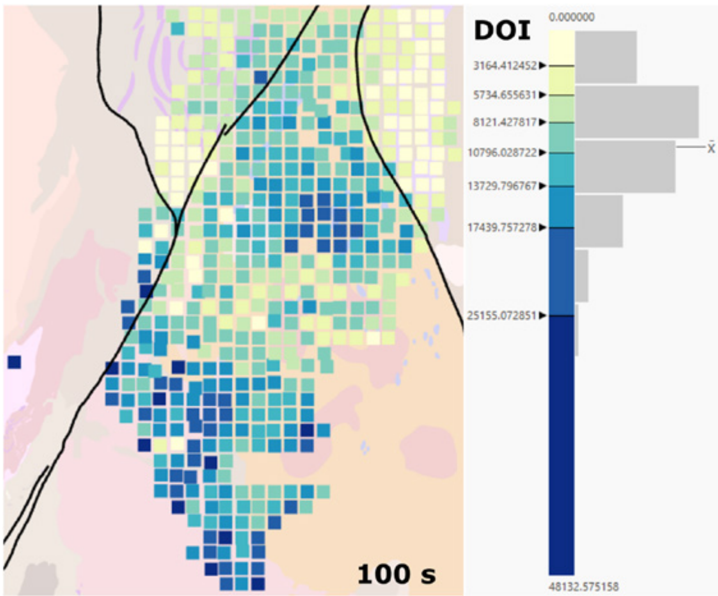


Figure 3. *Depth of investigation plot of the Cloncurry Extension MT survey for a period of 100 s. Washed out background colours are the solid geology. Faults are displayed in black. Colour bar indicates the distribution of depths for the period.*

Links

https://www.dnrme.qld.gov.au/mining-resources/initiatives/new-economy-minerals

https://geoscience.data.qld.gov.au/magnetotelluric/mt099998

Roger Cant, Janelle Simpson and Matthew Greenwood
Geological Survey of Queensland
Geophysics@resources.qld.gov.au

Geological Survey of Western Australia: AusAEM20-WA update

The TEMPEST® component of AusAEM20–WA Stage 1 is complete. Data from the Eastern Goldfields and the East Yilgarn survey blocks (Figure 1) were released on 4 February 2021, followed by the neighbouring Earaheedy–Desert block dataset on 25 March 2021. Figure 2 shows the location of the Stage 1 survey blocks for coverage with the TEMPEST® and SkyTEM® systems. AusAEM20–WA is a National Collaborative Framework Agreement project between GSWA and Geoscience Australia. Its objective is to complete 20 km AEM coverage of those parts of Western Australia that were not surveyed as part of Year 2 of Geoscience Australia's EFTF AusAEM survey.

Data acquisition with the SkyTEM system in the Southwest block resumed on 8 March 2021, after having been suspended in November 2020 when the survey helicopter was redeployed to summer bushfire work. Acquisition over the Murchison block will follow after the Southwest block is complete. Plans are for the data from both blocks to be available by the end of calendar year 2021.

Planning is in progress for coverage of the remaining strip in the southeast of Western Australia, tentatively in the 2021–22 financial year. Ultimately, the Western Australia coverage will go a long way towards attainment of the aspirational national goal of 20 km AEM coverage over continental Australia — AusAEM20.

Funding for AusAEM20–WA is from the Western Australian government's Exploration Incentive Scheme and additional support from the State's COVID-19 recovery plan.

Data from the recently released datasets (and other government-funded regional datasets) may be downloaded from GeoVIEW.WA — GSWA's interactive mapping, data discovery, and data delivery platform — or from the national Geophysical Archive Data Delivery System (GADDS) hosted by Geoscience Australia.

For more information, contact geophysics@dmirs.wa.gov.au.

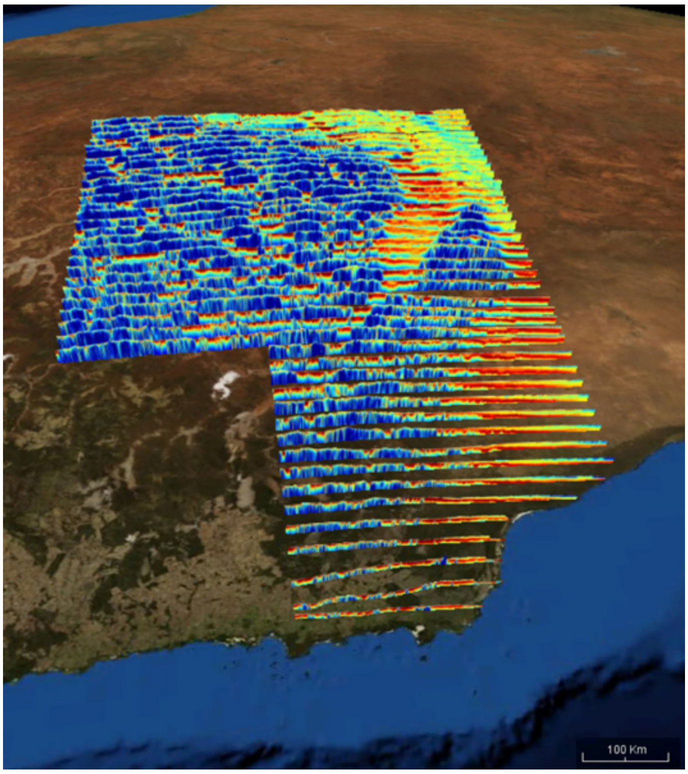


Figure 1. *AusAEM20–WA Eastern Goldfields and East Yilgarn blocks — stacked profiles of conductivity–depth images (image courtesy of Geoscience Australia).*

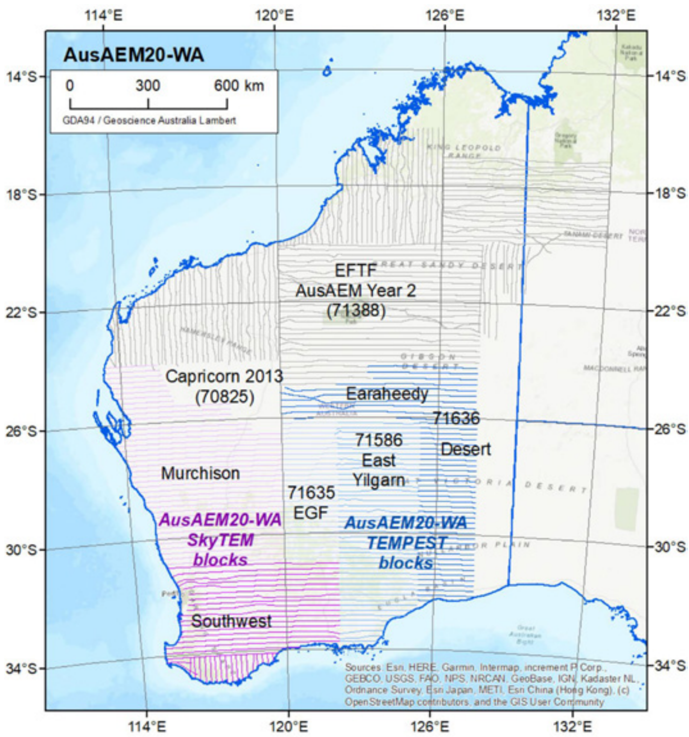


Figure 2. *Location of AusAEM20–WA survey areas. Numbers refer to dataset registration numbers in GSWA's MAGIX data repository.*

Canberra observed

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

What is the future of our universities?

The present government appears to have a love/hate relationship with our universities. On the one hand the country cannot prosper without them, and on the other the government is trying to increase its control over what they teach and where the research dollar goes. Hanging over all of this is the impact, both socially and economically, of the absence of international students.

Professor Deborah Terry, the Chair of Universities Australia, articulated her vision for the roles for universities in a Press Club address on 10 March 2021. She envisaged our universities helping to drive Australia's recovery from the COVID-19 pandemic in three significant ways:

- Contributing to the broad, flow-on economic and social benefits that our nation needs.
- Educating the skilled graduates who will shape our future.
- As a primary producer of innovation, providing the capacity to help turbo-charge Australia's economic growth and job creation.

Let us look at a few numbers.

Economic benefits

According to Deloitte Access Economics (2020), quoted by Professor Terry, in 2018 universities:

- Contributed annually $41 billion to the Australian economy.
- Supported 259 100 equivalent full-time jobs.
- Contributed $3 of additional taxation revenue for every $1 invested in university teaching and scholarship from government.
- Generated $5 to GDP for every $1 invested in higher education research and development.
- Generated annually an additional $1.8 billion of economic activity, a 0.09% increase in GDP.

The main conclusion from these numbers is that public investment in universities is a sound strategy, particularly after COVID-19. Unfortunately, the contribution from international students has fallen significantly, and created a huge gap in revenue.

International students

The number of international students enrolled in Australia grew by 58 % in the last five years (https://www.studying-in-australia.org/international-student-in-australia-statistics). Tables 1 and 2 show some of the numbers – they include students at all Australian educational institutions (Table 1). The increase in five years has been dramatic.

As you can see in Table 2 the economic impact has been huge, both to the universities and to the whole of the country. But it is not just the economic impact. The personal networks developed between Australians and other people in Asia are vital if we are to prosper in a post-COVID world. After all, it is not just what you know, it is who you know. Australia can only benefit from these interactions.

Universities Australia estimate that the equivalent of around 21 000 permanent jobs have been lost because of the absence of overseas students due to COVID-19. Many of these will be in specialised teaching positions, and will be gone until international travel is restored.

It was very disappointing that the government decided to deny universities access to Job-keeper funds. It never explained why it took this decision. I would have thought that it would have been more important to sustain our educational facilities than to give money to the likes of Harvey Norman, or to provide half price air fares for tourists to go to marginal electorates. The government thought otherwise.

The government relented to some extent by providing an additional $1 billion through the Research Support Program (RSP) to alleviate the immediate financial pressures on the research

Table 1. Total number international students (source: https://www.studying-in-australia.org/international-student-in-australia-statistics)

Calendar year	Number of international students
2015	465 508
2016	517 890
2017	586 627
2018	650 905
2019	738 107

Table 2. Economic impact and effect on larger universities (source: https://www.studying-in-australia.org/international-student-in-australia-statistics)

Number of students per country		Contribution to economy, $millions	University/international students total numbers and proportion in %		
China	203 295	12 095	Monash	25 690	30.7
India	109 736	5495	Sydney	25 532	38.2
Nepal	51 377	2628	Melbourne	21 858	32.1
Brazil	25 604	1015	Queensland	17 865	33.3
Vietnam	24 782	1368	RMIT	16 667	24.1
Malaysia	23 854	1378	New South Wales	15 741	25.2
South Korea,	20 152	0.984	UTS Sydney	13 672	29.7
			Deakin	13 044	21.9
			ANU	9782	37.0
			Macquarie	9414	21.1

activities undertaken at universities during the COVID-19 pandemic. The RSP provides block grants to higher education providers to support the systemic costs of research not supported directly through competitive and other grants, such as libraries, laboratories, consumables, computing centres and the salaries of support and technical staff. The RSP safety net will not be applied in allocating this additional funding. Note that the teaching components of universities appear to have received nothing.

University research commercialisation

In the 2020-21 Budget, the Government provided $5.8 million "to scope a University Research Commercialisation Scheme to better translate and commercialise university research outputs".

This may be built on the Cooperative Research Centres programme, which "Supports Australian industries' ability to compete and produce, by helping industry to partner with the research sector to solve industry-identified problems."

The Prime Minister said in his address to the Business Council of Australia on 19 November 2020:

"We want to provide a platform and a pathway for our talented researchers to partner with you, with businesses all around the country and to apply their intellectual firepower as research entrepreneurs."

Commercialisation has always been the most difficult outcome from research because it is usually very expensive. I think that the Prime Minister is looking at the issue the wrong way round. To be successful in business you first must identify the opportunities and then ways to capitalise on these with new services or products. Without a market there is no point in even thinking about commercialisation.

If you take COVID-19 as an example, the rapid development of vaccines was possible because there was a problem that needed a solution and, more importantly, the necessary basic research was already underway. The development of airborne geophysical techniques was driven by the requirement to find more mineral resources and a number of successful CRCs focused on important issues relating to the development of airborne geophysical techniques identified by industry.

Consequently, it is critically important that we continue to support a wide range of basic research. We never know when we might need the skills and knowledge created by basic research to support our ongoing prosperity. We must prepare for the future as best we can.

Finally, what is the future of our universities?

If the government continues to micromanage what it thinks should be taught, and what research should be carried out and how it should be done, then the future will not be bright. Government are not good at picking winners. Leave it to the universities.

Areas selected for 2021 offshore exploration acreage release

With oil price back up to over $US65/bl, there should be increasing interest in the latest release announcement on available offshore acreage.

The government is seeking feedback on 21 areas selected for offshore exploration release in 2021 (see the map in Figure 1). This consultation process provides an opportunity for comment on potential areas for release. Submissions will be considered by the government in determining which areas are made available for bidding as part of the 2021 acreage release.

It will make information from submissions publicly available unless marked confidential. Once published, potential bidders or explorers can access the information when preparing bids or as part of planning for exploration activities.

If you go to https://consult.industry.gov.au/offshore-exploration/2021-acreage-release-consultation/ you can see the detailed maps and more information.

The areas are situated in four main basins:

Bonaparte and Browse Basins: W21-1, 2 and 3; and AC21-1

Carnarvon Basin: W21-4, 5, 6, 7, 9, 10 and 11

Otway and Sorell Basins: T21-1, 2, 3 and 4; and V21-1, 2 and 3

Gippsland Basin: V21-4 and 5.

Have a look and see. The detailed maps produced are worth a visit, even if you are not going to be making a submission.

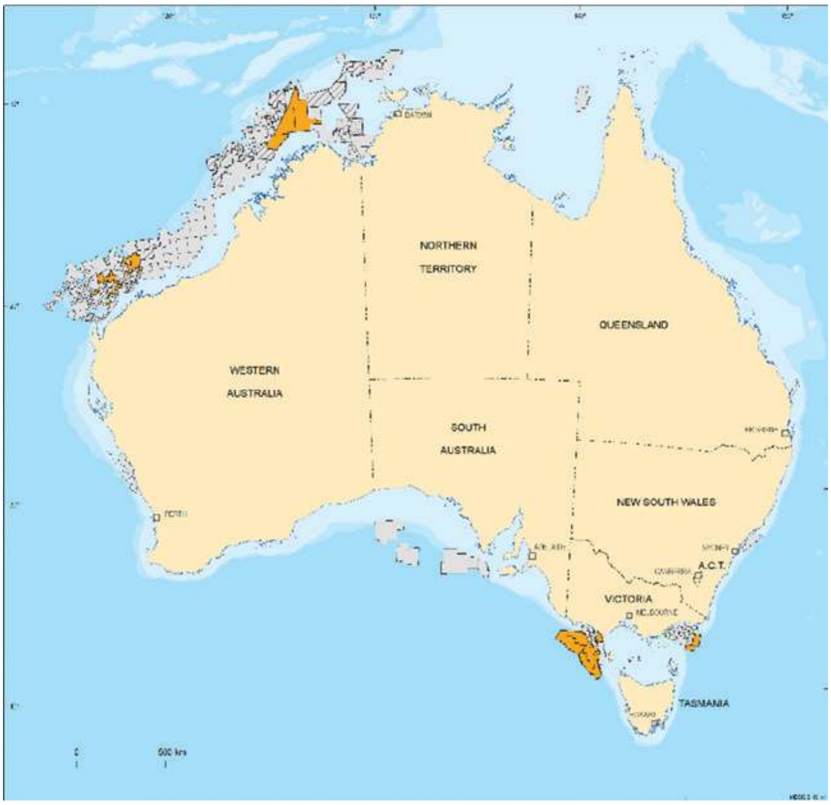


Figure 1. *The areas selected for consultation in the 2021 offshore acreage release are shown in orange (source: https://consult.industry.gov.au/offshore-exploration/2021-acreage-release-consultation/).*

Education matters

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

Presentations available on the ASEG's YouTube channel in 2021

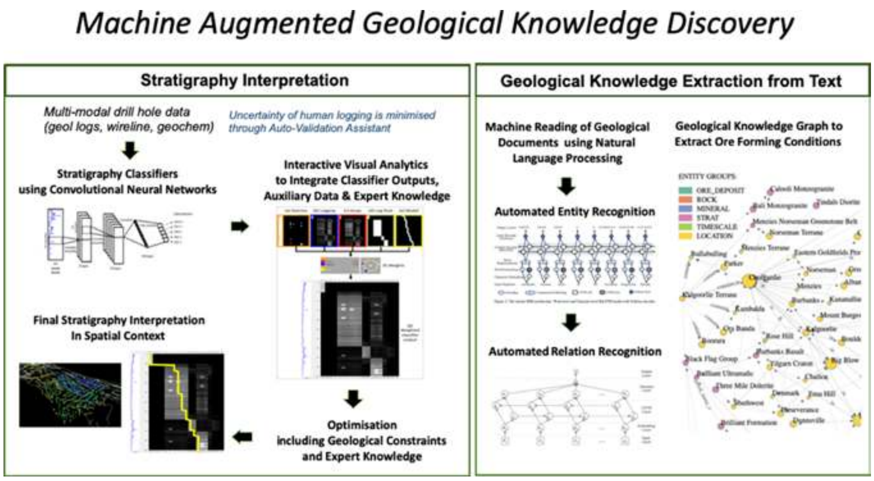
Presentations on the ASEG's YouTube channel are increasing in popularity, and I envisage the day when the channel reaches the million views threshold. In the last two months, four excellent presentations have replenished the ASEG video library. The presentation topics have ranged from machine learning through to the use of Bayesian joint inversion to image Australian crust, the use of magnetotellurics in minerals exploration, and establishing a methodology for surface magnetic surveys on Mars.

This month's column focuses on these presentations. Each title is followed by a link to the YouTube video of the presentation, and I thoroughly recommend watching each of them. Of course, the ASEG's channel includes presentations from 2020 and earlier on topics ranging from conventional exploration for minerals and hydrocarbons, through to the use of geophysical techniques in forensic and geotechnical applications. All are excellent and a wonderful avenue through which to introduce non-specialists to the possibilities of exploration geophysics.

EJ Holden: Geological knowledge discovery using machine augmented intelligence https://www.youtube.com/watch?v = 0Wjda4wzTK0

The year started with Professor Eun-Jung Holden (UWA), who presented some innovative machine-assisted technologies that improve the efficiency and the robustness of geological interpretation of different types of geodata used in the resources industry. Geological interpretation is a complex task where an interpreter's bias plays an important role. As a result, interpretation outcomes are variable and uncertain but, nevertheless, these outcomes form the basis of decisions with significant environmental, social and financial implications. Artificial intelligence and machine learning are increasingly being used in our daily lives, such as for information searching, online shopping, and virtual assistant AI. In the geoscientific domain machine learning and AI are also being increasingly used, primarily to assist with interpreting geology from data.

Professor Holden's talk described a number of applications of machine learning that were developed in collaboration with the mining industry for the analysis and integration of multi-modal drill-hole data. These applications integrate algorithms and workflows to assist human decisions in order to provide end users with control of the algorithmic process and to enable a seamless integration of algorithms in the interpreter's workflow using interactive visualisation. Case studies on different mineral deposits demonstrated the effectiveness of methods for rapidly and robustly transforming text data into structured information that faithfully represent the contents of the source reports.

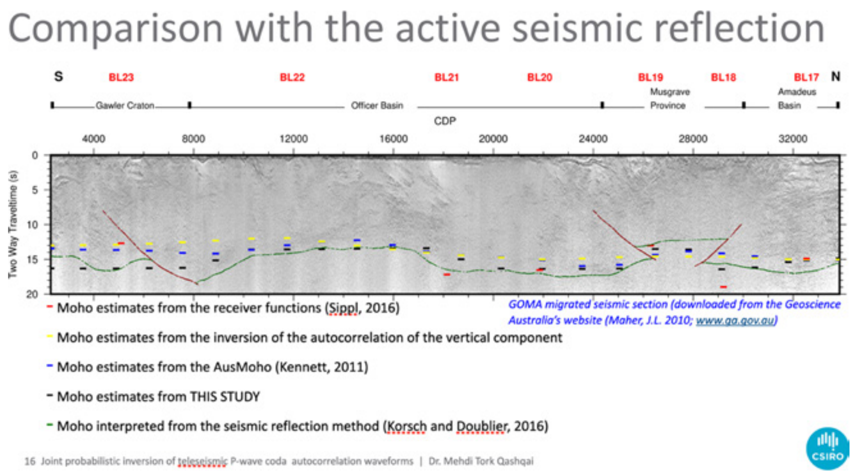


Slide from Prof Holden's presentation.

Mehdi Tork Quashqai: Seismic imaging of the crust using Bayesian joint inversion of teleseismic P-wave coda autocorrelation waveforms https://www.youtube.com/watch?v = ZAocmapX2Os

Dr Qashqai of CSIRO's Deep Earth Imaging Future Science Platform described seismic imaging of the earth's crust. Deep crustal-scale structures are critical for control and development of a wide range of mineral deposits. Incoming seismic waves generated from teleseismic earthquakes can be used to image the deep crustal structures. Travel times of the teleseismic P and mode-converted S-waves and their reverberations place a tight constraint on the Vp/Vs ratio, and their amplitude ratio provides tight bounds on the P and S wave velocity jumps across the main discontinuities/boundaries in the subsurface structure below a seismic receiver. Teleseismic P-to-S converted waveforms have been used for decades to estimate the shear-wave velocity of the subsurface and depths of major discontinuities below a seismic receiver through a method known as the P receiver functions.

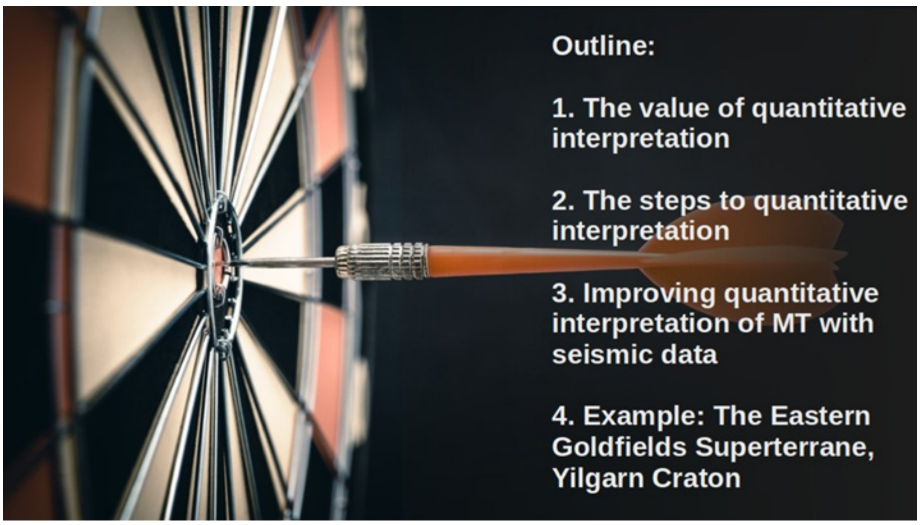
Dr Qashqai presented an alternative approach to imaging. Waveforms associated with the P and all mode-converted shear waves are extracted by the autocorrelation of the teleseismic P-wave coda recorded on the radial and vertical component of a three-component receiver. These waveforms are then jointly inverted using a probabilistic joint inversion framework to simultaneously estimate seismic properties of the crust (Vp, Vs and Vp/Vs). This approach is particularly useful when there are no high-quality and reliable receiver function waveforms. The approach is cost-effective and can be used in conjunction with the inversion of receiver function, or deep active seismic reflection profiling to obtain additional/complementary information on the subsurface structure, especially at middle and lower crustal depths where the deep seismic reflection method has penetration problem. Dr Qashqai's presentation included both synthetic and field data in order to demonstrate the feasibility of this imaging technique, and also to encourage further application of this approach.



Slide from Dr Qashqai's presentation.

Dr Kate Selway: Exploring for minerals, not anomalies: Developing quantitative interpretations of MT models https://www.youtube.com/watch?v = kZjjHX7BLDY

Exploration geophysicists are well acquainted with making quantitative interpretations of near-surface geophysical data. There is a reasonable understanding of how shallow anomalies in potential field, resistivity or EM datasets relate to mineralisation. However, as exploration models begin to include the lower crust and the lithospheric mantle, there remain significant gaps in our interpretation of deeper geophysical data. Dr Selway's talk highlighted some new advances in our ability to produce quantitative interpretations of these deeper geophysical data, with a particular focus on magnetotellurics and its joint interpretation with seismics. A highlight of Dr Selway's talk was the introduction of the software package 'MATE', which allows MT models to be interpreted in terms of temperature and composition. Dr Selway's talk concluded with a discussion of new results from the Eastern Goldfields, which showed how quantitatively interpreted MT models can feed into improved exploration strategies.



Introductory slide from Dr Selway's presentation.

Dr Clive Foss / Dr Jim Austin: From Tenterfield to Mars: Magnetic modelling with terrain https://www.youtube.com/watch?v = eeUH_yYUttg

The fourth talk of 2021 was perhaps a glimpse into the future of ASEG technical meetings. Dr Clive Foss and Dr Jim Austin, both from CSIRO, presented their talk as part of the NSW branch's Annual General Meeting.

Mars lacks a core dynamo magnetic field such as we have on the Earth – although the existing Martian magnetic field due to distributed crustal remnant magnetisation reveals that it once had a substantial field. Much of the surface of Mars consists of lava flows and shield volcanoes, which on Earth tend to have reasonably consistent and homogeneous properties within individual units. However, Mars lacks the air to support aeromagnetic mapping and, as a consequence, any sparse ground mapping of the magnetic field may need to be supplemented with low-resolution orbiter data.

Drs Foss and Austin presented a study using GSNSW Tenterfield aeromagnetic survey data and terrain-bound inversion models in which they recovered robust bulk magnetisation estimates for outcropping igneous units. They also presented magnetic fields forward computed from Martian terrain models of different magnetisation direction. The link between Tenterfield and Mars was made by demonstrating that input magnetisation directions could be recovered from models from inversion of sparse surface magnetic field data. This suggests that their Tenterfield study might be a first step towards establishing a methodology for surface magnetic surveys on Mars.

Virtual SEG DISC coming soon

A SEG Distinguished Instructor Short Course 2020-2021 "Survey design and seismic acquisition for land, marine, and in-between in light of new technology and techniques" by Dave Monk is coming to Australia as a virtual course this year. It has been postponed several times as Dave dreamed of touring Australia and visiting all the capitals of our beautiful country. However, with the COVID-19 related restrictions on international travel, the virtual course option looks

Dr Foss presenting to the NSW branch AGM.

like Hobson's choice. The course will be delivered in two days (four hours per day). One virtual event will bring together geophysicists from across Australia, although it means an early start for our colleagues from WA.

DISC 2020-2021: AUSTRALIA/ VIRTUAL

Survey design and seismic acquisition for land, marine, and in-between in light of new technology and techniques

Dave Monk
10-11 August 2021
1000 am AEST

Registration is open https://seg.org/shop/products/detail/287093232

Description

Seismic surveys are subject to many different design criteria, but often the parameters are established based on an outdated view of how data can be acquired, and how it will be processed. This course is designed to highlight what is possible using modern methods, and how they impact seismic survey design.

Survey designs are subject to a limited set of operational and geophysical considerations. What frequencies do we require (in the source), and what will or can we detect? What geometry will be utilized, and what record length will be recorded?

However, new techniques and processing methods require that we understand and answer a new and different set of questions:

- Are classic survey geometries outdated? What geometry is optimum given almost limitless availability of channels, and how are these best deployed if they are not constrained to be connected together?
- How do you QC data from a system that doesn't permit real time views of data?
- How do compressive sensing methodologies fit into classical geometry requirements, and can these significantly impact how data is acquired and processed? Is random "optimum" and is optimum unique?
- Do offset and sampling requirements change if processing will utilize FWI and/or least squares migration?
- Can very low frequencies be generated, detected and used for improved inversion?
- How should simultaneous sources be utilized, and can subsequent data be separated from the continuous records that will be required if this technique is used? If two sources are better than one, are four better than two?
- What should we expect of seismic data five or ten years from now?

This course is designed to cover some of the fundamentals of survey design, but will highlight the changes in technology that we have seen in the past five years, and those that are likely to develop in the next five years with a view to allowing seismic surveys to be designed and acquired to optimize technology efficiencies and interpretation requirements in light of new technology.

Goals

This course will not describe specific survey designs for particular geologic objectives, but after attending this course, the participant should:

- Understand the basic geophysical requirements of a seismic survey, based on geologic objectives
- Have a much-improved knowledge of the differences between classic survey design, and what is required for modern high-end processing techniques including FWI
- Understand the concepts of simultaneous sources, compressive sensing, node acquisition, and broadband data, and see how these fit into survey design techniques
- Understand that there is a relationship between acquisition parameters and seismic image quality
- Understand how the basic requirements tied to modern acquisition and processing ideas can fundamentally change the data that is presented to an interpreter, and why final data volumes can look significantly different from legacy data

Who should attend?

All those interested in seismic surveys should attend. Geophysicists involved in acquisition may discover new techniques and concepts which with they are unfamiliar. Geophysicists involved in processing seismic data will better understand the shortcomings of the data that they are given to process, and better understand what techniques will, and will not, work for a particular survey. The interpreter may better understand the difference between modern seismic volumes presented for interpretation, and the legacy data that he is accustomed to interpreting. For those directly involved in survey design, the concepts will open up the potential for acquiring better images of the subsurface more efficiently, and at less cost.

The course does not require extensive mathematical knowledge or background. Concepts will be explained in a way that the layman or manager can understand. Students will be able to follow and understand the course from the basics to the level of asking knowledgeable questions of those actually involved in seismic acquisition and processing.

Environmental geophysics

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

Welcome readers to this issue's column on geophysics applied to the environment. In this month's column I am handing the reins over to Greg Street from Loupe Geophysics. I've been doing some work with Greg lately and we got talking about the nature of interpretation. I thought that his thoughts were interesting (and he has been meaning to write them up for a while he says). Here is Greg's story.

Geophysical interpretation

Greg Street
gstreet@iinet.net.au

During the late 1980s and into 1990s at World Geoscience Corporation we carried out many surveys (mostly airborne electromagnetics) trying to understand the causes of dryland salinity in the agricultural areas of Australia. As we proceeded with this work, we realised that it was crucial to interpret multiple data sets together in order to arrive at some understanding of how the landscape was working, and how it had evolved. In the use of AEM data sets this was a vastly different approach to how I had used EM surveys in mineral exploration. In exploration, AEM was a tool to find anomalies and in many cases is still used in this mode today.

This work led me to the realisation that interpretation techniques in environmental geophysics were fundamentally different to techniques that I had applied in mineral exploration. For the environmental work we were using multiple whole datasets to get to conclusions in one great "melting pot", rather than interpreting individual datasets, discarding most of the data and concentrating on anomalies. For example, an ore-body may be found using airborne magnetics interpretation to locate anomalous areas, followed by ground magnetics and ground electrical surveys. In each step only a subset of the data is used. Data is 'lost' at each step and information gained for a specific goal.

When we use geophysics to interpret landscapes and landscape evolution, as we often do in salinity studies, we use all data in each step to maximise the information obtained. However, as in mineral exploration it is a one-way process. You can take a dataset and interpret it, but you cannot take an interpretation and return to original data. Some of the information is lost in the interpretation, and the look of your interpretation depends on the aim of the work at hand.

During that time, I was an "industry" supervisor on Ann-Marie Anderson-Mayes' PhD thesis (Anderson-Mayes, 1999), which focused on how to maximise information from multivariate datasets. This led to many discussions about "What is interpretation?". Ann-Marie stressed that the conventional approach where we manually, often separately, interpret each data set, had limitations. As part of her PhD project she developed a GIS-based analysis system that ultimately extracted a map of a study area that predicted which areas in the landscape were likely to be prone to salinity build-up.

At WGC we used that approach in later studies as part of the National Airborne Geophysics Project (Street *et al*, 1998, and Pracilio *et al*, 1998). Interestingly, this approach worked quite well in the southwest of Western Australia, but was less successful in Queensland and Victoria (I evaluate this further below).

This "automated" approach takes away the potential for interpreter bias, but is it right? The jury is still out – and we seem to be getting better these days at automating these processes, and incorporating more data.

At many times in my career, I have contemplated the nature of interpretation. While lecturing in Environmental Geophysics I tried to get my students to think about the nature of interpretation - which for the most part was met with very blank faces. The students strongly preferred a narrow, mostly mathematical approach to interpretation. Plug the numbers into a program and out comes an answer. One year, the Environmental Geophysics Field Day was at a suburban waste disposal site. The student reports were usually full of modelling of geophysical responses and short on conclusions about what the data was really telling us about the site. At these sites there are always artefacts in the data that trap the unwary. Most students did not understand that the "best" approach was to use all of the data to try to understand the underlying system, ignore the traps ("great, you found the buried powerline, but how does that help us with understanding the potential leakage from an abandoned factory to the northwest?") and see the big picture.

Interpretation has been pondered by many throughout history and across many disciplines. In geophysics we make observations and draw conclusions from them. We can also employ basic scientific principles and bring some geological understanding into the mix which dictate the causes and effects. Then there is the underlying mathematics that can be used to predict and explain how events happen. Many prominent philosophers and scientists have deliberated on the underlying philosophy behind the process we call interpretation. Plato stressed experience: as we grow older having made all (?) the mistakes, we should become better interpreters. A similar approach is inherent I believe in the teachings of many Buddhist philosophers in seeking enlightenment through suffering (or making mistakes).

Descartes was a questioning man and opted for a more rationalist (questioning?) approach to interpretation. I prefer this Cartesian approach as I believe we should all question our data all the time. Who collected the data and when?, for example. I have seen geophysical operators who consistently collected noisier data than others. Was this survey done at the right time or are there spherics, turbulence or other factors that affect the data quality in the data? Were the survey specifications right for the purpose intended and has the data been processed in the best possible way? What are the geological controls and can we bring in other data to support our interpretation?

Gottlob Frege on the other hand believed in a mathematical logic approach to interpretation. His approach was to eliminate any intuition or human element from the process. If there is any human element it should be evaluated and presented separately as an axiom. Thereafter the interpretation can be purely logical. However, if we largely ignore the human element and the vagaries of nature plus the possibility of noise then we may end up missing vital information about our system. Thus, I expect the answer to the question above (why did Anne-Maries "machine learning" approach work so well in WA and not so well in the east?) is that in the south-west of Australia we knew the conditions well and thus could almost follow a Frege approach. Elsewhere we were not so successful. We had not evaluated our axiom properly and we needed a bit of Cartesian logic.

Early in my mineral exploration career, we tried to figure out why a hole that we had drilled into an anomaly at Broken Hill Deep had intersected nothing of note. Based on the drilling, the anomaly was clearly due to a broad shallow feature. Based on the geophysical data, modelled in the office (not by me luckily) it looked to be 400 m deep. An expensive mistake. A bit of Plato's experience and Descartes rationalism means that mistake should not be repeated (at least by any of us working on that project). Even then, maybe it would not have happened if the interpreter looked at a topographic map and realised that there was a sequence of similar anomalies following a creek line, but in those dark old days we did not have GIS and it was only in the field that the relationship was obvious.

Each philosophy has advantages and disadvantages and ideally we should have a bet each way in our interpretation. In natural systems it is important to remember the complexity behind the system, and the simplicity of the answer we are searching for through the interpretation. How we approach an interpretation can greatly alter the results. From a rationalist point of view, failure to identify the objectives of the interpretation before starting will result in an ineffective interpretation. However, having a too narrow interpretation goal before we start may alienate the true solution from the interpretation.

Why am I rambling on about interpretation? It is because I heard a quotation the other day on Anh's Brush with Fame on ABC TV about art. "Art is an artefact of something you made in the time you had available. It is never finished. It is never perfect." The same may be said of interpretation.

References and related reading

Anderson-Mayes, A., 2000. *Enhancing Interpretation of Multivariate Airborne Geophysical Data for Dryland Salinity Studies*. PhD Thesis, University of Queensland.

Anderson-Mayes, A., 2002. Strategies to improve information extraction from multivariate geophysical data suites, *Exploration Geophysics* 33(2).

Street, G. J., Pracilio, G., Owers, M., Triggs, D., and Lane, R., 1998. National Dryland Salinity program. *Airborne Geophysical Surveys to assist in planning for salinity control – 1. Willaura SALTMAP Survey – Interpretation Report – June 1998* (92 pages, plus appendices and maps.), unpublished report for National Airborne Geophysics Project, AGSO.

Street, G. J., Pracilio, G., Nallan Chakravatula, P., Vukovich, D., Harvey, B., Sattel, D., Owers, M., and Lane, R., 1998. *National Dryland Salinity program. Airborne Geophysical Surveys to assist in planning for salinity control – 2. Balfes Creek SALTMAP Survey - Interpretation Report - August 1998*, unpublished report for National Airborne Geophysics Project, AGSO.

Pracilio, G., Street, G. J., Nallan Chakravatula, P., Nash, C., Owers, M., Triggs, D., and Lane, R., 1998. *National Dryland Salinity program. Airborne Geophysical Surveys to assist in planning for salinity control – 3. Lake Toolibin SALTMAP Survey – Interpretation Report – December 1998* (110 pages, plus appendices and maps), unpublished report for National Airborne Geophysics Project, AGSO.

Greg Street has a BSc (Hons) in geology (UNE, 1974) and an MSc in geophysics (London, 1980). In 1983 following 10 years in mineral exploration he joined the Geological Survey of WA where he worked on the application of geophysics for environment. This resulted in a joint project with Aerodata and the Department of Agriculture to develop an airborne electromagnetic system for land salinisation studies. From 1992 to 2000 he was Director of Environmental Services at World Geoscience Corporation and part of teams that applied airborne geophysical methods for environmental applications in Australia and overseas. For this work Greg's team received two Western Australian and one National Landcare Award. Greg was recruited to Sandfire Resources as General Manager and ran the company up to the discovery of the DeGrussa Copper Deposit a multi-billion, dollar deposit. He is a former senior lecturer in Environmental Geophysics at Curtin University. Greg is a former secretary (1988) and president of the Australian Society of Exploration Geophysicists (ASEG) in 1989 and 2014 as well as the recipient of the inaugural Lindsay Ingall Memorial Award. Greg is currently a Director of Loupe Geophysics, which has developed a new Electromagnetic system for shallow conductivity mapping.

Minerals geophysics

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

The Wild, Wild West

As with many of you, much of the earliest part of my career as a geophysicist was spent in the field conducting ground geophysical surveys. Unlike most of you, this time frame spanned the late 1960s and early 1970s. We did things a bit differently back then! My employer was Mines Exploration, the exploration subsidiary of Broken Hill South, which at that time was still mining the main lode at Broken Hill. We had a mandate to explore for both metallic and non-metallic resources throughout Australia; over those initial years I got to see a lot of the country.

Prior to the arrival of the MPPO-1 and the development of the SIROTEM time domain electromagnetic (EM) instrumentation, induced polarisation (IP) was the principal electrical geophysics technique used in mineral exploration in Australia. Mines Exploration typically had one or two IP crews working throughout the year. Initially, these were McPhar Geophysics crews contracted on a yearly basis; later the company formed their own crews using in-house personnel and equipment.

By today's standards the equipment we used was primitive. Transmitter output was limited, receivers were single channel, and results were read from dials and hand-written on field sheets. Crew leaders processed the results each evening, calculating values with a slide rule or basic calculator then plotting profiles and contouring plans and pseudosections by hand. Contouring resistivity values in log space became second nature.

This was a time of fierce rivalry between IP equipment manufacturers - time domain versus frequency domain. Time domain equipment tended to be less portable, so the gradient array was favoured. EM coupling was more problematic in the frequency domain, so the dipole-dipole array was favoured. We were in the frequency domain camp, and our receivers were really just bespoke AC voltmeters. To take a reading, the instrument was nulled with a potentiometer for a 3 hertz transmitted signal, the deviation from a second transmitted signal at 0.3 hertz was measured on a dial, then a repeat reading was taken at 3 hertz to check for drift. With these values, plus knowledge of the transmitted current and the disposition of the four electrodes, apparent resistivity and IP frequency effect values could be calculated. One transmitter-receiver dipole pair at a time.

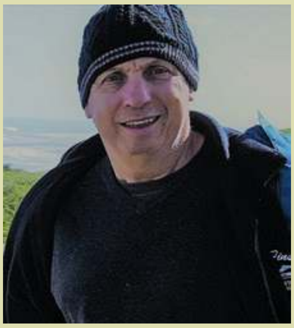
Broken Hill South had extensive ground in northwest Queensland over the Cambrian Beetle Creek Formation for exploration for rock phosphate. Proterozoic rocks beneath this were considered prospective for base metal mineralisation and IP-resistivity offered a means of searching for blind base-metal deposits in this environment. Accordingly, in the early 1970s, I was working way north of Mount Isa in northwest Queensland, surveying long lines of 100m, n = 3 & 4, dipole-dipole IP-resistivity. The countryside could charitably be called rolling woodlands, and lines were cleared with a light bulldozer blade to improve access. However, it soon became apparent that our geophysical equipment was not up to the task. The problem was inadequate transmitter current strength. Much of the ground surface was highly resistive silcrete, which, despite lots of effort in electrode preparation, effectively blocked transmitter current injection. We needed to penetrate the silcrete. Would explosives do the job?

This proved surprisingly easy to organise. A case of gelignite was purchased over the counter at the local Burns Philp Store in Mt Isa, along with a box of detonators and a roll of safety fuse. The gelignite and safety fuse went into the back of the truck, the detonators into the glove box. Testing in the field produced marked improvements. We developed quite a routine – open up a crack in the silcrete with a crowbar, carefully charge the hole with half a stick of gelignite primed with detonator and a metre of safety fuse, back-fill the hole with rubble, pile rocks, anthills and dead logs on top to contain the explosion, light the safety fuse, then drive 100 metres to the next site. Safety precautions consisted of taking extra care crimping the safety fuse to the detonator, using only a wooden skewer to pierce the gelignite to accommodate the detonator, not wiping your forehead after you'd handled gelignite, and ducking your head inside the vehicle when the explosion went off because at 100 metres we were still in fly rock range.

Then the rains came. Despite the improvements in current strength afforded by the wet ground, we decided to continue using explosives. Things went smoothly until one day we bogged the vehicle next to the charged hole. By the time we'd exhausted the easy options and got the doors open, the burning safety fuse had disappeared below ground level. We retired to a safe distance, abandoning the vehicle, then realised that the box of detonators was sitting on the front seat and there was a case of gelignite in the back. Fortunately there was no sympathetic explosion of detonators and gelignite, but the vehicle was showered with mud and debris. After that, we moved the vehicle to the next site before somebody lit the safety fuse.

None of this would be possible in today's comprehensive safety regime, thank goodness, but it did add extra interest to the survey!

Seismic window



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

Tracking geological features

Last week I watched a late night webinar (why are they always late at night?) which described using a "thalweg tracker" to map geological bodies in a 3D seismic data volume. Originally designed to follow the thalweg of a channel – here the thalweg is defined as the deepest / lowest part of a channel - the tracker searches for the lowest point in neighbouring cells given a single seed point on an elevation map. The thalweg tracker will also work with seismic amplitude or several other seismic attributes as an input, and because the interpreter can select how many points are picked some control can be exercised to limit any picked bodies to a particular facies.

Some properties of the thalweg tracker are:

- The result is almost independent of seed location. If it is in the same channel an almost identical result is obtained
- It tracks only positive amplitudes or negative amplitudes so it is always in either a peak or trough
- It is not restricted to tracking thalwegs. Other geological features can also be tracked
- The input can be any seismic attribute but amplitude is a good starting point

The examples shown in the webinar were impressive so I thought I'd give some Australian data a try. Initial results using an offshore dataset were poor, so I switched to using some SW Queensland data as input and the results were much more useful. The tracker produced an interesting channel feature that terminated in a fan and there were also some splay like features (Figure 1).

I quickly identified four more channels by using different seed points and a picture emerged of a series of west-east trending channels with associated fans (Figure 2). This is where I stopped, but the webinar continued and got very interesting. By identifying various facies as channels, splays, fans the thalweg tracker can be used to produce labelled training sets for application in a machine learning approach applied to classify the facies in an entire volume. A more detailed explanation can be found in *First Break* Vol 19, March 2021 "Seismic classification: A thalweg tracking/ machine learning approach" by Paul de Groot *et al* (2021). Take a look, it's worth reading.

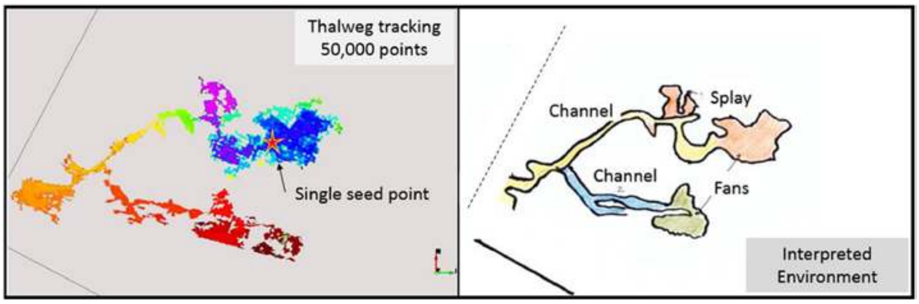


Figure 1. *South West Queensland example of a body comprising 50 000 cells tracked from a single seed point by the thalweg tracker (top). Environment of Deposition map (bottom) is interpreted from picked objects.*

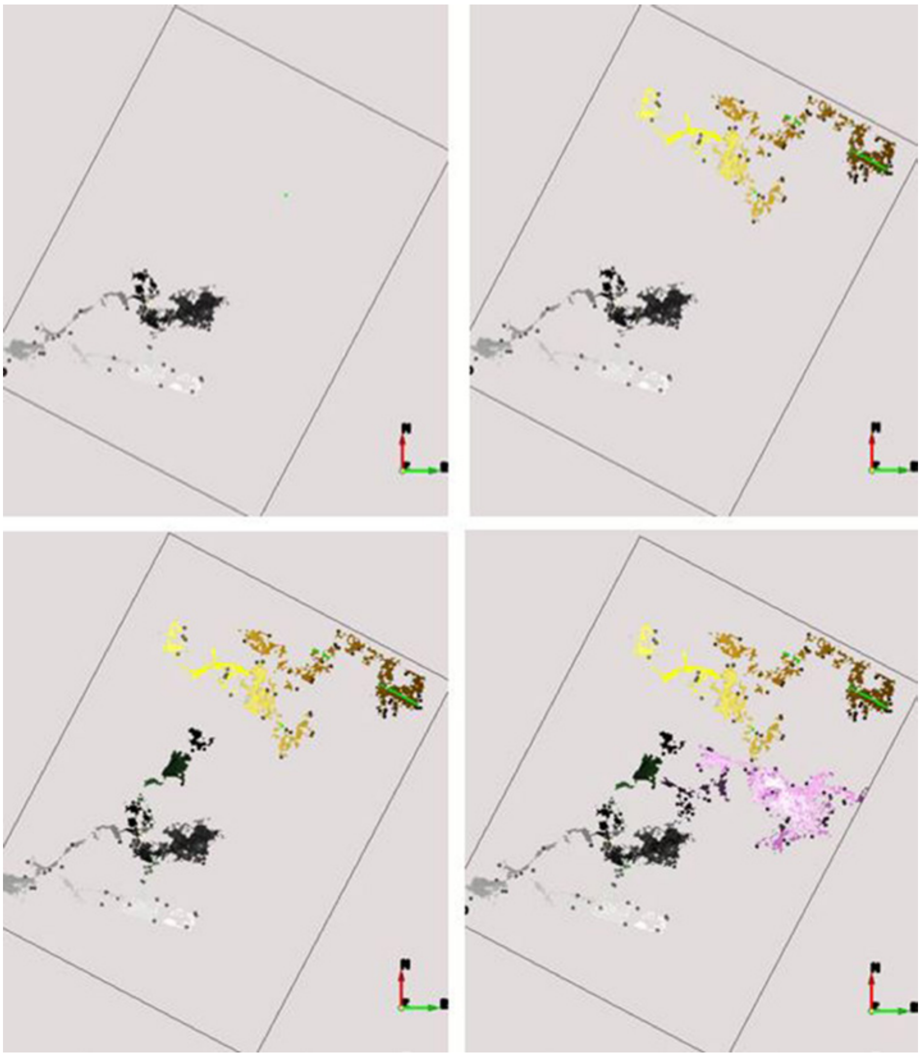


Figure 2. *Several bodies are picked across the area of interest, each with its own seed point.*

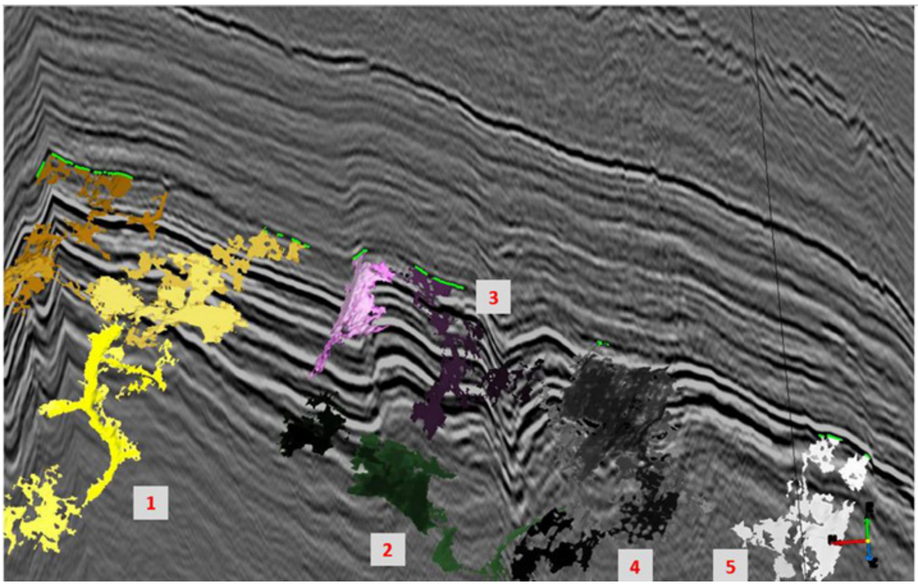


Figure 3. *Showing up to five different channel systems and associated fans: 3D view of picked bodies.*

Data trends

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

Regularising and mixing points with grids

I present results of my short ArcGIS™ Python code for regularising points using gravity stations from Andamooka, South Australia (Figure 1 - top). I hope it is easy to use and implementation is explained effectively. The demonstration area is 13.2 km x 9 km and contains 10 gravity surveys ranging in acquisition date from a 1970 survey carried out by WMC survey to the 2009 Northern Olympic Domain (NOD) survey with company infill. The most common station spacing is 200 m, but "incursions" from several 1970 and early 1980s surveys with spacing varying from 100 m to 600 m cause overlap, effective duplication at some locations and some clear disagreements in levelling.

A 50 m cell-sized grid of the original located data shows high frequency responses and multiple linear features are prominent characteristics (Figure 2 – top). The grey scale colour stretch shows artefacts due to the near or overlapping survey stations (Figure 3 – top).

The regularised grid began with points 3200 m apart being assigned the nearest real value within a radius. This method was used to generate a grid at quarter spacing (800 m cell size). The second iteration created points with half the spacing (1600 m) and these were assigned the nearest real values. Any points still empty were assigned the nearest interpolated value from the

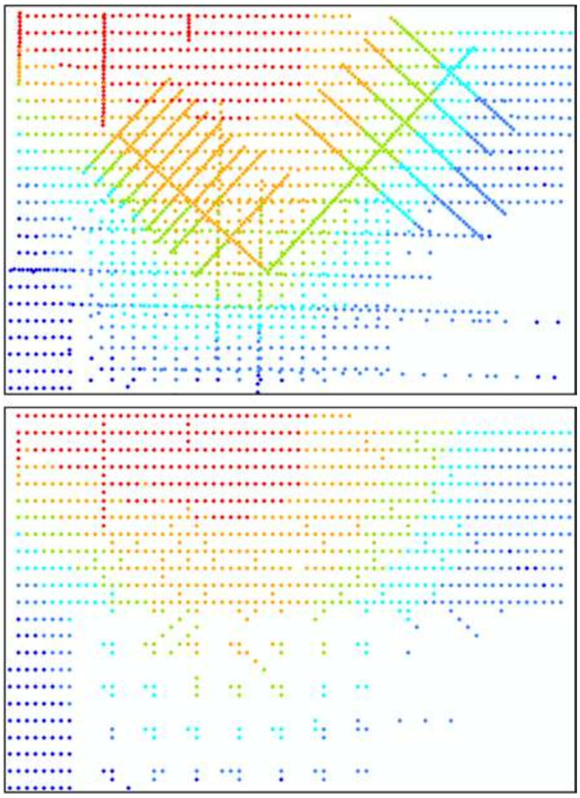


Figure 1. *Gravity stations in the Andamooka region. Top – original locations. Bottom - regularised by the Python code to 200 m spacing.*

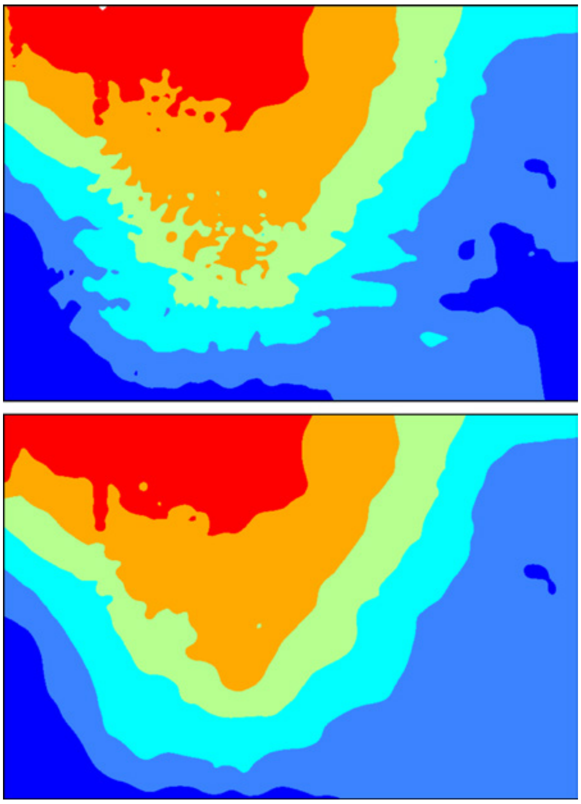


Figure 2. *Colour stretched 50 m cell size grids of gravity stations shown in Figure 1 using ArcGIS spline function. Top – original locations. Bottom – regularised to 200 m*

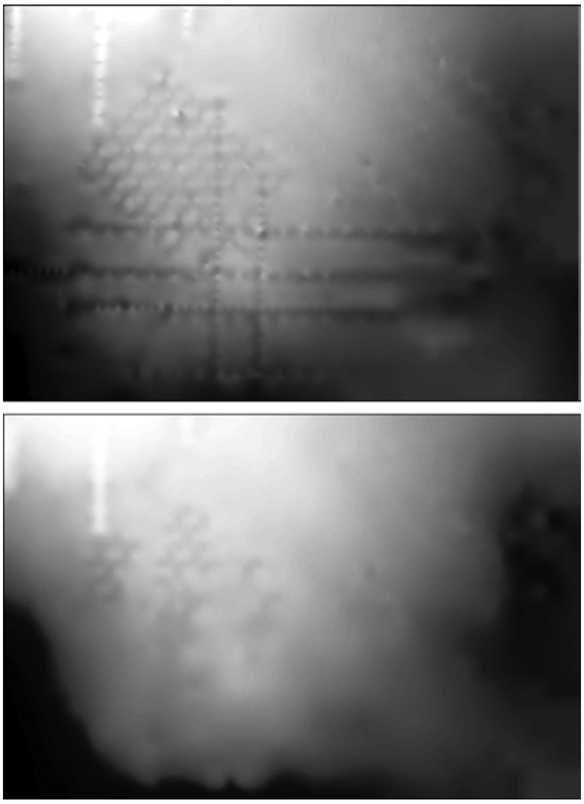


Figure 3. *Grey scale image of grids in Figure 3 displaying grid artefacts. Top – using original location data. Bottom – using regularised location data.*

800 m grid. This, in turn, generated a 400m grid to feed the next iteration.

Five iterations finished with a set of points 200 m apart (Figure 1 – bottom). The null points were removed outside this process and a grid at 50 m cell size produced (Figure 2 – bottom). Artefacts have been visibly subdued with both the high frequency and linear features greatly reduced (Figure 3 – bottom). The result still warrants comparison with other smoothing techniques, but linear features that could be mistaken for structures have been successfully removed.

Of course, this process demonstrates that a cycle of nice solutions can hide problems, and I do not pretend that the method is a substitute for removing or correcting conflicts in data. It is worth remembering that smoother, less fractious grids may not be a good basis for a drilling programme. If you intend to use the data for that purpose then have a think about possible data conflicts before you start.

The code was written with ArcGIS high level functions so that you can copy and run or read as pseudo code. Function names either sound like their output or can be looked up online (Appendix 1).

A more sophisticated version would offer variable search radius and weightings to fill more of the bottom right hand "hole" in the initial stages. The process would also be better managed with two tools. One tool to create the series of point sets assigned with nearest real values, and another to import the grids and to fill gaps in the point sets.

The procedure is as follows:

1. Add a new script in ArcMap toolbox that points to this script. Create 5 parameters with relevant data types (Figure 4).
    a. Layer – to choose the point shapefile/feature that will be regularised
    b. Workspace – to choose the folder/directory all files will be written to
    c. Point separation – the largest starting that will begin the process
    d. Iterations – how many times the separation size will be halved
    e. Fraction – the grid cell size is calculated as fraction of current point separation
2. Add a point shape file to ArcMap so it is now a "layer"
3. Run the script.

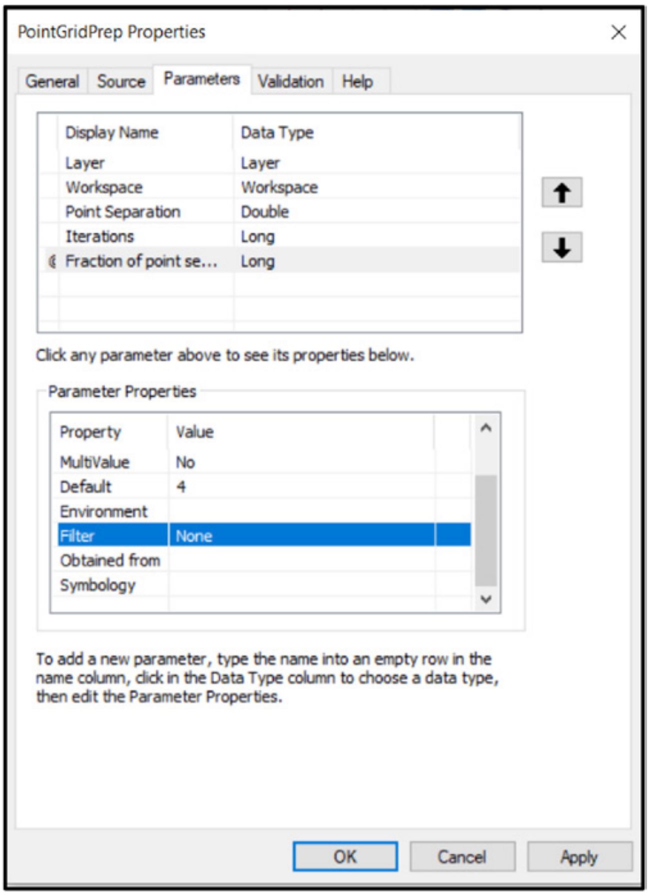


Figure 4. *Screenshot of ArcGIS toolbox parameters used to run the code.*

Appendix 1. ARCGIS Python code

Table 1. ARCGIS Python code for regularising points

```
import arcpy, os, sys
from arcpy.sa import *

arcpy.env.overwriteOutput = True

input_lyr = arcpy.GetParameter(0) # Choose a layer in ArcMap
arcpy.env.workspace = arcpy.GetParameterAsText(1) # Working directory for all files produced
# Python does not have Do While so double the separation distance to fit the while loop
pt_spacing = str(float(arcpy.GetParameterAsText(2)) * 2) # the largest spacing you want to start from
i = int(arcpy.GetParameterAsText(3)) # how many iterations
Pt_sep_divisor = int(arcpy.GetParameterAsText(4)) # divide spacing by this number: default is 4

desc = arcpy.Describe(input_lyr)
arcpy.env.outputCoordinateSystem = desc.SpatialReference
origin_offset = 0
while i > 0:
pt_spacing = str(float(pt_spacing) / 2)
polyFC = arcpy.env.workspace + "\\" + str(int(float(pt_spacing))) + ".shp"
  if i = = int(arcpy.GetParameterAsText(3)):
  origin_offset = 0
  else:
  origin_offset = float(pt_spacing)/2
  originXY = str(desc.extent.XMin - origin_offset) + ' ' + str(desc.extent.YMin - origin_offset)
  endXY = str(desc.extent.XMax) + ' ' + str(desc.extent.YMax)
arcpy.AddMessage('Iter: ' + str(i) + ' pt_spacing: ' + pt_spacing + ' offset: ' + str(origin_offset) + ' Origin: ' + originXY)

  coords = originXY.split(' ')
  yDir = coords[0] + ' ' + str(float(coords[1]) + 10)
  # Fishnet creates both a polygon and points of same name with _labels suffix
  arcpy.CreateFishnet_management(polyFC, originXY, yDir, pt_spacing, pt_spacing, "", "", endXY, 'LABELS', input_lyr,
  'POLYGON')
  ptFC = polyFC.replace('.shp', '_label.shp')
  arcpy.Delete_management(polyFC)
  # Assign the nearest gravity values within a radius to the points
  Joined_input_lyr = ptFC.replace("_label.shp", "") + "_join_" + input_lyr.name + ".shp"
  join_radius = str((float(pt_spacing)/Pt_sep_divisor) - 1.0)
  arcpy.SpatialJoin_analysis(ptFC, input_lyr, Joined_input_lyr, 'JOIN_ONE_TO_ONE', 'KEEP_ALL', '#', 'WITHIN_A_
  DISTANCE', join_radius)
  # Plus a buffer layer showing the radius
  arcpy.Buffer_analysis(ptFC, ptFC.replace("_label.shp", "_buffer.shp"), join_radius)


  if origin_offset ! = 0:
  temp = Joined_input_lyr.replace(".shp", "_zeroes.shp")
  arcpy.SpatialJoin_analysis(Joined_input_lyr, currSpline, temp, 'JOIN_ONE_TO_ONE', 'KEEP_ALL', '#', 'INTERSECT')
#field = "BA_1984_MG"
    #sql = """{0} = 0""".format(arcpy.AddFieldDelimiters(temp, "BA_1984_MG"))
    #arcpy.MakeFeatureLayer_management(temp, 'temp', sql)
    exp = "getVal( !BA_1984_MG!, !grid_code!)"
    pycode = """def getVal(v1,v2):
if (v1 == 0):
  return v2
  else:
  return v1"""
  arcpy.CalculateField_management(temp, "BA_1984_MG", exp, "PYTHON_9.3", pycode)

  # Interpolate at quarter line spacing
```

```
    if i > 1:
    arcpy.MakeFeatureLayer_management(Joined_input_lyr, 'Joined_input_lyr')
    currSpline = ptFC.replace("_label.shp", "_spline.shp")
    raster_spline = arcpy.sa.Spline('Joined_input_lyr', 'BA_1984_MG', join_radius, 'TENSION', 0.5, 12)
    #raster_spline.save(currSpline.replace('.shp', '.img'))
    arcpy.RasterToPoint_conversion(raster_spline, currSpline, 'Value') 68

i = i - 1

# Cut down final points to the extents of the original data
input_lyr_cnrs = arcpy.Array([desc.extent.lowerLeft, desc.extent.upperLeft, desc.extent.upperRight, desc.extent.
lowerRight, desc.extent.lowerLeft])
input_lyr_box = arcpy.Polygon(input_lyr_cnrs, desc.SpatialReference)
outBox = arcpy.env.workspace + "\\" + input_lyr.name + "_box.shp"
arcpy.CopyFeatures_management(input_lyr_box, outBox)
arcpy.MakeFeatureLayer_management(outBox, 'Box_input_lyr')
78
    # Interpolate at quarter line spacing
    if i > 1:
    arcpy.MakeFeatureLayer_management(Joined_input_lyr, 'Joined_input_lyr')
    currSpline = ptFC.replace("_label.shp", "_spline.shp")
    raster_spline = arcpy.sa.Spline('Joined_input_lyr', 'BA_1984_MG', join_radius, 'TENSION', 0.5, 12)
    #raster_spline.save(currSpline.replace('.shp', '.img'))
    arcpy.RasterToPoint_conversion(raster_spline, currSpline, 'Value') 68

i = i - 1

# Cut down final points to the extents of the original data
input_lyr_cnrs = arcpy.Array([desc.extent.lowerLeft, desc.extent.upperLeft, desc.extent.upperRight, desc.extent.
lowerRight, desc.extent.lowerLeft])
input_lyr_box = arcpy.Polygon(input_lyr_cnrs, desc.SpatialReference)
outBox = arcpy.env.workspace + "\\" + input_lyr.name + "_box.shp"
arcpy.CopyFeatures_management(input_lyr_box, outBox)
arcpy.MakeFeatureLayer_management(outBox, 'Box_input_lyr') 78
```

The ASEG in social media

Have you liked/followed/subscribed to our social media channels? We regularly share relevant geoscience articles, events, opportunities and lots more. Subscribe to our Youtube channel for recorded webinars and other content.

Email our Communications Chair Millicent Crowe at Communications@aseg.org.au for suggestions for our social media channels.

Facebook: https://www.facebook.com/AustralianSocietyOfExplorationGeophysicists

LinkedIn company page: https://www.linkedin.com/company/australian-society-of-exploration-geophysicists/

Twitter: https://twitter.com/ASEG_news

YouTube: https://www.youtube.com/channel/UCNvsVEu1pVw_BdYOyi2avLg

Instagram: https://www.instagram.com/aseg_news/

Webwaves

Ian James
ASEG Webmaster
webmaster@aseg.org.au

Who is using the ASEG website?

The ASEG website continues to be the main presence the Society has on the internet, supplemented by the social media channels maintained by the Society which include:

Twitter: https://twitter.com/ASEG_news

Instagram: https://www.instagram.com/aseg_news/

LinkedIn: https://www.linkedin.com/company/australian-society-of-exploration-geophysicists/

Facebook: https://www.facebook.com/AustralianSocietyOfExplorationGeophysicists

YouTube: https://www.youtube.com/c/ASEGVideos

Have you liked/followed/subscribed to our social media channels? We regularly share relevant geoscience articles, events, opportunities and lots more. Subscribe to our YouTube channel for recorded webinars and other content. Email our Communications Chair Millicent Crowe at communications@aseg.org.au for suggestions for our social media channels. Access to the ASEG website in 2020 was predominantly through direct access or an internet search, with social media resulting in 3.9% of sessions (Figure 1). While small, this is a large percentage increase on the 2.6% of sessions in 2019.

In the past year, the ASEG has become an increasingly digital society, with more content on the website, including all historic issues of *Preview*, the first virtual AGM, and virtual technical talks hosted over Zoom and published on our YouTube channel. This provides increased value to our Members, especially those overseas or unable to attend in-person meetings. Membership statistics for the 2020 calendar year are published here https://www.aseg.org.au/members/overview.

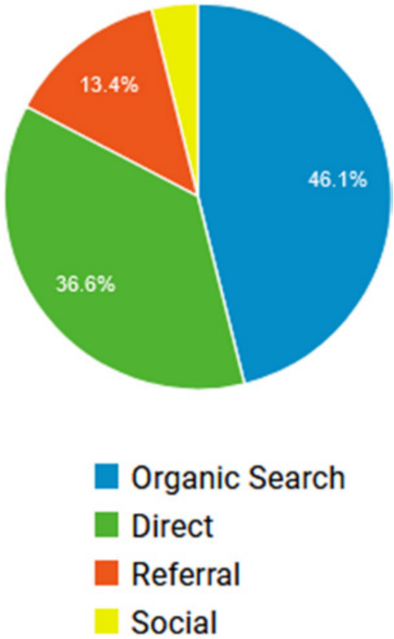


Figure 1. *Website access by channel.*

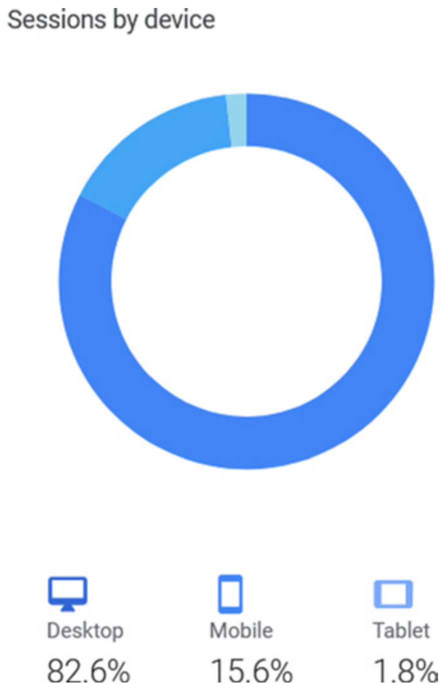


Figure 2. *Website access by device type.*

Access to the website in 2020 continued to be dominated by desktop devices, at over 82% of sessions. This represented a >2% increase on 2019, with tablet and mobile access falling over the same period (Figure 2).

The most popular webpage last year was, again, digital access to the current *Preview* edition, with the newsletter and events webpages also recording significant interest. So far in 2021, it looks like the *Preview* digital library of historic issues is proving popular. Another entry in the top 10 webpages on the ASEG website is the digital copy of David Isles and Leigh Rankin's "Geological Interpretation of Aeromagnetic Data", reflecting the interest in geophysical ebooks on the website.

In *Webwaves* in the June 2019 issue of *Preview* (#200) I showed a figure illustrating website access globally, and pointed out a number of countries/territories absent from our viewership. I have updated this information in Figure 3, and am happy to report that we have now had viewers in Greenland, Paraguay and Turkmenistan - although we have still not yet broken into the North Korean market. In the past two years, the distribution of viewers globally has stayed largely the same: Australia (45%), USA (14%), Canada (4%) and India (4%) still the top four countries. China is now fifth, displacing the UK.

With website access dominated by devices in Australia, it is no surprise that users are active on the website between 0600 and 1700 on weekdays (AWST), see Figure 4, but, surprisingly, also on Friday evenings when we have a similar volume of traffic… I knew we were doing a good job with the website.

The website is undergoing continual improvement. Another addition is the hosting of recent *Exploration Geophysics* volumes that have been released by Taylor & Francis. Members who have logged in will find Volume 50 onwards on the ASEG website here: https://www.aseg.org.au/publications/publications-members-only.

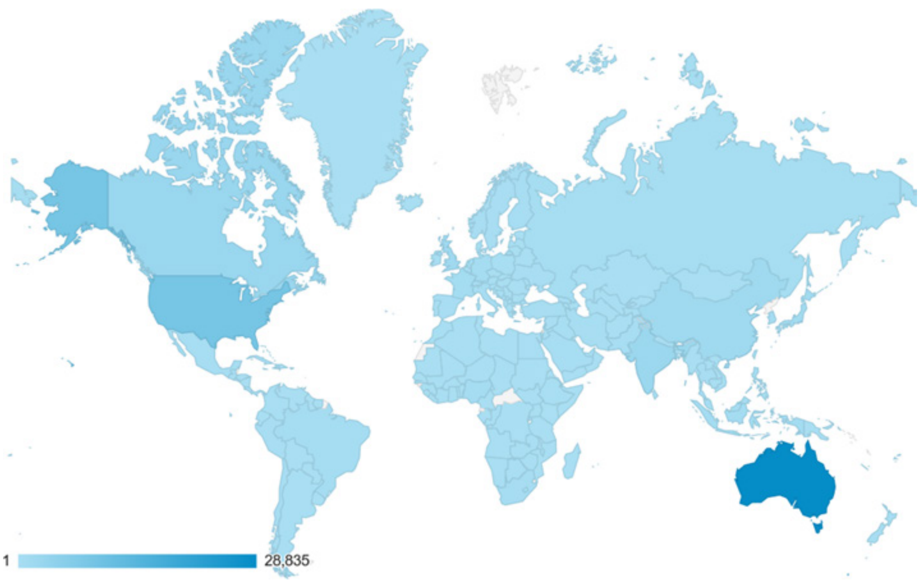


Figure 3. *ASEG website global views.*

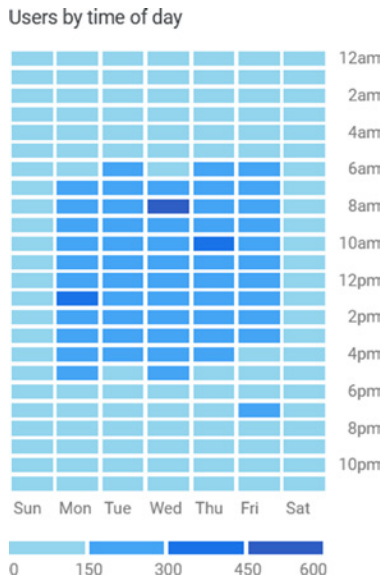


Figure 4. *ASEG website views by time of day.*

Australian Society of Exploration Geophysicists

1970-2020

Free access to publications

- Exploration Geophysics - high-quality international technical journal
- Preview Magazine - stay up to date with current trends in exploration geophysics

Professional & Networking Development opportunities

- Reduced registration fee to the Australasian Exploration Geoscience Convention
- Short courses
- Technical Events
- Social Events

Huge range of online content

- Webinars
- Workshops
- Job advertisements

Students

- **Free** membership, support through the ASEG Research Foundation
- Travel scholarships and funding support available

Exclusive member-only discounted wines

Visit ASEG.org.au or email secretary@aseg.org.au for more details

Scan to sign up

Preamble to Universal horizontal slab and spherical cap Bouguer corrections

Des Fitzgerald
des@intrepid-geophysics.com

In the year before he died Richard Lane spent a lot of time on the compilation of continental gravity data for Australia. This was the first time that he applied himself to this subject, despite being involved on the sidelines during previous updates.

It would be fair to say that, with the retirement of many of the geophysicists at GA with years of practical experience of dealing with gravity surveys, Richard, with the help of Phillip Wynne, was last man standing. His determination to apply rigour to the task led him to reflect on aspects not often checked.

Notable issues addressed by Richard included:

- Blending old and new land gravity surveys to create the best representation of the field while suppressing the noise and historic errors and inconsistencies in the data
- Adjusting for the Earth's curvature, and how this might result in improvements to simple assumptions (this is the subject of the following draft paper).
- Checking and improving on the final continental correction for deep mountain range roots i.e. the isostatic correction (he prepared notes on why the original USGS implementation missed one of the factors).

Some of our correspondence in regard to these matters is reproduced below:

Correspondence:

FROM Richard to Des

Hello Des.

With the benefit (?) of being at home, I have completed a draft of a paper on spherical cap Bouguer corrections (see attached). This rounds off some work that Dominik started some years ago. I don't know why, but his paper left out the spherical cap solution for offshore airborne observations. I thought that I would tidy this up.

I wonder if you could cast your eye over the manuscript and let me know if there are things that I could do to improve it? Or alternatively if I should forget about it!

On another subject, has there been any progress with the isostatic corrections?

Hope that you are staying busy and healthy.

… Richard

TO Richard from Des

richard

pretty good effort. Needs a bit of upgrading to be a full technical paper of greater benefit to the community.

I am happy with the figures, the explanation, the layout, and the development of the argument.

It is almost ready for cut and paste into the training material.

I think Domink had already done this work as well with our code, after the paper was published.

A couple of suggestions.

a. please discuss the infinite slab option vs Cap for the radiometry case. We simply state that a simple Bouguer correction makes no sense for the infinite slab.

As you point out, the spherical cap does make a small difference in the case of gradiometry.

b. Central to the paper is the notion of vertical component. You have avoided the obvious issue of, and some difficulties, of how do you define vertical?

I raise this, as this is rarely discussed. Sander have all the components, so how does the spherical cap correction effect the two horizontal components?

c. I think I have only ever seen the rationale for 166.7 km explained once. There is also an old earth curvature correction we use, passed down from Mario and prior practise. This is tied to the 166.7 km figure.

d. Typo in abstract with the sentence starting "Armed with these tools…. slab **or** spherical

des

FROM Richard to Des

Hello Des.

Thanks for your comments and suggestions.

== = ==

d) This typo has been corrected. Thanks

== = ==

a) Gradiometry

Thanks for drawing my attention to this subject. As you note, the gradients for an infinite horizontal slab are all zero, so the corrections for this geometry are trivially zero. In contrast, the vertical gradient is non-zero for a spherical cap geometry. I can certainly add this qualitative information to the paper.

The development of the mathematics for the vertical gradient would be a significant undertaking. My feeling is that this should be left for another day and another paper.

== = == =

b) What is vertical?

For Sander with their AIRGrav system, vertical is defined with respect to the ellipsoid. This means that there can be non-zero *horizontal components. If vertical was defined with respect to the geoid, there would only ever be a vertical component since vertical would be defined by the direction of the gravity vector!*

The maths that I show are developed for a spheroid (not an ellipsoid), and for a spherically symmetric Earth such that the geoid and spheroid coincide. The horizontal components of both the infinite horizontal slab and the spherical cap are zero under these circumstances.

As per (a), I can add this information to the paper. I shall leave the maths for elliptical cap corrections to greater minds than myself.

== = ==

c) 166.7 km

You are not alone in wondering where this number comes from. I wrote about this as part of an ASEG abstract in 2009.

The short answer is that a radius of 166.7 km or an arc length of 1°29′58″ for a spherical Earth of radius 6371 km was the outer radius of Zone O defined by Hayford and Bowie (1912). This was the outer limit of a set of "near" zones A through to O. This distance became more entrenched when Bullard (1936) chose this distance as the radius of the Bullard B corrections. The combination of infinite slab (Bullard A) and Earth curvature (Bullard B) corrections approximate spherical cap corrections.

Following is a more lengthy extract from that 2009 abstract.

"The figure of 166.7 km as the threshold distance when curvature effects become extremely significant arose from an analysis by Hayford and Bowie (1912). This distance corresponds to the outer limit of what became known as Hayford-Bowie gravity terrain correction Zone O. This was defined as an angular distance of 1°29′58″ for a spherical Earth of radius 6371 km. Hayford and Bowie wished to calculate gravity terrain and isostatic effects to assist with geodetic and geological applications. There were no precedents to provide guidance on whether gravity and surface topography information for the entire Earth needed to be considered, nor whether curvature effects needed to be taken into account. Since the computations were carried out by hand, significant time savings could be achieved if a Cartesian modelling approximation could be used for all, or the majority, of the work. A number of trial calculations for both Cartesian and spherical frameworks established that the error budget for the terrain correction of "1 part in 200" would be exceeded if curvature effects for the contributions beyond Zone O were ignored, and also established that contributions from the entire Earth were indeed required. An arc length of 166.7 km has since become the default distance for modellers to start to worry about curvature effects. However, widespread acceptance of this distance figure does not take into account the specific accuracy requirements for any particular job at hand, the majority of which would show little resemblance to the issue of calculating terrain and isostatic corrections to an accuracy of "1 part in 200"!"

"The apparent importance of an arc length of 166.7 km became further entrenched through common use of a 3-part procedure for calculating terrain corrections for gravity introduced by Bullard (1936). The Bullard A correction is the infinite Bouguer slab correction that gives rise to Simple Bouguer Anomaly values. The Bullard A and B corrections combine to produce a terrain correction equivalent to a spherical cap with arc length 166.7 km. The Bullard C correction introduces further refinements for variations in surface topography for locations within the extent of the spherical cap. The application of Bullard A, B and C corrections gives rise to Complete Bouguer Anomaly values. The common practice when calculating Bullard C corrections is to use a Cartesian framework and to then make a correction to account for the curvature of the Earth. Hinze et al. (2005) describe a set of revised procedures for making the common adjustments to observed gravity values that produce various anomaly values (i.e., residual values). They combine the Bullard A and B corrections into a single spherical cap Bouguer correction for an arc length of 166.7 km. It is worth noting that the terrain correction procedures used by Hinze et al. (2005), that are equivalent to the Bullard C corrections, account for curvature effects for source locations beyond 14 km rather than the previous standard of using a Cartesian framework for all sources within an arc length of 166.7 km. The spherical cap and terrain corrections are both truncated at an arc length of 166.7 km "by convention" rather than for any solid reasoning. They note that the terrain corrections of limited extent associated with Bouguer Anomaly values should be supplemented with corrections for the effects of distant topographic and bathymetric relief. This is precisely the approach that was used by both Hayford and Bowie (1912) and Bullard (1936) in their pioneering work. More recently, Karki et al. (1961) and Mikuška et al. (2006) present modelling results for distant terrain and isostatic effects in the case of Karki et al. (1961) that were calculated in a spherical framework. These can be used with the anomalies obtained after applying the Bullard A, B and C corrections."

Bullard, E.C., 1936, Gravity measurements in East Africa: Philosophical Transactions of the Royal Society of London, Series A, 235, 445-534.

Hayford, J.F., and Bowie, W., 1912, The effect of topography and isostatic compensation upon the intensity of gravity: Special Publication No. 10 of the U.S. Coast and Geodetic Survey, Washington D.C.

Karki, P., Kivioja, L., and Heiskanen, W.A., 1961, Topographic-isostatic reduction maps for the world for the Hayford Zones 18-1, Airy-Heiskanen System, T = 30 km: The Isostatic Institute of the International Association of Geodesy, Helsinki, Finland.

Mikuška, J., Pasteka, R., and Marusiak, I., 2006, Estimation of distant relief effect in gravimetry: Geophysics, 71, J59-J69."

After Richard's death I suggested that the draft of his paper, now called "Universal horizontal slab and spherical cap Bouguer corrections" be published in the pages of *Preview*. Geoscience Australia gave their permission and the paper appears below. It contains Richard's original diagrams, partly because they are an indication that the paper is in draft form, but also because they are a mark of the man - detailed and meticulously composed.

A final word about someone I counted as a dear friend and colleague: Richard did not accept a lack of rigour in the thinking of his professional colleagues. However, rather than engaging in confrontation he would return to the subject a day or so later with a fully developed rejoinder, not only to the betterment of the individual, but also to the evolution of their practice. Would that we all lived with his grace and courage.

Universal horizontal slab and spherical cap Bouguer corrections

Richard Lane
Geoscience Australia

Abstract

Equations are presented for calculating infinite horizontal slab and spherical cap Bouguer vertical gravity corrections for surface and airborne observations, for both onshore or offshore situations, and for both a geoid or ellipsoid vertical datum. The equation for the gravity response of an infinite horizontal slab is relatively simple. In the general case, Bouguer corrections for a slab geometry involve two infinite horizontal slabs: one for sea water and one for solid rock. The equation giving the gravity response for a spherical cap is more complex. It is based on the equation for the vertical gravity response of a spherical cone. In the general case, the equation for the spherical cap Bouguer correction is expressed as the sum of the response for four such cones with different densities and radii. Armed with these tools, the choice of whether to use a horizontal slab of spherical cap geometry for Bouguer corrections can be made on better criteria than the availability of suitable equations. To assist with the choice of geometry, comparisons of infinite horizontal slab and spherical cap Bouguer corrections are given for a range of terrain clearances, water depths, and surface elevations. These comparisons show that the differences between the corrections are relatively small, that the corrections for a spherical cap geometry decrease in magnitude with increasing terrain clearance, and that the differences change polarity for a given terrain clearance as the elevation of the terrain surface or the depth of the ocean increases.

Introduction

Complete Bouguer Anomaly gravity values (g_{CBA}) are derived from observations of the vertical component of gravity (g_{obs}) via a sequence of corrections. There are two options for performing these corrections (Equations 1 and 2):

$$g_{CBA} = g_{obs} - g_t - g_{atm} - g_{fac} - g_{tc}\text{, or} \qquad (1)$$

$$g_{CBA} = g_{obs} - g_t - g_{atm} - g_{fac} - g_B - g_{ta}, \qquad (2)$$

where g_t is the theoretical gravity correction, g_{atm} is the atmospheric correction, g_{fac} is the free air correction, g_{tc} is the full terrain correction, g_B is the Bouguer correction, and g_{ta} is the terrain adjustment. In equation *1*, the vertical gravity response of the terrain at and surrounding each observation point is calculated in one step by calculating the full response for a terrain model extending out to some radius, generally taken to be 166.735 km. In equation 2, this response is calculated in two parts: (i) the Bouguer correction, and (ii) a terrain adjustment which is the difference in response between that obtained for the simple depiction of the Earth used in (i) and the response of a full terrain model. The terrain adjustment, g_{ta}, is often referred to as a terrain "correction", but I use the word "adjustment" to avoid confusion with g_{tc}.

The focus of this paper is the Bouguer correction, g_B. The Earth model used for the Bouguer correction can be either an infinite horizontal slab or a spherical cap. It is straightforward to use the equation for the vertical gravity response of an infinite horizontal slab to deduce the correction for any possible scenario of surface or airborne location, for either onshore or offshore situations, and for either a geoid or ellipsoid vertical datum. It is more challenging to do this for a spherical cap geometry. LaFehr (1991) gave the equations for the gravity response of a spherical cap when the observation is made directly on the surface of the spherical cap. Argast *et al* (2009) repeated the derivation for observations made on the surface in onshore locations but then went on to extend the range of solutions to airborne observations above onshore locations and to observations made on the surface of the ocean. The available solutions unfortunately omit the scenario of airborne observations in offshore locations. This gap is closed in the following with the presentation of a general equation for spherical cap Bouguer corrections.

Bouguer corrections for an infinite horizontal slab

The vertical gravity response, $g_{z,HS}$, in m/s^2 for an infinite horizontal slab geometry is given by the equation

$$g_{z,HS,} = 2\,\pi\,G\,\rho\,h \qquad (3)$$

where G is the gravitational constant which has an accepted value of 6.67430e-11 m^3 kg^{-1} s^{-2} at this time (Tiesinga *et al*, 2019), ρ is the density of the material making up the slab in kg/m^3, and h is the thickness of the slab in metres.

The horizontal slab Bouguer correction for an onshore location involves the gravity response of a single slab that has its upper surface at the level of the ground surface vertically below the observation point and its lower surface at the level of the vertical datum, regardless of whether this is a geoid or an ellipsoid vertical datum.

In the case of an offshore location and a geoid vertical datum that coincides with the ocean surface, the horizontal slab Bouguer correction once again involves a single slab between the ocean bottom and the ocean surface.

When an ellipsoid vertical datum is used, as recommended by Hinze *et al* (2005) and implemented in Australia (Tracey *et al*, 2007), a pair of slabs must be used to derive the Bouguer correction. The first slab accounts for the sea water column beneath the observation. The second slab provides a correction for the crustal material between the ocean bottom and the level of the vertical datum.

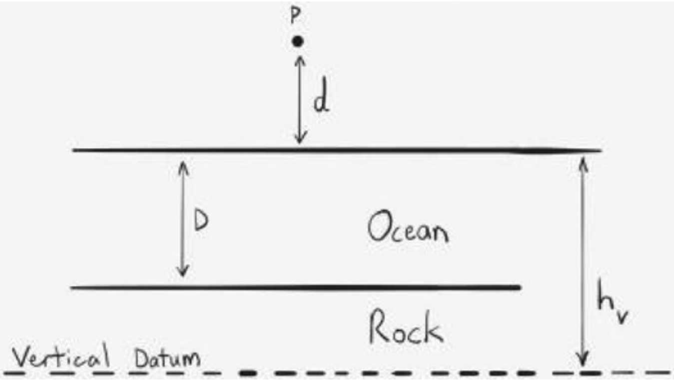


Figure 1. *Cross section for the general case of a Bouguer correction using infinite horizontal slabs.*

In the general case (Figure 1), we can write the horizontal slab Bouguer correction, $g_{B,HS}$, at a point P at height d above the ocean surface as

$$g_{B,HS} = (2\,\pi\,G\,\rho_{SW} D) + (2\,\pi\,G\,\rho_t [h_\nu - D]) \qquad (4)$$

where D is the ocean depth in metres (≥ 0), ρ_{sw} is the density of sea water in kg/m^3 (> 0), ρ_t is the density of the terrain in kg/m^3 (> 0), and h_v is the height of the ocean or ground surface above the level of the vertical datum.

Since the correction is independent of the height of the observation point above the surface, the correction in equation 4 can be applied not just to observations made on the ground or ocean surface but to airborne observations, for either onshore or offshore situations, and for either a geoid or ellipsoid vertical datum.

Bouguer corrections for a spherical cap

Spherical cap Bouguer corrections use a portion of a spherical shell as the model geometry. By convention, the cap has a surface radius of 166.735 km.

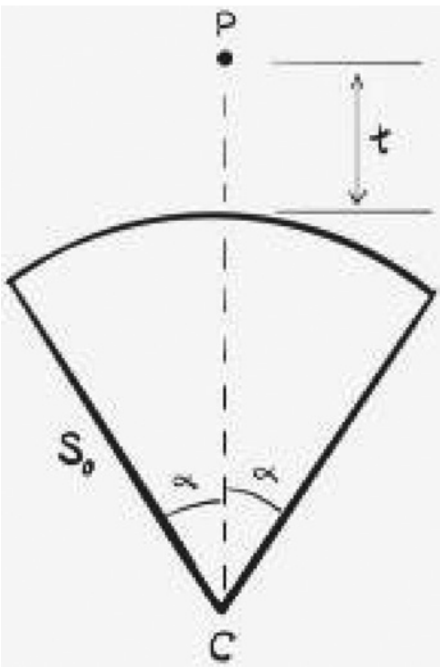


Figure 2. *Cross section through a spherical cone.*

The equations for spherical cap Bouguer corrections presented here are based on the equations that define the vertical gravity response of a spherical cone (Figure 2). The equations are given by Argast *et al* (2009) and are reproduced here for convenience as equations 5 through to 16.

The cone has its apex at the centre of a sphere, C, with radius S_0 metres. It subtends an angle of 2_α at the apex and has a density of ρ kg/m^3. The measurement point, P, is at a height of t metres above the surface of the sphere.

The vertical gravity response for this spherical cone, $g_z\,(S_0, t, \rho)$, in m/s^2 is given by

$$g_{z,cone}(S_0, t, \rho) = 2\,\pi\,G\,\rho\,((S_0 + t)(1 + \lambda - \kappa) - t\,(1 + \mu) \qquad (5)$$

where

$$\alpha = R_b\,/\,R_0 \qquad (6)$$

$$\eta = t\,/\,(S_0 + t) \qquad (7)$$

$$\mu = (1/3)\eta^2 - \eta \qquad (8)$$

$$\delta = S_0/(S_0 + t) \qquad (9)$$

$$k = sin^2(\alpha) \qquad (10)$$

$$f = \cos(\alpha) \qquad (11)$$

$$d = 3cos^2(\alpha) - 2 \qquad (12)$$

$$m = -3\cos(\alpha)sin^2(\alpha) \qquad (13)$$

$$\lambda = (1/3)\Big((d + f\delta + \delta^2)\sqrt{((f-\delta)^2 + k} - m\ln\Big((f-\delta) + \sqrt{((f-\delta)^2 + k)}\Big)\Big) \qquad (14)$$

$$b = 2cos^2(\alpha/2) \qquad (15)$$

$$\kappa = (1/3)(d + 2 - m\ln(b)) \qquad (16)$$

and R_b is the Bullard B surface radius 166735 m (Bullard, 1936; LaFehr, 1991), R_0 is the mean radius of the Earth, which for the GRS80 ellipsoid is 6371008.7714 m (Moritz, 2000), and G is the gravitational constant 6.67430e-11 m^3 kg^{-1} s^{-2} (Tiesinga *et al,* 2019).

The response of a spherical cap can be obtained from the response for a pair of spherical cones (Figure 3). To obtain the response for the shaded spherical cap at point P

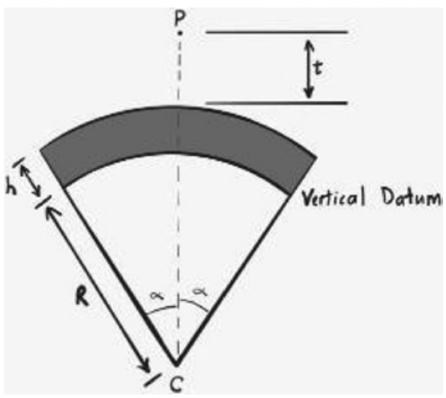


Figure 3. *Cross section through a spherical cap (shaded area) that is defined as the difference between two spherical cones, one of radius R + h and another with radius R.*

(Equation 17), the response at a height of $t+h$ above the surface of a cone of radius R is subtracted from the response at a height of t above the surface of a cone with the same density but a radius of $R+h$.

$$g_{z,cap} = g_{z,cone}(R+h, t, \rho) - g_{z,cone}(R, t+h, \rho) \quad (17)$$

The equation for a general spherical cap Bouguer correction, $g_{B,SC}$, has 4 terms that are grouped into two pairs, as indicated by the braces, where each of these pairs is the response of a spherical cap (Equation 18). As per equation 4 for the general horizontal slab Bouguer correction, the first of these pairs provides the vertical gravity response that accounts for the sea water column beneath the observation. The second pair of terms provides a correction for the crustal material between the ocean floor and the level of the vertical datum.

The inputs to the general spherical cap Bouguer correction (Figure 4) are the height of the surface above the vertical datum (h_v) in metres, the surface clearance of the observation point (d) in metres (≥ 0), the ocean depth (D) in metres (≥ 0), the density of the terrain (ρ_t) in kg/m^3 (> 0), and the density of sea water (ρ_{sw}) in kg/m^3 (> 0).

The general spherical cap Bouguer correction is

$$g_{B,SC}(h_\nu, d, D, \rho_t, \rho_{sw}) = (g_{z,cone,A} - g_{z,cone,B}) + (g_{z,cone,C} - g_{z,cone,D}) \quad (18)$$

where

$$g_{z,cone,A} = g_{z,cone}(R_0 + h_\nu, d, \rho_{sw}) \quad (19)$$

$$g_{z,cone,B} = g_{z,cone}(R_0 + h\nu - D, D + d, \rho_{sw}) \quad (20)$$

$$g_{z,cone,C} = g_{z,cone}(R_0 + h_\nu - D, D + d, \rho_t) \quad (21)$$

$$g_{z,cone,D} = g_{z,cone}(R_0, h_\nu + d, \rho_t) \quad (22)$$

For specific situations, equation 18 can be simplified. In the case of onshore observations, the 1st and 2nd terms in the definition of the spherical cap Bouguer correction cancel each other out. With the further restriction of onshore observations made directly on the surface, the first two terms reduce down to the

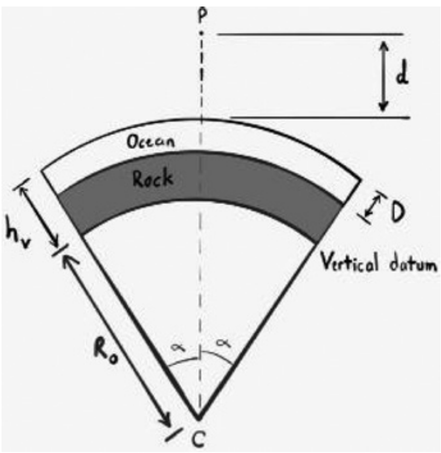


Figure 4. *Cross section for the general case of a spherical cap Bouguer.*

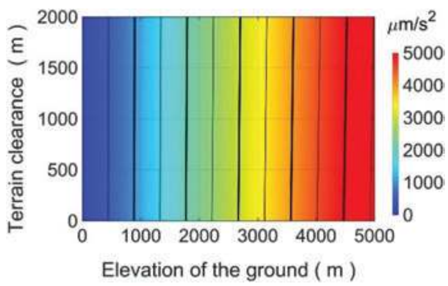


Figure 5. *An image of the spherical cap correction values for onshore locations as a function of ground elevation and terrain clearance.*

expression given by LaFehr (1991). This is an outcome that is also noted by Argast *et al* (2009).

Comparison of infinite horizontal slab and spherical cap Bouguer corrections

An image displaying the spherical cap correction for onshore locations as a function of ground elevation and terrain clearance is given in Figure 5. It is clear that the principal control on the magnitude of the correction is the elevation of the ground, but it can be seen from the small angle that the contour lines make with respect to the y-axis that there is also a subtle reduction in the magnitude of the correction with increasing terrain clearance. Bouguer corrections using an infinite horizontal slab are different in this respect since there is no change in these corrections with terrain clearance.

To highlight some of the characteristics of the two Bouguer correction geometries, images showing the differences between the two corrections are provided. The differences between these two corrections for onshore locations are presented in Figure 6 as an image for a range of surface elevations and heights above the ground.

The first point to note is that the magnitude of the differences is 1% or less of the corrections themselves. The conclusion that can be drawn from this is that the two corrections are very similar to one another.

Next, we can look at the variation parallel to the x-axis for any specific terrain clearance. As an example, the differences for zero elevation along the base of the image can be examined. The difference is zero at the origin when the ground surface coincides with the vertical datum. The difference between these two corrections reaches a maximum of around +15 µm/s^2 when the ground surface has an elevation of approximately 2000 m above the vertical datum. The difference is again equal to zero

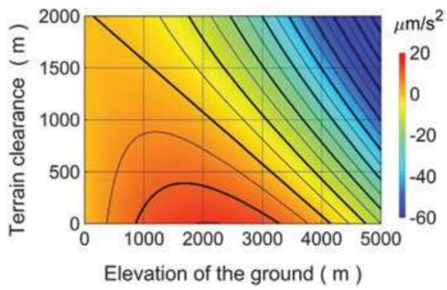


Figure 6. *Differences between spherical cap and infinite horizontal slab Bouguer corrections for onshore locations for terrain clearances of 0 m to 2000 m and surface elevations of 0 m to 5000 m.*

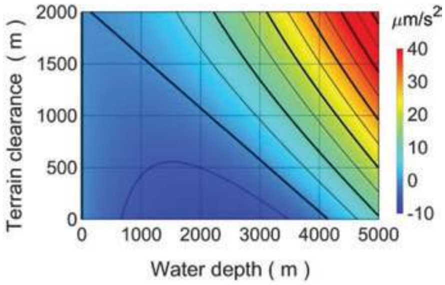


Figure 7. *Differences between spherical cap and infinite horizontal slab Bouguer corrections for offshore locations for terrain clearances of 0 to 5000 m, ocean depths of 0 to 5000 m, and an ellipsoid-geoid separation of 0 m.*

when the ground surface has an elevation of approximately 4150 m above the vertical datum. For elevations greater than this, the difference is negative indicating that the correction for an infinite horizontal slab geometry is larger than the correction for a spherical cap geometry. It should be noted that the values quoted above are identical to those shown for the same scenario in figure 2 of LaFehr (1991).

The behaviour described above can be summarised for any terrain clearance as follows: a zero difference for zero ground elevation, a positive difference for small to moderate elevations, and a negative difference at large values of surface elevation.

The final aspect of the image in Figure 6 to be examined is the change parallel to the y-axis representing the differences for any single value of the ground elevation. With the trivial exception of the case of zero ground elevation, the amplitude of the difference decreases with increasing terrain clearance. Since the corrections for an infinite horizontal slab geometry do not vary as the height of the observations above the surface increases, this indicates that the corrections for an infinite horizontal slab geometry decrease in amplitude as the height of the observations above the surface increases.

Turning our attention to offshore locations, the differences between the corrections for spherical cap and infinite horizontal slab geometries for a range of ocean depths and heights above the ocean surface are presented in figure 7. It should be noted that the calculations were made for an ellipsoid-geoid separation of 0 m, or in other words, for the case when the vertical datum coincides with the ocean surface.

The trends of the changes as demonstrated by the form of the contour lines are the same as those in Figure 6, but the polarity is the reverse. Examining the changes parallel to the x-axis for any given ocean clearance, the difference is zero for zero water depth, negative at small to moderate water depths, and positive over the deep ocean. Looking at the changes parallel to the y-axis for any given water depth, the magnitude of the differences decreases with increasing ocean surface clearance. As previously explained, this is a reflection of the decreasing amplitude of corrections for a spherical cap geometry as the terrain clearance increases.

Conclusions

Equations covering the application of both infinite horizontal slab and spherical cap Bouguer corrections have been presented. These equations cover the complete range of scenarios for onshore and offshore locations, for observations made on and above the surface, and for both geoid and ellipsoid vertical datums. This will enable people to choose to use either of these geometries for Bouguer corrections. Recognising the increasing importance of airborne gravity methods, comparisons of the correction for the two geometries were provided for observations made at different surface clearances. Images of the difference between the corrections for the two geometries were given for a range of ground clearances as a function of onshore ground surface elevation and offshore water depth. These images highlighted two important characteristics of the two corrections, namely that (1) spherical cap Bouguer corrections decrease in amplitude with increasing ground clearance, and (2) the difference between the two corrections changes sign as a function of onshore ground elevation and offshore water depth.

References

Argast, Dominik, M. Bacchin and R. Tracey, 2009 An extension of the closed-form solution for the gravity curvature (Bullard B) correction in the marine and airborne cases: *ASEG Extended Abstracts 2009*, 1-6, http://dx.doi.org/10.1071/ASEG2009ab129, DOI 10.1071/ASEG2009ab129.

Bullard, E. C., 1936. Gravity measurements in East Africa: *Phil. Trans. Roy. Soc. London*, 235, 757, 486-497.

Hinze, W. J., C. Aiken, J. Brozena, B. Coakley, D. Dater, G. Flanagan, R. Forsberg, T. Hildenbrand, R. Kellar, J. Kellogg, R. Kucks, X. Li, A. Mainville, R. Morin, M. Pilkington, D. Plouff, D. Ravat, D. Roman, U. F. Jamie, M. Veronneau, M. Webring, and D. Winester, 2005, New standards for reducing gravity data: the North American gravity database: *Geophysics*, 70, J25-J32.

LaFehr, T. R., 1991. An exact solution for the gravity curvature (Bullard B) correction: *Geophysics*, 56, 1179-1184.

Moritz, H., 2000, Geodetic Reference System 1980: *J. Geod.*, 74 (1), 128-162, doi: 10.1007/S001900050278.

Tiesinga, E, P. J. Mohr, D. B. Newell, and B. N. Taylor, 2019. The 2018 CODATA Recommended Values of the Fundamental Physical Constants (Web Version 8.0): Database developed by J. Baker, M. Douma, and S. Kotochigova, Available at http://physics.nist.gov/constants, National Institute of Standards and Technology, Gaithersburg, MD 20899.

Tracey, R., M. Bacchin, and P. Wynne, 2007. AAGD07: A new absolute gravity datum for Australian gravity and new standards for the Australian National Gravity Database: *Expanded Abstract, 19th ASEG/PESA International Geophysical Conference & Exhibition*, Perth, Western Australia, 1-3, http://library.seg.org/doi/abs/10.1071/ASEG2007ab149

The first measurements of gravity in Australia

Roger Henderson
rogah@tpg.com.au

In his comprehensive history of geophysics in Australia Dr A A Day (Day, 1966) first refers to gravity measurements being made in Sydney by L. S. de Freycinet and his company in 1819. They used pendulums[1]. Freycinet was, however, unable to compile his results for publication until 1826 (de Freycinet, 1826).

Day (1966) states they were the "first of four determinations of gravity to be made there in a space of ten years" without giving any more information. He then notes that when Sir Thomas Brisbane arrived at Port Jackson in 1821 to be Governor of the Colony, he and his assistant, J. Dunlop, soon swung the Kater pendulum that Brisbane had brought from London at the new observatory Brisbane had established at Parramatta[2]. As he had swung the Kater pendulum before leaving London, Brisbane was able to determine the difference in gravity between London and Parramatta. The results were forwarded to Henry Kater in England who published them in 1823, three years before de Freycinet published his (Kater, 1823).

Recent research and later publications than Day (1966) suggest that determinations of gravity had taken place in Sydney earlier than those made by de Freycinet. For example, the Malaspina Expedition (1789–1794), a five-year maritime scientific exploration from Cadiz, Spain, under the command of Don Alexandro Malaspina di Mulazzo, visited Sydney for a month from 13 March to 12 April, 1793[3]. It is presumed that Malaspina had swung a pendulum there, as they had swung a pendulum at various places on the voyage from Cadiz for purposes of determining the figure of the Earth.

Some grounds for this presumption include the caption to a figure in King (1990, p 66), a translation of Malaspina's report on the British settlement, which shows a pendulum in a tent with Malaspina seated alongside. The caption included "experiments were made wherever the expedition landed, including Sydney"[4].

Further detail on this supposition is given in the introduction of King (1990 p2): "Bennelong's hut, on the east point of Sydney Cove, was assigned to the visitors to store their instruments while they made astronomical and gravitational observations" and (p3): "Before the expedition left Sydney, the results of all their scientific observations and calculations were made available to the English officers…"[5]. What happened to these results? And did they include determinations of gravity?

Well-known ASEG historian Doug Morrison and his colleague, Ivan Barko, carried out extensive research and were able to report (Morrison and Barko, 2009) that the earliest gravity determinations in Sydney Cove (and therefore in Australia) with surviving results were made by William Dawes in 1788. Other measurements may have been made a few days earlier by the French astronomer J. L. Dagelet in Botany Bay, but his results were lost when his ship was wrecked on its way home to France[6].

William Dawes came to Sydney in 1788 as a Lieutenant of Marines on the First Fleet transporting convicts[7]. He was supplied with the necessary navigational and astronomical equipment by the British Astronomer Royal, Rev Dr Nevil Maskelyne[8]. Maskelyne had persuaded the Board of Longitude that the equipment could be used to observe a comet that was expected to return in September 1788, and which would be best seen in the Southern Hemisphere[9]. Maskelyne had nominated Dawes to operate the equipment; however, the Board requested that the equipment be entrusted only to Captain Arthur Phillip, the commander of the First Fleet (Laurie, 1988). This decision was later to lead to some episodes of disagreement between Dawes and Phillip, and ultimately to Dawes being sent back to England after only three years[10].

Very soon after his arrival, Dawes set up an observatory, according to a model recommended by Maskelyne, on what is today known as Dawes Point - adjacent to the southern pylons of Sydney Harbour Bridge[11]. Figure 1 is a sketch of the area surrounding Sydney Cove including the location of the observatory.

The comet that Maskelyne had predicted that Dawes could observe with his instruments did not appear, but Dawes nevertheless made the usual measurements of latitude and

[1]Louis-Claude de Saulces de Freycinet was in command of l'Uranie. He conducted scientific observations around the world (1817-1820) and visited Port Jackson (Sydney) in December 1819 to make gravity and magnetic measurements.

[2]The observatory was established by Brisbane at his own expense in the grounds of Government House at Parramatta.

[3]The definitive account of the expedition was finally published as; Museo Naval y Ministerio de Defensa, *La Expedición Malaspina, 1789-1794,* Barcelona, Lunwerg, tomos 1-9, 1987-1999.

[4]Also, in "First Geophysical Measurement at Sydney in 1793?" in *Preview* October 1991 p 15 (as reprinted from NZ Geological Society, Historical Studies Group Newsletter March 1991), is a comment by Malaspina that "experiments on gravitation have been repeated in both hemispheres and in various latitudes…"

[5]Bennelong's hut was on Bennelong Point, now the site of the Sydney Opera House. See Figure 1.

[6]Joseph Lepaute Dagelet was the astronomer of the La Pérouse expedition of 1785-1787, which was under the command of Jean-Francois de Galaup de La Pérouse and left Sydney on 10 March 1788 never to be seen again by any British or French citizen. Much more on this French connection is in Morrison and Barko (2009).

[7]Biographies and other details on Dawes include; Dawes, William (1762-1836), Aust. Dictionary of Biography; Laurie, 1988.

[8]For a detailed list of the equipment supplied see Laurie, 1988 p 470.

[9]The Board of Longitude was a body created by an Act of Parliament in 1714 to study aspects of navigation.

[10]In part, Phillip was too protective of the equipment on occasions on the voyage out when Dawes could have used it.

[11]Originally, Captain Phillip named the area Point Maskelyne. The coordinates of the location as best estimated are: 33° 51′ 25″ S, 151° 12′ 30″ E.

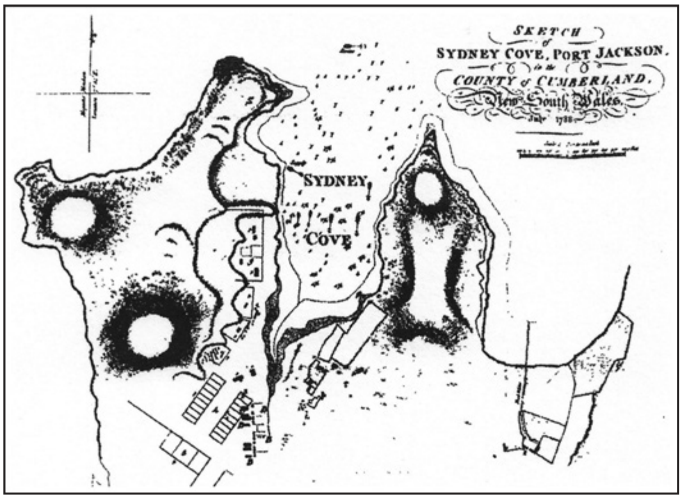


Figure 1. *This sketch of Sydney Cove with coastline drawn by W. Dawes has the position of the observatory on the northernmost headland on the western side of the Cove. The headland on the eastern side is Bennelong Point (after Laurie, 1988).*

longitude. Of more interest to geophysicists, however, are his readings of gravity. Morrison and Barko (2009) were able to establish that Dawes, "over a period from February 1788 to early 1790, also undertook observations specifically to determine (the value of) gravity at his Sydney Cove observatory". The values were forwarded to Dr Maskelyne in Britain who calculated the 'absolute' gravity. (Morrison and Barko, 2009). Thus, unlike Dagelet, the French observer of gravity, Dawes' results survived, making them the first gravity measurements in Australia.

Morrison and Barko (2009) were finally able to confirm that William Dawes' gravity readings, after correction by C. Bosloper (2020), resulted in the value at Sydney Cove as 9.79705 m/s^2 or 979.705 gal. This value agrees well with current absolute determinations[12].

Finally, it can be noted that Captain James Cook made clock measurements on his second voyage on the Resolution (1772-75) that enabled gravity to be derived at a number of ports of call (for a list of locations see Bosloper, 2010 -Table 3). If Cook had had the requisite equipment on his first voyage on Endeavour (1768-71) he may have been able to make similar measurements when he was moored for a time at Botany Bay in 1770. They would certainly then have been the first known determinations of gravity in Australia.

It is interesting to observe that scientists in the eighteenth century, "the age of enlightenment", shared their few priceless astronomical instruments. Instruments were even shared between warring countries such as Britain and France. Morrison and Barko (2009), in their detailed revelations about the visit of the La Perouse expedition to Sydney (1785-87) to measure gravity, suggest that one of the three astronomical clocks (pendulums) used by the astronomer Dagelet was also used by Pierre Bouguer and Charles-Marie de La Condamine on their expedition to Peru (1736-45) to measure the shape of the earth (see Henderson 2020). The measurements of plumb-line deviations due to mountain masses in Peru made by Bouguer and Condamine were verified in 1774 in Scotland by the British astronomer Maskelyne. Maskelyne mentored William Dawes and supplied him with the instruments used to produce the first published measurements of gravity in Australia (Morrison and Barko, 2009). It is not known if Dawes used an instrument that was already well travelled, but it is possible.

References

Day, A.A., 1966-67. The development of geophysics in Australia: *Journal and Proceedings of the Royal Society of NSW*, 100, 33-60.

De Freycinet, L.S., 1826. *Voyage autour du monde, 1817-1820*. Observations du pendule: Paris. *Pillet Ainé*, 292 pp.

Henderson, R., 2020. Bouguer's gravity corrections and the shape of the Earth. *Preview*, 208, 39-43.

Morrison, D. and Barko, I., 2009. Dagelet and Dawes: Their Meeting, Their Instruments and the First Scientific Experiments on Australian Soil*: Historical Records of Australian Science*, 20, 1-40, CSIRO publishing for Australian Academy of Science 2009. http://www.publish.csiro.au/nid/108/paper/HR09002.htm

Laurie, P.S., 1988. William Dawes, and Australia's first observatory: *Quarterly Journal of the Australian Astronomical Society*, 29, 469-482. http://articles.adsabs.harvard.edu//full/1988QJRAS..29..469L/0000469.000.html

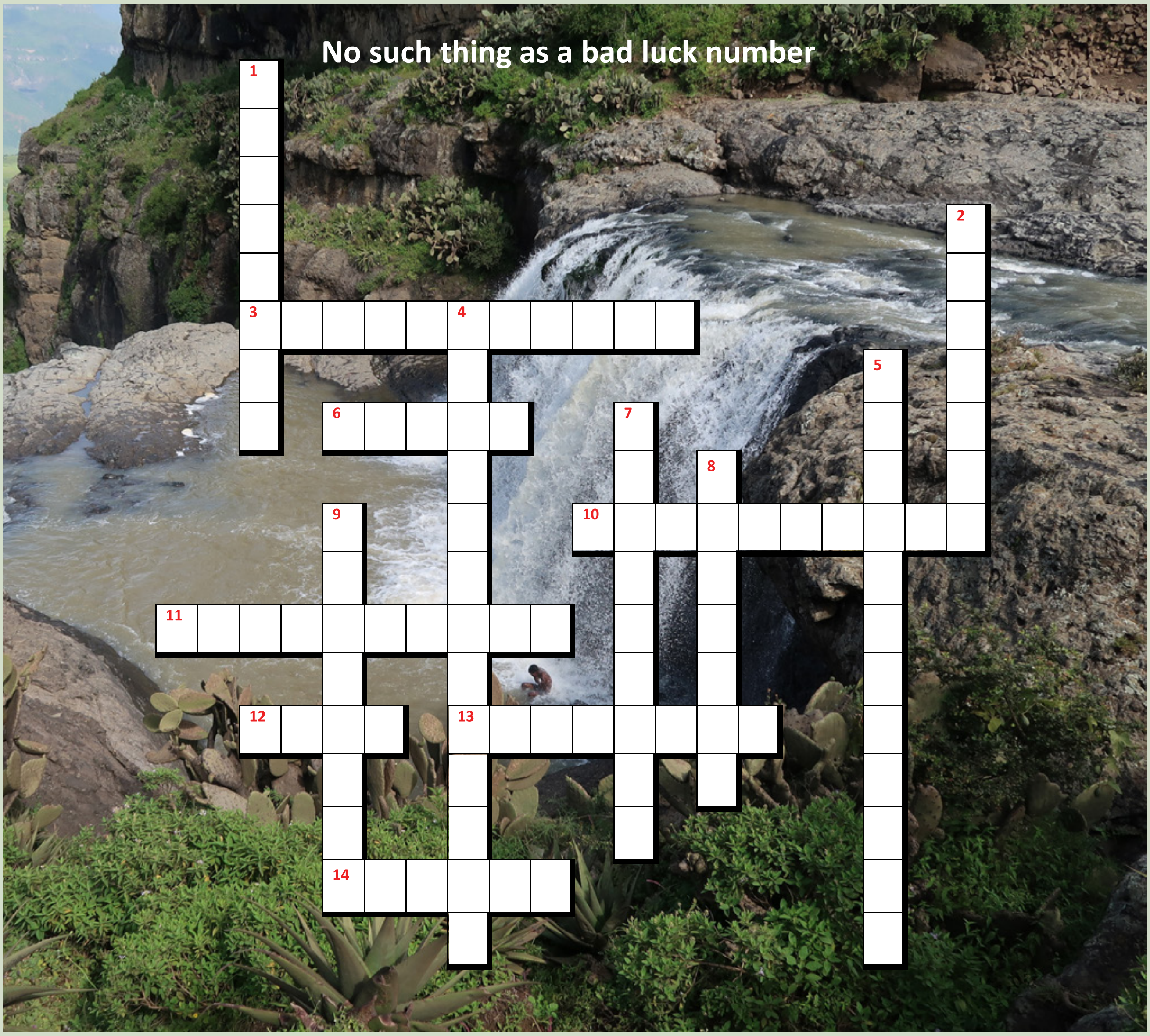
Bosloper, C., 2010. William Dawes' gravity measurements in Sydney Cove, 1788: *International Federation of Surveyors Congress 2010*. 11-16 April, 2010, Sydney, Australia.

Kater, H., 1823. An account of experiments made with an invariable pendulum at New South Wales by Major-General Sir Thomas Brisbane, K.C.B., F.R.S.: *Phil. Trans. Roy. Soc. Lond.,* 113, 308-325.

King, R.J., 1990. *The Secret History of the Convict Colony: Alexandro Malaspina's report on the British settlement of New South Wales.* Allen & Unwin, Sydney, 1990. ISBN 0-04-610020-2.

[12]According to C. Bosloper (2020), Dawes made a mistake in setting the pendulum nut wrong by a whole turn, which effectively shortened the pendulum length. As this has been noted to have occurred on subsequent voyages by Captain Cook and others, Bosloper was able to correct this.

Preview crossword #13



Across

3. Dehydration of an area by a process e.g. drainage, evaporation etc., in the absence of changes in precipitation levels.

6. A coastal inlet similar to a fjord, but with lower relief.

10. The elevated part of the landscape that extends between two adjacent valleys.

11. The amount of incoming solar radiation that is received over a unit area of the Earth's surface.

12. A compact variety of naturally occurring diamond, often used as an abrasive in drill bits, saws and gem cutting wheels

13. Vent in a volcanically active area that emits steam, gas, or other volatile constituents at high temperatures.

14. A stationary or standing wave in an enclosed body of water.

Down

1. The first spacecraft to cross the heliosphere and enter interstellar space.

2. Rock debris deposit left behind by a moving glacier.

4. An apparent force acting on moving objects that results from the Earth's rotation.

5. The process of becoming or making a liquid by heating, cooling, or a change in pressure.

7. The Latin word for 'window' used to describe irregular cavities found in carbonate sediments.

8. The fleshy stalk which attaches most brachiopods to the sea floor.

9. The oceanic equatorial zone, which has low pressure and light, variable winds.

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 – which can be used after cinemas re-open. The answers will be published in the next edition of *Preview.*

Good luck!

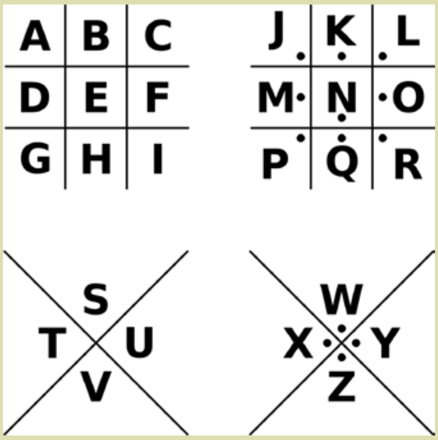
Preview ~~crossword~~ puzzle #12

Reflections

Look again at that dot. That's here. That's home. That's us. On it everyone you love, everyone you know, everyone you ever heard of, every human being who ever was, lived out their lives. The aggregate of our joy and suffering, thousands of confident religions, ideologies, and economic doctrines, every hunter and forager, every hero and coward, every creator and destroyer of civilization, every king and peasant, every young couple in love, every mother and father, hopeful child, inventor and explorer, every teacher of morals, every corrupt politician, every "superstar", every "supreme leader", every saint and sinner in the history of our species lived there – on a mote of dust suspended in a sunbeam.

Extract from Carl Sagan's speech "Pale Blue Dot"

The cipher used to encode this message was Pigpen or Freemason's code.



Business directory

AUSTRALIAN SOCIETY OF EXPLORATION GEOPHYSICISTS
A.B.N. 71 000 876 040
PO BOX 576, CROWS NEST NSW 1585 AUSTRALIA
Phone: +61 2 9431 8691) Fax: +61 2 9431 8677
Email: secretary@aseg.org.au Website: www.aseg.org.au

Application for Active & Associate Membership 2021

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. Student members must include a Supervisors Name and Signature. Under exceptional circumstances the Federal Executive Committee may waive these requirements.
3. Attach the appropriate dues and submit the two pages of your application to the Secretariat at the address shown on the top of this page, retaining a copy of this page for your own records. If payment is to be made by credit card, the application may be sent by fax.

Section 1. Personal Identification

Surname | Date of Birth
Given Names | Mr / Mrs / Miss / Ms / Other
Address
State | Post Code
Organisation
E-mail
Phone (W) | Phone (H) | Fax
Mobile

Section 2. Choice of Membership Grade (Tick one)

- ☐ Active — Please complete all sections
- ☐ Associate — Please complete all sections
- ☐ 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

Section 4. Nominators (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 Membership Directory Record

Please complete this section for the ASEG membership database. The same information is included in the ASEG Website (www.aseg.org.au)

Employment area:
❑ Industry ❑ Contract/Service Provider ❑ Government ❑ Student
❑ Education ❑ Consulting ❑ Other _______________

Type of Business:
❑ Oil/Gas ❑ Ground Water/Environmental ❑ Coal ❑ Survey/Geotechnical/Engineering
❑ Minerals ❑ Petrophysics/Log Analysis ❑ Research/Education ❑ Data Acquisition
❑ Solid Earth Geophysics ❑ Archaeology/Marine Salvaging ❑ Computer/Data Processing ❑ Other _______________

Section 7. Payment Details (This document will be an Australian Tax Invoice when you have made payment)

MEMBERSHIP GRADES AND RATES

❑ Active/Associate (Australia) - $175.00	❑ Active/Associate 5 Year Membership (Australia) - $874.50
❑ Active/Associate (Group IV Countries) - $159.00	❑ Active/Associate 5 Year Membership (Group IV Countries) - $795.00
❑ Active/Associate (Group III Countries) - $69.00	❑ Active/Associate 5 Year Membership (Group III Countries) - $345.00
❑ Active/Associate (Group I & II Countries) - $13.30	❑ Active/Associate 5 Year Membership (Group I & II Countries) - $66.50
❑ Graduate (Australia) - $69.00	

Section 8. Preview & Exploration Geophysics

The ASEG produces a magazine called Preview and a peer-reviewed journal called Exploration Geophysics. Please read and agree to the following in order to receive ASEG publications:

1) I grant permission for the ASEG to provide my email and postal address to the Taylor & Francis Group so that I can receive copies of the ASEG publications. Taylor & Francis have given an undertaking not to use the member list for any purpose other than advertising and distributing Exploration Geophysics and Preview.

2) I understand and agree that online access to Exploration Geophysics is for my private use and the articles shall not be made available to any other person, either as a loan or by sale, nor shall it be used to substitute for an existing or potential library or other subscription.

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 (please circle)

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.)
❑ I (or my business) am interested in advertising in ASEG's publications.

Section 10. 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:*_______________

AUSTRALIAN SOCIETY OF EXPLORATION GEOPHYSICISTS
A.B.N. 71 000 876 040

PO BOX 576, CROWS NEST NSW 1585 AUSTRALIA
Phone: +61 2 9431 8691) Fax: +61 2 9431 8677
Email: secretary@aseg.org.au Website: www.aseg.org.au

Application for Student Membership 2021

INSTRUCTIONS FOR APPLICANTS

1. Student Membership is available to anyone who is a full-time student in good standing at a recognised university 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. However, Student Membership must be renewed annually. The duration of a Student Membership is limited to five years.
2. Fill out the application form, ensuring that your supervisor signs Section 2.
3. Submit the two pages of your application to the Secretariat at the address shown on the top of this page, retaining a copy of this page for your own records.

Section 1. Personal Details

Surname ______ Date of Birth ______

Given Names ______

Mr / Mrs / Miss / Ms / Other (list) ______

Address ______

______ State ______ Post Code ______

E-mail ______

Phone (W) ______ Phone (H) ______ Fax (W) ______

Mobile ______

Section 2. Student Declaration

Institution ______

Department ______

Major Subject ______ Expected Year for completion of studies ______

Supervisor/Lecturer ______ Supervisor Signature ______

Section 3 Membership Grade
(This document will be an Australian Tax Invoice when you have made payment)

MEMBERSHIP GRADES AND RATES	
❑ Student (Australia & Group IV Countries)	FREE
❑ Student (Group III Countries)	FREE
❑ Student (Group I & II Countries)	FREE

Section 4 Preview & Exploration Geophysics

The ASEG produces a magazine called Preview and a peer-reviewed journal called Exploration Geophysics. Please read and agree to the following in order to receive ASEG publications:

1) I grant permission for the ASEG to provide my email and postal address to the Taylor & Francis Group so that I can receive copies of the ASEG publications. Taylor & Francis have given an undertaking not to use the member list for any purpose other than advertising and distributing Exploration Geophysics and Preview.

2) I understand and agree that online access to Exploration Geophysics is for my private use and the articles shall not be made available to any other person, either as a loan or by sale, nor shall it be used to substitute for an existing or potential library or other subscription.

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 (please circle)

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:*______________

ASEG CODE OF ETHICS

Clause 4 of the Articles of Association of the ASEG states that "Membership of any class shall be contingent upon conformance with the established principles of professional ethics":

1. A member shall conduct all professional work in a spirit of fidelity towards clients and employees, fairness to employees, colleagues and contractors, and devotion to high ideals of personal integrity and professional responsibility.
2. A member shall treat as confidential all knowledge of the business affairs, geophysical or geological information, or technical processes of employers when their interests require secrecy and not disclose such confidential information without the consent of the client or employer.
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.
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.

April	2021		
25–30	European Geosciences Union https://www.egu2021.eu/	Vienna	Austria
May	**2021**		
4–6	5th Myanmar Oil & Gas Conference https://eage.eventsair.com/fifth-aapg-eage-myanmar-conference/	Yagoon	Myanmar
June	**2021**		
14–17	82nd EAGE Annual Conference and Exhibition https://eage.eventsair.com/eageannual2021/	Amsterdam	The Netherlands
July	**2021**		
26–28	Unconventional Resources Technology Conference (URTeC) https://urtec.org/2021	Houston	USA
August	**2021**		
3–5	Machine Learning: The artificially intelligent Earth exploration	Kuala Lumpur	Malaysia
16–21	36th International Geological Congress https://www.36igc.org/	Delhi	India
23–27	Advanced Earth Observation Forum 2020 https://earthobsforum.org/	Brisbane	Australia
September	**2021**		
8–10	Mines and Wines 2021 Discoveries in the Tasmanides https://minesandwines.com.au/	Orange	Australia
15–20	Australasian Exploration Geoscience Conference (AEGC 2021) 2021.aegc.com.au	Brisbane	Australia
26–1 Oct	SEG International Exhibition and 91st Annual Meeting https://seg.org/AM	Denver	USA
October	**2021**		
10–14	11th Balkan Geophysical Congress https://appliedgeophysics.ro/events/bgs2021/	Bucharest	Romania
13–14	Geophysics in Geothermal Energy – Today And Tomorrow https://seg.org/Events/Geophysics-in-Geothermal-Energy-Today-and-Tomorrow	Jakarta	Indonesia
18–21	Sapporo, Hokkaido, Japan 14th SEGJ International https://www.segj.org/is/14th/	Sapporo	Japan
25–28	Sixth International Conference on Engineering Geophysics (ICEG) https://seg.org/Events/iceg21	Al Ain	UAE
November	**2021**		
15–17	Dorothy Hill Symposium https://absoluteevents.eventsair.com/dhweess-2021/	Brisbane	Australia
30	EAGE 4th Asia Pacific meeting on Near Surface Geoscience & Engineering https://eage.eventsair.com/4th-ap-meeting-on-near-surface-geoscience-engineering/	Ho Chi Minh City	Vietnam
December	**2021**		
13–17	AGU Fall Meeting	New Orleans	USA
March	**2022**		
20–23	Geo-Congress 2022 https://www.geocongress.org/	Charlotte	USA
August	**2022**		
15–19	12th International Kimberlite Conference https://12ikc.ca/	Yellowknife	Canada
September	**2022**		
26–30	Australian and New Zealand Geomorphology Group Conference https://www.anzgg.org/conferences	Alice Springs	Australia

Preview is published for the Australian Society of Exploration Geophysicists. It contains news of advances in geophysical techniques, news and comments on the exploration industry, easy-to-read reviews and case histories, opinions of Members, book reviews, and matters of general interest.

Advertising and editorial content in *Preview* does not necessarily represent the views of the ASEG or publisher unless expressly stated. No responsibility is accepted for the accuracy of any of the opinions or information or claims contained in *Preview* and readers should rely on their own enquiries in making decisions affecting their own interests. Material published in *Preview* becomes the copyright of the ASEG.

Permission to reproduce text, photos and artwork must be obtained from the ASEG through the Editor. We reserve the right to edit all submissions. Reprints will not be provided, but authors can obtain, on request, a digital file of their article.

Single copies of *Preview* can be purchased from the Publisher.

All proposed contributions should be submitted to the Editor by email at previeweditor@aseg.org.au

For style considerations, please refer to the For Authors section of the *Preview* website at: https://www.tandfonline.com/toc/texp20/current

Preview is published bimonthly in February, April, June, August, October and December. The deadline for submission of material to the Editor is usually the second Friday of the month prior to the month of issue. The deadline for the June issue is 14 May 2021.

For the advertising copy deadline please contact the Publisher on advertising@taylorandfrancis.com.au